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Exploring teachers' self-efficacy about technology use in learning design and student performance in mathematics: A qualitative study about math anxiety

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EXPLORING TEACHERS' SELF-EFFICACY ABOUT TECHNOLOGY USE IN LEARNING DESIGN AND STUDENT PERFORMANCE IN MATHEMATICS: A QUALITATIVE STUDY ABOUT MATH ANXIETY

by

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Dedications

In dedication to "Team Vorensky" - Abe, Joshua and Mark - whose love and support has always been steadfast and everlasting. Thank you for joining me on this incredible journey.

In dedication to my parents, Simon and Sally, for instilling a love of learning.

And finally, this work is dedicated to my sister and brothers, Risa, Randy, and Ray, with whom I can also count as my closest friends. Thanks for being there always.

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Abstract

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The purpose of this study was to explore teachers’ perceived self-efficacy about mathematics and using educational technology and its influence on lessening students’ math anxiety in the classroom. Building upon previous research by Sun and Pyzdrowski (2009), this study examined teachers’ beliefs about mathematics and their own ability to use online educational mathematics resources to lessen students’ math anxiety, increase self-efficacy and encourage academic achievement. A qualitative research design was used in this study. Data was collected sequentially from teacher observations during math instruction, surveys, and semi-structured interviews with third and fourth grade teachers. Results support previous self-efficacy research about the significance of mathematics anxiety and its impact on instructional choices. Findings suggest that teachers' self-efficacy about mathematics along with teachers' professional assignments contribute to decisions about how to best use educational technology in teaching. Educational math software provides opportunities for feedback that lessens mathematics anxiety. This study suggests that teachers use a variety of strategies to overcome challenges using technology in the classroom. And finally, teachers used a variety of non-tech and technology strategies for lessening students' math anxiety. Implications for educational leadership, including research, policy and practice are discussed.

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Chapter 1

Introduction

The discussion about how mathematics should be taught in schools has been debated in the U.S. and reflected in conceptual shifts in curricular focus over the past century (Cobb, et al., 1992; Ellis, 2003; Ladson-Billings, 1997; Loveless, 2001; Oakes, 1985; Price & Ball, 1997). In fact, political control, both nationally and on a state level, has been increasingly influential in shaping current trends in education (Epstein, 2004). In the past fifty years, school administrators implementing curricular platforms have experienced mounting pressure from various local, state and national constituencies advocating for educational policy reform and a greater degree of accountability for quality education through standardized testing measures (Conley, 2003).

Ellis and Berry (2005) have discussed conflicting views about the selection of math concepts that are important to teach to students. How do teachers academically prepare students for future careers? For example, has practicing basic multiplication facts remained essential to math educational curriculum? The fundamental issue of identifying mathematics skills that students should be knowledgeable of and teachers required to teach in math education historically have resulted in conflicting opinions about how to best prepare students for the future (Ellis & Berry, 2005). For example, instructional strategies in math education focused on academic ability tracking in mathematics, first introduced in the 1940's, continues to gain both traction and controversy regarding delivering high quality, equitable educational experiences for all students (Ellis & Berry, 2005; Ladson-Billings, 1997; Oakes, 1985). Conversely, other instructional approaches, including a traditional back-to-basics movement which views mathematics as a set of “rapid and accurate computational skills” continues to be “deeply rooted” in our nation’s belief system about mathematics education (Price & Ball, 1997). Moreover, a review of mathematics education in the United States has presented itself as a pedagogical pendulum which swings its emphasis towards procedurally-based, process-based, or a combination of both in its instructional approach to mathematics education (Ellis, 2003; Ellis & Berry, 2005).

Ultimately though, the adoption of a particular instructional conceptual approach in mathematics education as communicated through curricular directives and subsequently selected teaching strategies, has long range implications for students’ learning as well as what teachers are expected to teach (Ball, Thames, & Phelps, 2008; Price & Ball, 1997). Culturally, our experiences shape us and how we view our world (Schein, 2010). It should be assumed then that learning is affected by the idea that, “Humans develop through their changing participation in the socio-cultural activities of their communities, which also change” (Rogoff, 2003, p.11). Moreover, socially constructing knowledge based on an individual’s development and prior experiences is an important component to learning (Vygotsky, 1978). This is a consideration for best educational practices, for example, when striving for equity in teaching procedural fluency to students who come from diverse sociocultural backgrounds. It is also important to consider the extent of a teacher’s own knowledge base and the critical thinking that he or she is capable and comfortable communicating to students (Ball, Thames, & Phelps, 2008).

Widely adopted by 42 of 50 U.S. states, the Common Core State Standards, have advocated for the National Council of Teachers of Mathematics’ (NCTM) recommendations to incorporate a greater focus on problem solving and higher order reasoning into instruction along with the National Research Council's report recommendations to include "adaptive reasoning, strategic competence, conceptual understanding, procedural fluency, and productive disposition" into students' learning of mathematics in schools ("Common Core State Standards Initiative", n.d.). This conceptual shift towards integrating mathematics education represents a departure from past computational initiatives that have been traditionally limited in focus to challenging teachers to adapt to possibly newly defined skill sets and teaching methods (Ellis & Berry, 2005). Moreover, this sociocultural emphasis places teachers in the position of understanding instructionally how to potentially use a variety of math curricular strategies and resources in order to effectively teach diverse student populations. In doing so, teachers' own self-efficacy beliefs about teaching mathematics play a role in the teachers' own confidence, motivation and ability to deliver quality math educational curriculum to all students.

Self-efficacy is defined as "belief in one's ability to succeed" and influences the extent to which an individual is motivated and committed to persevering through a learning process (Bandura, 1993). Students with low self-efficacy in mathematics may avoid a task that they would otherwise be able to complete successfully, resulting in negative consequences in realized mathematics achievement (Meece, J., Wigfield, A., & Eccles, J., 1990; Wigfield & Eccles, 2000). A teacher who has low self-efficacy about his or her own ability to solve or explain math concepts, will indirectly communicate those feelings and beliefs about mathematics to his or her students (Pajares & Miller, 1994). This holds potentially serious implications considering new teaching responsibilities including curriculum standards which require an expertise in application skills involving critical thinking and emphasizing logical reasoning in mathematics. Poor self-efficacy about teaching mathematics may also create a situation where both teachers and students feel anxious about mathematics content in school resulting in some students underachieving and not reaching academic potential. In fact, mathematics anxiety and mathematics self-efficacy are inherently linked and have resulted in potentially negative consequences to achievement based on excessive worry and poor self-beliefs about one's mathematical ability.

Mathematics anxiety is central to generally influencing students' academic achievement throughout school. As a nation striving to encourage more students to pursue higher level mathematics and STEM courses in order to strengthen the United States' future workforce, addressing math anxiety is essential to these efforts. Mathematics anxiety may be defined as "involving negative cognitions, avoidance behaviors, feelings of pressure and performance inadequacy that interfere with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations" (Vahedi & Farrokhi, 2011, p. 47). Mathematics anxiety is comprised of physiological and cognitive components, and negatively impacts students' academic success in achieving in mathematics (Ashcraft, 2002; Ashcraft & Krause, 2007).

In this chapter and the literature review, I have discussed self-efficacy and anxiety in greater detail as well as using technology as a resource to lessen students' poor self-efficacy and mathematics anxiety in the classroom. Since self-efficacy and anxiety are factors that influence students' academic potential, it is important to understand teachers' own self-efficacy and anxiety and the role it plays in students' achievement. For this study, I have explored third and fourth grade teachers' own anxiety, beliefs and attitudes about mathematics and using technology as a resource to lessen students' anxiety while promoting critical thinking and achievement among elementary school students in the mathematics classroom.

Background

In the following section, I will briefly summarize highlights of mathematics education reform that frame the educational issues that my research study have examined in greater detail. By reviewing previous changes in instructional initiatives, I have been able to provide a better understanding of the justification for current instructional directives which educators are obligated to adapt to when developing their own teaching practices.

In the early 20th century, students were thought to acquire concepts that sequentially fostered abstract thinking (Ellis & Berry, 2005). A computational, drill and practice approach to mathematics emphasized procedural fluency and hierarchical order. This approach resulted in a teaching curriculum which provided insufficient practice of applying mathematical skill sets and logical reasoning (Ellis & Berry, 2005; Price & Ball, 1997). Following this teacher-directed approach, reform efforts were in place to critically evaluate and redirect traditional educational practices (Ellis & Berry, 2005). The Progressive Movement was instrumental in redesigning the focus of education and significantly streamlining mathematics curriculum according to students' interests (Ellis & Berry, 2005). In response to reform efforts, tracking students by mathematical ability was introduced and became popular (Ellis & Berry, 2005; Loveless, 1998). Controversial for promoting educational inequities, tracking practices continue today (Oakes, 1985).

Historically, political events have had a significant impact on formulating educational directives and school districts' accountability (Conley, 2003; Epstein, 2004). This was evident with the emphasis on 'new math' that was ushered in during the Cold War era (Ellis & Berry, 2005). Conceived by mathematicians to prepare students to compete globally, 'new math' was widely viewed as insufficient for being too abstract and geared towards an elite subset of students, and ultimately made it possible for ushering in the 'back-to-basics' movement (Klein, 2003). Critics of the back-to-basics movement argued an overemphasis on procedural step-by-step mathematics instruction that was not easily transferrable to problem solving tasks (Ellis & Berry, 2005; Klein, 2003). Despite public criticism of the lack of mathematical reasoning encouraged in the back-to-basics paradigm, Price and Ball (1997) have suggested that drill and practice teaching practices still retain popularity today.

Ellis and Berry (2005) have summarized major educational reforms as the following:

> The revisions of the past century situated many learners in an *a priori* deficit position relative to disembodied mathematical knowledge – meaning learning mathematics was taken to be harder for certain groups of students due to their backgrounds and/or innate abilities – and failed to acknowledge the importance of mathematics for all students.
>
> Excellence, as defined by these models, meant either remembering rules and procedures with little concern for the connection of mathematics to students' lived

experiences or, in the case of the progressives, focusing on the child's perceived interests or needs to the exclusion of being concerned with the learning of critical mathematical concepts.

Addressing current national concerns about how to best educate all students and prepare today's students to become part of a vibrant workforce in the near future continues to spark political and educational discussions and debate about what are the best instructional teaching practices in mathematics.

However, when examining statistics, the need for academic excellence is undisputable. For instance, according to the United States Department of Commerce, Economics, and Statistics Administration, job opportunities in Science, Technology, Engineering and Math (STEM) related fields are projected to grow at almost double the rate of growth of non-STEM careers in the near future (United States Department of Commerce, 2011). Moreover, although the majority of STEM jobs may earn a college graduate wages above the national average (Dill, 2014), *Forbes* has reported that "…only 5% of U.S. workers are employed in fields related to science and engineering yet they are responsible for more than 50% of our sustained economic expansion" (Adkins, 2012). The United States Bureau of Labor and Statistics (2015) has reported that there currently is a surplus of STEM jobs in academia, however, there continues to be a need for employees to fill STEM jobs in electrical and mechanical engineering at the government level and software developers and data scientists in the private sector.

Although the economic forecast for a stronger workforce targeting STEM skills is necessary and apparent, the reality of recent national trends in mathematics in schools reveals a different picture. Considering international mathematics assessments, U.S.

teens consistently underperform compared to their international peers (PISA, 2012). And although it has been reported by the Pew Research Center (n.d.) that there have been marginal improvements in mathematics scores as cited in The 2012 Programme for International Assessment (PISA) results, U.S. students continue to earn scores which place them in the middle compared to their international peers. Encouraging students to pursue higher level mathematics is essential to developing and retaining skills comparable and competitive to global standards.

In response to this issue, a new conceptual shift in mathematics education, the cognitive-cultural paradigm, expects to better educate U.S. students in mathematics in order to provide equitable opportunities for achievement. This approach considers students' diverse backgrounds when developing an effective and more equitable mathematics curriculum. Cobb, Yackel, and Wood (1992) have suggested that learning mathematics is a "social practice" and that students actively interpret their own experiences around them to make sense and acquire skills. Current approaches to teaching mathematics, like the cognitive-cultural paradigm, advocate for a constructivist view to acquiring knowledge. A departure from the traditionalist, early 20th century approach, the cognitive-cultural movement seeks to bridge the socio-cultural aspect of prior knowledge and critical higher order thinking and integrate the two principles into mathematics instruction (Ellis & Berry, 2005). In general, recent conceptual shifts in education have focused on equity and the objective of overhauling the quality and value of what education has to offer *all* students (Conley, 2003).

Ellis and Berry (2005) have stated the objectives of this academic approach as follows:

> Emphasis is shifted from seeing mathematics as *apart from* human experience to mathematics *as part of* human experience and interaction. Rather, for students to really understand mathematics they need opportunities to both a) share common experiences with and around mathematics that allow them to meaningfully communicate about and from connections between important mathematical concepts and ideas, and b) engage in critical thinking about the ways in which mathematics may be used to understand relevant aspects of their everyday lives.

This current paradigm has been aligned with the goal of targeting process oriented thinking as outlined by the current Common Core State Standards in Mathematics ("Common Core State Standards Initiative", n.d.). The Common Core State Standards (CCSS) were developed by a non-profit organization in coordination with the National Governors Association and the Council of Chief State School Officers (Robbins & Bauerlein, 2013). The CCSS are "based on rigorous content", "application of knowledge through higher order thinking skills", and "informed by other top-performing countries to prepare all students for success in our global economy and society" ("Common Core State Standards Initiative", n.d.).

Although compliance with a national set of mathematics standards is not mandatory, 42 of 50 states have adopted common core standards in English Language Arts and Mathematics ("Common Core State Standards Initiative", n.d.). Under the direction of Governor Chris Christie, New Jersey has adopted New Jersey Student Learning Standards (NJSLS) (NJDOE, 2015-2016). Functionally, the NJSLS generally represents the content and intent of the CCSS with minimal changes to curriculum skills objectives in mathematics (NJDOE, 2015-2016). Moreover, New Jersey students are assessed currently using The Partnership for Assessment of Readiness for College and Careers (PARCC) exam which tests skill development according to the parameters set by CCSS in mathematics ("Partnership for Assessment of Readiness of College and Careers", n.d.). Considering the focus to improve U.S. performance on international mathematics assessments among teens, the Organization for Economic and Cooperative Development (2012) has suggested that the adoption of CCSS will help to narrow the gap when comparing other international scores.

The Trends in International Mathematics and Science Study (TIMSS) compares international scores among 4th and 8th grade students every four years, beginning in 1995, in order to identify trends in mathematics achievement. Results from the TIMSS 2017 study report indicated that although there were moderate gains among higher achieving U.S. students in comparison to scores from previous years, U.S. students in the lowest performing range, showed little marketable improvement from 2007 or 2011 to 2015 (National Center for Educational Statistics, n.d.). Is this a reflection of a current paradigm shift or is there another consideration that has not been explored regarding student achievement and performance?

Students and Math Anxiety

Math anxiety influencing mathematics achievement affects both children and adults and is prevalent in students of all ages. Students may avoid mathematics for a variety of reasons; one of which may be that they are anxious about the subject and internalize limited possibility of mastering skills (Tobias, 1993). Scarpello (2007) citing National Research Council research has written that 75% of the American population decide to "…stop studying math before they have completed the educational requirements for their career or job" (p.34). Feeling anxious may lead to avoiding taking elective classes in mathematics in high school and college (Ashcraft, 2002; Ashcraft & Krause, 2007). Chipman, Krantz, and Silver (1992) have suggested that students who avoid taking mathematics in high school subsequently avoid science and math-related careers.

Both affective and cognitive components contribute to math anxiety (Ashcraft, 2002; Ashcraft & Krause, 2007). Fear of failure in mathematics may trigger a negative, physiological reaction in an individual's affect that interferes with otherwise succeeding in math (Meece, Wigfield, & Eccles, 1990; Wigfield & Meece, 1988). For instance, a highly anxious student may anticipate that there is little chance to achieve, resulting in a potentially negative emotional reaction which presents an obstacle to doing well and unintentionally derails success (Buckley, 2011; Pekrun, 2006).

Ashkraft and Kirk (2001) and others (e.g., Beilock & Maloney, 2015; Lyons & Beilock, 2012; Wigfield & Meece, 1988) have discussed how math anxiety impedes working memory affecting the cognitive processes. Acting as a distractor, math anxiety limits the capacity of working memory (Ashcraft & Kirk, 2001; Lyons & Beilock, 2012). Mathematical concepts, with the exception of those that involve memory retrieval, frequently require working memory to process problem solving needed for mathematics (Ashcraft & Krause, 2007). Moreover, Ashcraft and Krause (2007) have suggested that "strategy-based solutions" require complex processing from working memory and is subsequently more vulnerable to the negative consequences of math anxiety.

Ma and Xu's (2004) research has posited that mathematics achievement remains relatively stable throughout the secondary years beginning in grade 7, while math anxiety is consistent beginning at grade 8 and throughout the high school years (Ma & Xu. 2004). Emphasis on researching how teachers should engage students in academics and lessen students' math anxiety is essential in order to maximize students' academic potential throughout all grade levels (Ma & Xu, 2004). Encouraging confidence and minimizing mathematics anxiety in the elementary school years pays positive dividends regarding achievement and career choices later on (Chipman et al., 1992). Considering the consequences of not attending to students' excessive worrisome behavior regarding mathematics, researching instructional strategies for highly anxious students to minimize math anxiety may result in better opportunities for higher levels of achievement and growth in the area of mathematics education as a nation (Lyons & Beilock, 2012).

Teachers and Math Anxiety

In their article, Beilock, Gunderson, Ramirez and Levine (2009) have suggested that teachers' own math anxiety negatively impacts students' achievement. The authors have discussed the influence of stereotype threat as a factor regarding preconceived self-efficacy as well (Beilock et al., 2009).

Beilock, et al. (2009) have suggested the following:

> …When the math-anxious individuals are female elementary school teachers, their math anxiety carries negative consequences for the math achievement of their female students. Early elementary school teachers in the United States are almost exclusively female (>90%), and … female teachers' anxieties relate to girls' math achievement via girls' beliefs about who is good at math.

Beilock et al. (2009) have posited that mathematics anxiety influences not only what we think of our own capabilities but projects our beliefs about success and mathematics to others. Understanding to what extent teachers' math anxiety influences instructional choices regarding the depth of information that is taught and encouraging students' critical thinking when educational online resources are available, will provide important information about how students are prepared for both international mathematics tests and STEM related careers.

Students and Self-Efficacy

Preconceived self-efficacy about one's own mathematics ability is a factor when predicting achievement in mathematics (Pajares & Miller, 1994). Poor self-efficacy affects how motivated an individual is committed to succeeding and persevering through the learning process (Bandura, 1991). Self-efficacy can be described as a powerful characteristic that influences an individual's motivation about his or her own choices to engage in mathematics (Bandura, 1993). Self-efficacy also influences beliefs about the ability to regulate one's learning process, individual decisions about how much effort should be allocated to completing a task and to what degree that task can be successfully completed (Bandura, 1993).

Identifying resources to encourage students' taking academic risks to overcome math anxiety and strengthen self-efficacy about mathematic ability is important to improving our international competitive standing in mathematics (PISA, 2012) as well as meeting the projected economic job market in STEM related fields (U.S. Department of Commerce, 2011). Sun and Pzydrowski (2009), in their meta-analysis and reviewing literature from 1996 – 2009, have suggested that teachers' use of educational technology in instruction successfully lessens students' math anxiety in the classroom. Sun and Pzydrowski's (2009) research suggests that the

"… idea that unfamiliarly with technology can compound mathematics anxiety is not covered … it is noteworthy that this possibility does exist and the topic is worthy of study" (p. 39).

The authors indicate a gap in literature that was not addressed in their research. Although Sun and Pzydrowski (2009) were referring to students' beliefs in the above quote, this research study will explore teachers' beliefs about their own familiarity and perspectives about using technological software resources to teach mathematics. Teachers' self-efficacy is important to recognize as a strong external factor which influences students' behavior (Pajares & Miller, 1994). Self-efficacy can pertain to not only technology, but views about mathematics as well.

This research study's intent was to address a gap that was also essential to explore considering school districts' long-term technology initiatives to meet a greater emphasis on STEM-related skills. Understanding teachers' self-efficacy about technology and mathematics as well as mathematics anxiety and its impact on students' learning, has been helpful to understanding how to maximize instructional resources and strategies related to mathematics curriculum.

Teachers and Self-Efficacy

Bandura (1993) has discussed the impact of teachers' own math self-efficacy and its effect on students' attitudes and beliefs about mathematics. An individual's self-efficacy or beliefs about achieving in mathematics and math anxiety are inherently linked. Peker's (2016) research examined the connection between pre-service teachers' mathematics teaching anxiety and self-efficacy beliefs about mathematics. The path diagram in Figure 1 illustrates the interconnected relationship of math teaching anxiety and self-efficacy beliefs towards mathematics teaching.

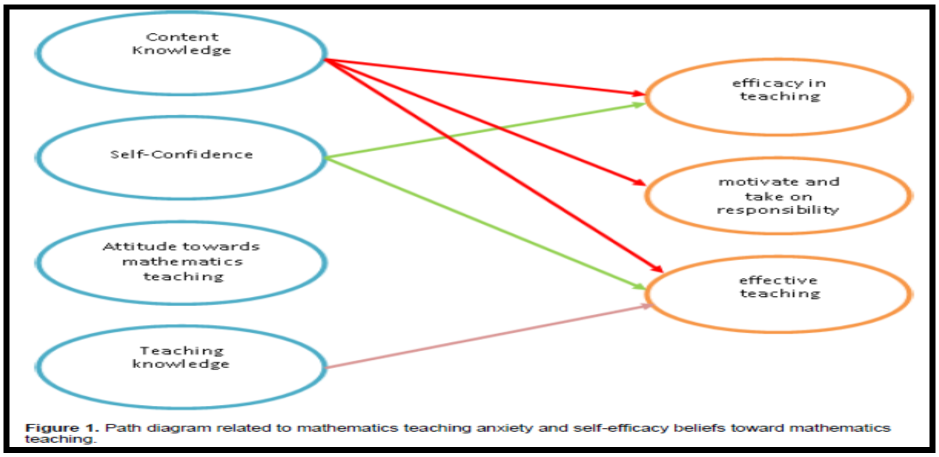


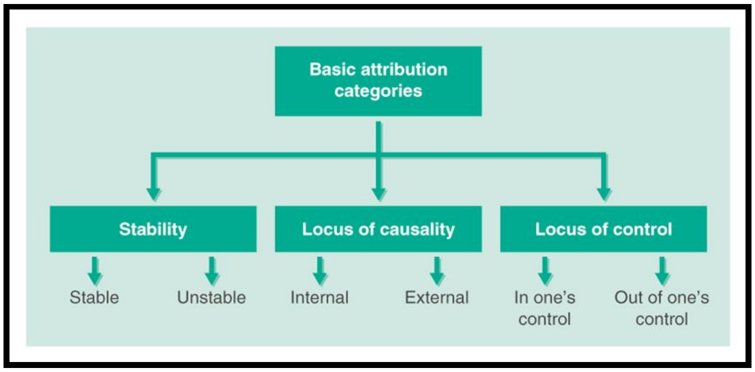
Figure 1. Path Diagram Related to Math Teaching Anxiety and Math Self-Efficacy

As represented in Figure 1 above, the results indicated that there were specific indicators related to anxiety that then affected self-efficacy beliefs (Peker, 2016). For example, a teacher's excessive worrisome behavior about his or her ability to teach math content negatively influenced the teacher's attitudes related to how effective he or she could be when asked to teach mathematics and also how motivated the teacher was to learn and improve instructional practices (Peker, 2016). Additionally, teachers' poor self-confidence as a result of feeling anxious about teaching mathematics also influenced the quality and effectiveness of teaching mathematics to students (Peker, 2016). In other research, Gootenboer and Marshman (2016) have discussed how increased affectivity due to one's beliefs, values, attitudes and emotions or feelings all result in a decreased perception of stability related to the ability to successfully complete cognitive tasks. The reverse is true as well. The less anxious about the upcoming task and more confident an individual feels about being able to succeed, the greater chance that the math task will be completed to a person's potential (Gootenboer & Marshman, 2016).

Theoretical Framework

An individual's self-efficacy beliefs about the degree to which one can successfully complete a task influences how motivated a person is to persevere through that task to completion (Bandura, 1991). Bandura (1993) has discussed that, "Most motivation is cognitively generated" and people generally anticipate outcomes and set goals for tasks based on an individual's self-efficacy beliefs. Casual attributions, how individuals interpret success or failure from observable behavior, are influenced by self-efficacy (Bandura, 1993). Self-efficacy and casual attributions can be described in a scenario related to achievement in mathematics. For example, a student is experiencing difficulty when solving a word problem involving fraction operations on an exam. A highly self-efficacious student may attribute failure to effort and think that he may have been able to be successful if he prepared more effectively by participating in classroom discussions and learning how to use fractions to problem solve for the exam. A student with low self-efficacy in mathematics may attribute failure on the exam by concluding that he has low aptitude for both fraction operations and problem solving and there's no point in learning about fractions since failure is beyond his control.

Casual attributions related to motivation can be examined through the lens of theoretical framework related to Attribution Theory (Weiner, 1985). Attribution Theory relates to how deliberate behavior is interpreted by attributed it to why it was happening after it has been observed (Weiner, 1972).



Source: Pentin, S. (2014) as cited in Gill (2014).

Figure 2. Attribution Theory.

Attribution theory is comprised of three categories: stability, locus of causality, and locus of control (Pentin, 2014). Referring to Figure 2 above, responses to each of these categories in reaction to one's own observable and deliberate behavior will help to determine future behaviors as well (Weiner, 1972). The following scenario illustrates application of Attribution Theory. For example, a teacher returns a mathematics exam with a failing grade to a student. How the student interprets that grade depends upon his reaction to the characteristics associated with stability, locus of causality and locus of control. If the student is highly stable, then he may think that he expected to earn this grade because he didn't prepare adequately for the exam. If he exhibits internal locus of causality and behavior that was within his locus of control, then he would attribute the failing grade to not mastering the test material and not approaching the teacher for extra help before the exam. Future behavior may most likely be positive as the student would use this failing experience to better prepare and soliciting extra help from the teacher prior to the next math test.

Considering that self-efficacy significantly influences motivation to learn and subsequent achievement, it is essential to explore self-efficacy towards mathematics and strategies about how to bolster both teachers' and students' attitudes and beliefs so that students are motivated to reach their academic potential in mathematics.

Teachers and Learning Design

In the following section, I have addressed the current teaching demands of critical thinking and mathematics curriculum. Hurrell (2013) has posited, "It may seem almost self-evident that if society requires effective learning, then effective teaching is necessary" (p. 54). Considering the current curricular focus on applying reasoning in different contexts reflective of the goals set by the common core standards, both teachers' and students' understanding of process-oriented problem solving skills is essential (Ball & Forzani, 2009; Ball, Thames, & Phelps, 2008; Ball, Hill, & Bass, 2005). For instance, Lachner and Nuckles' (2016) research study compared problem solving instruction provided to students by mathematicians with less pedagogical content knowledge and high content knowledge and, teachers with high pedagogical content knowledge but low content knowledge. Their findings suggested that students were able to better understand the explanations provided by mathematicians due to the deeper understanding of the nature of the mathematical problems even without a strong pedagogical content knowledge background in mathematics (Lachner & Nuckles, 2016). Moreover, Das and

Das (2013) have suggested that students' benefit from teaching strategies that involve a variety of learning styles, activities and strategies when teaching students problem solving skills in mathematics.

Ball, Thames, and Phelps (2008), adding to previous educational theoretical framework developed by Shulman (1986), have suggested that in order for teachers to be adequately prepared to teach, they require a balance of both subject matter knowledge and pedagogical content knowledge. Moreover, understanding the extent of teachers' expertise in mathematics and the depth of that knowledge is essential for students' success in the classroom. The authors insightfully posit that understanding how to solve a problem is not enough to be effective in the classroom. A teacher with strong subject matter knowledge has to be able to possess specialized content knowledge – a creative approach of the different ways of presenting strategies to solve a problem (Ball, Thames, & Phelps, 2008). Additionally, horizon content knowledge – an overall skill of understanding a students' past knowledge and what will be required to move forward, is an important component of instructional delivery by the teacher (Ball, Thames, & Phelps, 2008). Finally, pedagogical knowledge includes a combination of being adept at how to use resources and teaching methods effectively while also supporting what is expected of students in terms of mathematical concepts and students' learning (Ball, et al., 2008).

Ellis (2003) has suggested that in contrast to past traditional conceptual frameworks where the teacher was regarded as the expert, the current model of mathematics education advocates for the premise that, "…Learning of both teachers and students evolve during social interaction of knowledge" (Ellis, 2003). Cobb, Yackel, and Wood (1992) have discussed how an individual teacher-directed traditional model as well as cooperative learning experiences are both influenced by the social experience of classroom learning. Vygotsky (1978) has discussed an individual's "zone of proximal development" that marks the "distance between actual developmental level as determined by individual problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p.86). When socially constructing knowledge, it is important to recognize how teachers and students both bring their interpretations of content area knowledge into the learning environment and how this shapes the experiences and beliefs of others in the classroom (Remillard, 1999).

This is especially essential considering the nature of CCSS' emphasis on process-oriented problem solving tasks ("Common Core State Standards Initiative", n.d.). The CCSS represents a significant conceptual shift in teaching mathematics as learning is now focused on narrowing concepts taught per grade and increasing fluency and automaticity, application, and rigor ("Common Core State Standards Initiative", n.d.). The CCSS advocate for supporting not only focus and rigor, but also coherence by, "Thinking across the grades and linking to major topics within grades" ("Achieve the Core", n.d.).

Moreover, instead of teaching skills in a building block, hierarchal method where a foundational mathematics concept is revisited each school year, skills are now differentiated according to a blending of previous topics ("Achieve the Core", n.d.). This presents an educational challenge to both teachers and students. There are fewer mathematical concepts as indicated by common core state standard indicators that teachers are required to focus on each year, yet students *and* teachers are *both* accountable for mastery of general skill application of those standards through state standardized testing assessments. The curriculum which reflects the objectives of common core state standards is designed to be rigorous.

NCTM (2017) describes rigor in mathematics for teacher instruction as follows:

> Rigor involves all partners in teaching and learning. Teachers must consider rigor in planning lessons, tasks, and assignments. Rigorous lessons build on and extend prior knowledge. They encourage productive struggling. Although the objective of a lesson should be clear in the teacher's mind, the lesson should not focus on one correct path to a solution or even one correct answer. A rigorous lesson embraces the messiness of a good mathematics task and the deep learning that it has the potential to achieve.

NCTM (2017) describes rigorous learning for students as follows:

> Students who are successful in a rigorous learning environment take responsibility for their learning. They learn to reflect on their thinking. They persist in solving a problem when the path to solution is not immediately obvious. They recognize when they are not on the correct path and need to switch directions during the solution process.

Many districts are adopting their own benchmark assessments prior to PARCC standardized testing exams in order to regularly assess students' progress and teaching practices. Teachers are required to draw from their own background to meet new rigorous academic specialized content challenges (Ball, Thames, & Phelps, 2008). For instance, the procedural skill of multiplying and dividing fractions and mixed numbers, once introduced in sixth grade, is now taught in fifth grade and then subsequently applied in problem solving contexts the school years that follow. This educational perspective assumes that students will grasp the 'nuts and bolts' of how to solve a computation-based problem sufficiently in the designated time and then retain and apply that knowledge in critical thinking and reasoning contexts over the course of their school careers.

One of the challenges for teachers is to be able to understand and apply the extent of mathematical concept knowledge across grade levels and the projected expectations for students' learning ("Achieve the Core", n.d.). Moreover, it is important to be able to conceptualize skills so that a teacher must now be able to have a grasp on not only what must be taught in her own grade level, but develop 'horizon knowledge'; an understanding of what skills will be needed using the concepts she has taught as a skills base for her students throughout their schooling (Ball, Thames, & Phelps, 2008).

Goodykoontz' (2008) research suggests that students develop their own attitudes and beliefs about mathematics from a teacher's own beliefs as well as teaching strategies and classroom practices (Goodykoontz, 2008; Grootenboer & Marshman, 2016). In order to promote success in mathematics and experience significant gains in overall achievement, it is important to examine how teachers' beliefs and depth of one's own knowledge in concert with chosen instructional strategies, like using technology as an effective instructional resource, actively influences learning mathematics.

Socio-Cultural Background

In the following section, I will discuss the academic demands of students to learn mathematics according to the Common Core State Standards objectives through the lens of diversity and students' socio-cultural backgrounds which are influential and play a role in the success or failure in the learning process in schools. The purpose of this section is to summarize socio-cultural issues that may play a factor in how students see themselves as learners and reflected by students' level of mathematics anxiety, self-efficacy and mathematics achievement.

As discussed earlier in this chapter, and serving partially as a catalyst for educational reform in mathematics education, the results of international assessments among teens globally have placed the United States lagging behind other industrialized nations. Analyzing the results, the OECD (2012) has commented on potential improvements and continuing concerns.

OECD (2012) cites the following:

> Students in the United States have particular weaknesses in performing mathematics tasks with higher cognitive demands, such as taking real-world situations, translating them into mathematical terms, and interpreting mathematical aspects in real-world problems. An alignment study between the Common Core State Standards for Mathematics and PISA suggests that a successful implementation of the Common Core Standards would yield significant performance gains also in PISA.

OECD (2012) has also acknowledged potential obstacles:

> Socio-economic background has a significant impact on student performance in the United States, with some 15% of the variation in student performance explained by this, similar to the OECD average. Although this impact has weakened over time, disadvantaged (U.S) students show less engagement, drive, motivation and self-beliefs.

MacLeod (1995) has discussed students' cultural capital, or what students bring related to prior knowledge, to the school experience. For example, if a student has had extensive experiences of visiting pyramid exhibits at a science museum before a unit on geometry is introduced in class, he will most likely have more background knowledge and ability to contribute to a new lesson introduced by the teacher differently and possibly more in-depth, than a student who is being exposed to the curricular material for the first time. Cultural capital is particularly important considering the Common Core State Standards' and subsequent testing focus on process-oriented problem solving which requires fluency and application of core content areas in mathematics ("Common Core State Standards Initiative", n.d.). Acquiring knowledge is a socially constructed process (Rogoff, 2003; Vygotsky, 1978). Students' culturally diverse backgrounds help to shape their own learning experiences and perceptions driven by teacher-directed instruction within an established school culture (MacLeod, 1995). This presents a powerful consideration for students' self-efficacy beliefs about their own academic potential and achievement in mathematics. In review of the literature related to cultural capital, MacLeod (1995) has discussed research related to students' "linguistic capital" and the advantages and disadvantages that it brings to students' learning. Students with varying social status as dictated by family background, bring diverse linguistic patterns through culturally different experiences (MacLeod, 1995). It is important to recognize then, that students that are learning mathematics may interpret content which teachers are introducing in class with different meanings and interpretations. Considering the impact of self-efficacy and anxiety in both teaching and students' learning, socio-cultural factors, like linguistic cultural capital, is important. For example, a teacher with a low self-efficacy towards teaching mathematics may not perceive herself capable or motivated enough to teach mathematics concepts in a variety of different ways to meet the needs and instructional challenges of diverse students in the classroom.

Jackson and Cobb (2011) have discussed the issue of equity considering the ‘ambitious’ curricular objectives set forth by current mathematics standards. The authors have posited that although teachers have been provided vague guidelines as to how to meet established mathematics standards, there currently exists a lack of concrete instructional strategies that have been documented and provided to teachers in order to guarantee a more equitable education for all students (Jackson & Cobb, 2011). In this situation, teachers are responsible for meeting the demands of diverse socio-cultural student populations. This may play a role in teachers’ self-efficacy about teaching mathematics and teachers’ math anxiety. Jackson and Cobb (2010) have suggested adding instructional strategies for mathematics teachers which include “…supporting students in understanding the cultural suppositions of the task scenario and in developing situation-specific images of mathematical relationships described…and rephrasing or re-voicing students’ reasoning expressed using informal or non-mathematical language explanations” (p.27).

Another socio-cultural issue to consider is ability tracking in mathematics. According to the 2013 Brown Center Report on American Education, tracking U.S. students in mathematics has remained popular, especially beginning in fourth grade, despite intense debate about its role in sustaining socioeconomic and other cultural inequities among students through mathematic education (Loveless, 2013). Ladson-Billings (1997) and others (e.g., Oakes, 1985; Aronowitz & Girioux, 1993) have discussed that mathematics curriculum has been designed to be unjust by sustaining class status through maintaining inequities in education. Ladson-Billings (1997) further posits that exposure to demanding, more equitable mathematics curriculum will result in "increased educational and economic opportunity" and a chance for future achievement, which would not have been attainable otherwise, for all students regardless of socioeconomic background and race.

As discussed, students' socio-cultural backgrounds impact the success or failure in the learning process in schools. Mathematics anxiety is a factor to consider when discussing math education and diverse socio-cultural populations. For example, a student may struggle in math class due to factors outside of capacity to learn; such as linguistic challenges, weak foundational skills due to background, or ability tracking issues. However, the academic struggle that the student experiences may be interpreted as how she sees herself as a learner. This may subsequently be exhibited by being anxious about succeeding in math taught in the classroom. The anxiety may then play a self-sustaining role in underachievement in mathematics by participating less in teacher-led activities, expecting to fail on assessments, and excessive worry about all tasks that involve learning mathematics. Feeling overly anxious about understanding math concepts eventually leads to poor self-efficacy or belief that success is possible.

Setting

This research study was conducted in a small, suburban school district in New Jersey. I targeted a maximum of 18 third and fourth grade teachers who teach mathematics at one elementary school within this school district. Third and fourth grade teachers were chosen as participants because although all teachers are elementary school certified, not all teachers have a specialty certification in mathematics. This provided valuable insight about self-efficacy and anxiety. Teachers' own self-efficacy about teaching mathematics were explored since the elementary certified participants in this study are diverse regarding the extent of experiences with current content knowledge.

Mathematics is ability grouped at this elementary school beginning in third grade. Teachers are designated a professional assignment that may change from year to year depending upon the size of the school district's student enrollment. The factor that teaching assignments frequently change was interesting to research considering the demands of standardized testing and standards in mathematics which teachers are responsible for and evaluated on as well. This set of participants and research study setting provided the opportunity to collect data from a heterogeneous group of participants from the perspective of teachers' attitudes, educational backgrounds and beliefs about teaching mathematics.

The one elementary school that was chosen provided insightful data due to its recent ongoing cultural transformation. The school district partially in response to the demands of a changing demographics, visions of new senior administrators, and aggressive development efforts in town has become a high achieving district. Data regarding students' achievement on standardized tests by teacher and grade are monitored and evaluated in order to strive for academic excellence as a school district. Representing a culturally diverse student population, it was interesting to explore teachers' own self-efficacy about teaching mathematics and using technology resources to lessen students' math anxiety and promoting achievement in an elementary school setting. This study coincides with the school districts' own long range plan of implementing one-to-one technology successfully in all classrooms over the next few years. Currently, third and fourth grade classrooms are equipped with some technology. There are two Chromebook carts. One is allocated for third grade and another for fourth grade and each house one class set of Chromebooks. The school district's technology plan includes one to one Chromebooks for students in grades 5 – 12. When the plan is implemented, existing Chromebook carts currently at the middle school will be designated to be used to better support classes at the elementary school. It was exciting and provided valuable insight to have the opportunity of studying self-efficacy about technology in addition to mathematics at the beginning of a technological initiative launched in this school district.

Methodology

I conducted a qualitative research study. I have chosen this methodology because it provided the opportunity for exploring nuances in this research study about self-efficacy and anxiety (Rubin & Rubin, 2012). I examined the data collected and analyzed how it added to current research regarding the theoretical framework about self-efficacy and Attribution Theory. For this study, I had the opportunity to triangulate my data sources and collect information from teacher observations, teacher surveys and teacher semi-structured interviews. The interview process involved both new and veteran teachers which provided insight as to the demands of teaching mathematics to students in a school district operating in a climate in the midst of change; academically and socio-culturally. Data was collected and analyzed using descriptive, in vivo, and pattern coding techniques (Saldana, 2009).

Purpose

When evaluating past and current educational reform movements, the focus of how to best serve all students equitably continues to present itself as a dilemma without a solution. How do we encourage mathematics achievement among all students? Where and how are we as a nation missing the mark? Moreover, the stakes are high: considering the lack-luster United States' standing academically among teens on international assessments along with mounting economic pressures to compete globally by cultivating our commitment to STEM related careers through enhancing educational opportunities.

The purpose of this study is to explore teachers' perceived self-efficacy about mathematics and using educational technology and its influence on lessening students' math anxiety in the classroom. Building upon previous research by Sun and Pyzdrowski (2009), this study examined teachers' beliefs about mathematics and their own ability to use online educational mathematics resources to lessen students' math anxiety, increase self-efficacy and encourage academic achievement.

This research study also explored the frequency and degree of critical thinking in mathematics that teachers use in their teaching when incorporating strategies which involve technology into classroom instructional practices. Considering the rigorous demands of current teaching standards in mathematics, it is important to also study this aspect of teaching from the perspective of teachers' attitudes towards mathematics and resources to teach mathematics effectively. Researching critical thinking in relation to teachers' own self-efficacy about mathematics provided insight about how self-efficacy and anxiety influence teaching mathematics to children.

Research Questions

From the perspective of a veteran math teacher and instructional mathematics coach, I am particularly interested in exploring issues about math education. Additionally, understanding the current national focus on math achievement is central to the importance of this research. This study explored issues related to self-efficacy and mathematics anxiety and subsequent impact on mathematics achievement. Considering the research about teachers' self-efficacy and mathematics anxiety, I conducted a research study that examines teachers' beliefs about using technology as a resource to lessen students' mathematics anxiety in the classroom. As part of this study, I also examined the critical thinking aspect associated with teaching mathematics.

The research questions for this research study are as follows:

1. How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of using educational technology as an instructional resource tool to lessen students' math anxiety?
2. How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of encouraging critical thinking tasks among students in mathematics classrooms?
3. To what extent do the results of this qualitative study support previous research about factors affecting teachers' use of educational technology on teachers' self-efficacy related to the selection of instructional methods to lessen students' math anxiety?
4. To what extent do the results of this qualitative study support previous research about factors affecting teachers' mathematics anxiety and self-efficacy about teaching mathematics to lessen students' math anxiety in the elementary school classroom?

Assumptions

It was assumed that all participants provided honest answers to the best of their ability. In order to accomplish this, I encouraged a collaborative, trusting environment by delivering questions in a nonjudgmental manner. I also delivered questions in a consistent manner that encourages open-ended dialogue. When observing teachers' lessons, I was non-obtrusive and sensitive to the teachers' classroom routine. I audio-taped interviews and took field notes during classroom observations when given permission to do so. During the interview process, I created and asked questions that were focused on the research study objectives rather than personal opinion.

Although my goal was to collect these sources from all eighteen third and fourth grade elementary school teachers, there was a limitation beyond my control when not all teachers would like to participate or choose to participate in part of the collection process. For instance, two participants were surveyed and interviewed but not observed. In this scenario, I collected the data that was available. I used first and second cycle coding (Saldana, 2009) of all data collected and then report all trends and patterns of the research. Finally, I compared the data results that I analyzed through the lens of existing theoretical framework related to self-efficacy and math anxiety.

Definition of Key Terms

The following key terms are central to the focus of this research study. For clarification purposes, definitions for all the key terms are listed.

Common core standards. "The Common Core is a set of high-quality academic standards in mathematics and English language arts/literacy (ELA). These learning goals outline what a student should know and be able to do at the end of each grade. The standards were created to ensure that all students graduate from high school with the skills and knowledge necessary to succeed in college, career, and life, regardless of where they live. Forty-two states have voluntarily adopted and are moving forward with the Common Core" ("Common Core State Standards Initiative", n.d.).

Conceptual understanding. "Mathematics in context. Conceptual understanding is knowing more than isolated facts and methods. The successful student understands mathematical ideas, and has the ability to transfer their knowledge into new situations and apply it to new contexts" (Dream Box Learning, n.d.).

Educational technology. Education Technology (also known as “EdTech”) refers to "the creation, use, and management of technological resources in education" (Educational technology, n.d.).

Math anxiety. "Mathematics anxiety involves negative cognitions, avoidance behaviors, feelings of pressure and performance inadequacy that interfere with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations” (Vahedi and Farrokhi, 2011).

Math self-efficacy. "The extent to which students believe in their own ability to solve specific mathematics tasks" (OECD, 2012).

One-to-One technology. "The term one-to-one is applied to programs that provide all students in a school, district, or state with their own laptop, netbook, tablet computer, or other mobile-computing device. One-to-one refers to one computer for every student" (One-to-one, 2013).

Procedural fluency. "Procedural fluency is the ability to apply procedures accurately, efficiently, and flexibly; to transfer procedures to different problems and contexts; to build or modify procedures from other procedures; and to recognize when one strategy or procedure is more appropriate to apply than another" (NCTM, n.d.).

Self-efficacy. "One's belief in one's ability to succeed in specific situations or accomplish a task. One's sense of self-efficacy can play a major role in how one approaches goals, tasks, and challenges" (Bandura, 1994/1998).

STEM. "STEM is a curriculum based on the idea of educating students in four specific disciplines — science, technology, engineering and mathematics — in an interdisciplinary and applied approach. Rather than teach the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world" (Hom, E.J., 2014).

Summary

This study addressed a previous gap in research that builds upon work by Sun and Pzydrwoski (2009). Sun and Pzydrowski's (2009) findings suggested that educational technology has been beneficial when lessening students' math anxiety in the classroom. The authors suggest that more research may be warranted regarding how individuals view their ability to use technology for these purposes. Understanding that self-efficacy and math anxiety are inherently linked and powerful influencers generally in education, I developed an understanding of how third and fourth grade teachers perceive their own self-efficacy about mathematics and technology and how they then use educational technology as an instructional resource to lessen students' math anxiety in the classroom. Also essential to this study is an exploration of the participants' own self-efficacy about mathematics and math anxiety, and, if this plays a secondary role about how technology is used in math instruction. It is important that research was conducted to explore whether the way in which educational on-line resources are used, is influenced by teachers' self-efficacy about mathematics and math anxiety and then, reflected in the degree of critical thinking that is encouraged among students by the teacher during class discussions. Given the national focus of STEM education and technology, it is essential that more students are encouraged to pursue more in-depth mathematics throughout the school experience. Understanding teachers' self-efficacy about technology and mathematics and its influence on instructional practices and students' math anxiety, learning, and achievement were the first steps in understanding these issues in a broader national context.

Chapter 2

Literature Review

This paper examined the connection between teachers' perceptions of using specific instructional methods and students' mathematics anxiety. The topic of how mathematics teachers describe their own self-efficacy using educational technology as an effective instructional method to lessen students' math anxiety was explored in this study.

This literature review focused on exploring research related to mathematics anxiety. In order to do so, I summarized theory through the lens of current mathematics teaching practices. Defining math anxiety as well as examining its consequences to achievement was discussed. A summary of affective and cognitive components of math anxiety, including a discussion about working memory and academic potential follows. This literature review addresses research outlining the role of self-efficacy for this topic. Finally, I reviewed limited research available examining the possible connection and relationship of educational technology and mathematics anxiety.

Classroom Practices and Mathematics

It has been posited that students learn mathematics best through socially-constructed reasoning (Steele, 2001). Vygotsky (1978) has suggested that people learn from taking what they know and reforming ideas based on social experiences. Students learn mathematics within their own 'zone of proximal development' using existing knowledge as a foundational base in order to adjust and expand conceptual understanding of mathematical skills (Vygotsky, 1978; Rogoff, 2003). For instance, Steele (2001) has documented instructional practices demonstrating this where teachers were actively involved with guiding and scaffolding math lessons. In one example, an elementary teacher presented a question about finding the center of a circle to her students, then allotted time for independent hands-on investigation and encouraged cooperative learning prior to the teacher's direct instruction (Steele, 2001). By actively listening and providing the opportunity for students to draw upon the existing knowledge and opinions of others, the teacher was able to effectively model the conceptual understanding of math skills (Steele, 2001). This is especially important considering that generally mathematics curriculum is dependent upon the extensive use of symbols and vocabulary (Ball, Ferrini-Mundy, Kilpatrick, Schmid, & Schaar, 2005). Also, capitalizing on teaching reasoning skills is consistent with the skills needed to meet the demands of Science Technology Engineering and Math (STEM) careers (STEM Coalition, 2016).

However, there are challenges when providing instruction that is essentially student-driven in its approach. For instance, planning for flexibility like this in instructional methods, requires teachers to feel confident about math content and skills (Steele, 2001). In fact, Steele (2001) and others (Hill and Ball, 2004) have discussed the importance of developing expertise in teaching mathematics. A teacher's in-depth understanding of curricular knowledge is essential since this is how mathematics is effectively portrayed and successfully communicated to students as they develop their own academic potential (Steele, 2001).

Defining Math Anxiety

Beilock and Maloney (2015) have suggested that math anxiety is commonplace among students and that it significantly influences students' learning outcomes (Wigfield & Meece, 1988; Ashcraft & Faust, 1994; Ashcraft, 2002; Ashcraft & Kirk, 2001; Geist, 2010). In fact, it has been suggested that the majority of the U.S. population has experienced math anxiety sometime in their school careers (Furner & Duffy, 2002; Scarpello, 2007; Sun & Pydrowski, 2009). Indeed, some have speculated that worrying about mathematics may begin as early as first grade (Ramirez, Gunderson, Levine, & Beilock, 2013; Beilock, 2010; Harmes, 2012). Moreover, most literature has discussed the negative impact of math anxiety (Meece, Wigfield, & Eccles, 1990; Gunderson, Ramirez, Levine, & Beilock, 2012; Geist, 2010). It has been posited that there are benefits of mild forms of math anxiety in situations when high achieving students are highly motivated to engage in math (Wang, et al., 2015), but this research is limited and overshadowed by the vast number of studies that discuss the negative consequences of math anxiety.

Defining math anxiety has varied in focus historically as some definitions have targeted individual's tense feelings and subsequent emotional reactions to completing a math task (Spicer, 2004), while others have expanded the definition of math anxiety to include its influence on both academic situations and ordinary life (Richardson & Suinn, 1972; Vahedi and Farrokhi, 2011). Ashcraft's (2002) definition attends to more of an academic focus: "A feeling of tension, apprehension or fear that interferes with math performance" (p.181). However, Vahedi and Farrokhi's (2011) definition perhaps best represents a holistic understanding of math anxiety: "Mathematics anxiety involves negative cognitions, avoidance behaviors, feelings of pressure and performance inadequacy that interfere with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations" (p.47).The latter definition speaks to more broad consequences of math anxiety which have far-reaching implications for an individual's academic and professional choices.

Consequences

Until recently, a widely-held assumption about math anxiety was that it occurred in late middle school, when students begin to tackle Algebra and other critical thinking problem solving tasks (Maloney & Beilock, 2012). In fact, some research has posited that anxiety about mathematics shows marketable increases in the earlier high school years (Meece, Wigfield, & Eccles, 1990; Buckley, 2011). Dowker, Sakar & Looi (2016) have discussed that math anxiety may increase with age. However, it is now understood that negative experiences and anxiety can occur at any time and certainly earlier than adolescence (Ramirez et al., 2013; Beilock, 2010; Harmes, 2012). Since it is pervasive, understanding when math anxiety occurs and reasons for it are helpful to then identifying its consequences.

There are a variety of triggers that lead to fear of mathematics. A student might be struggling academically (Beilock & Maloney, 2015) and then develop poor perceived self-efficacy about succeeding in math (Ashcraft & Krause, 2007). Additionally, individuals may pick up negative cues indirectly from others that subsequently affect academic performance (Meece, Wigfield, & Eccles, 1990; Tobias, 1993; Pajares & Miller, 1994; Peker & Ertekin, 2011). Regardless of the catalyst, the negative consequences of math anxiety frequently influence personal choices to avoid or limit exposure to mathematics (Chipman, Krantz & Silver, 1992; Maloney et al., 2015). Common cultural attitudes condoning math anxiety and avoidance are prevalent in our society and compound efforts to change this behavior (Buckley, 2011).

Tobias (1993) has discussed the anticipation of a highly anxious student's expectation to be 'nonmathematical' may translate into passivity and withdrawal in the classroom; ultimately short-changing the learning experience. Not engaging in math results in particularly important negative academic consequences. Equally important, our broader views of what it means to be high achieving in mathematics is linked to societal beliefs and values (Buckley, 2011).

Culturally, mathematics is viewed by parents and students as an inherently challenging subject (Ashcraft, 2002) that is associated with intelligence (Buckley, 2011), and fear of it can mask otherwise ability and competence in math (Meece, Wigfield, & Eccles, 1990). Moreover, highly anxious students may demonstrate behaviors like rushing through an assignment, which could be mistaken for carelessness, but are actually attempts to avoid failure (Ashcraft, 2002). There is a parallel that can be drawn between students' actions to mask these insecurities about succeeding and preconceived self-efficacy about their own academic capabilities. This will be addressed in greater detail below when discussing self-efficacy and mathematics.

Additionally, other non-productive behaviors may include exhibiting limited or no persistence in solving math problems and an over-reliance on drill and practice textbook learning (Tobias, 1993). These math avoidance techniques inadvertently sabotage opportunities for students to develop a foundation in the subject. In this scenario, avoidance is in response to an anxious students' feeling of helplessness rather than ability (Chinn, 2012). One unfortunate consequence of persisting in relying on avoidance behaviors is establishing a vicious cycle of underperformance compared to math potential. For example, a highly anxious student may passively avoid participating in class discussions central to skill development, and then fall behind academically, resulting in greater anxiety and weaker skills. Over time, it may be challenging to tease out what is driving each outcome: the high math anxiety or the poor math performance (Ma & Xu, 2004; Carey, Devine, & Szucs, 2015). Gafoor and Kurukkan (2015) have suggested, those foundational math concepts learned in the early grades become the building blocks of more abstract learning later on, thereby lending considerable weight to the importance of acquiring math skills at a young age.

Highly anxious math students may also incorrectly assume that it is impossible to learn basic concepts later in their academic experience (Tobias, 1993) and then avoid taking elective classes in mathematics in high school and college (Ashcraft, 2002; Ashcraft & Krause, 2007). Chipman, Krantz, & Silver, (1992) suggest that this may result in subsequently avoiding science and math-related careers (Chipman, et al., 1992). This is alarming, since being skillful at mathematics is increasingly essential for today's students who are living in our age of information technology and digital era (Grootenboer & Marshman, 2016). Moreover, this has long-term consequences considering the importance of students' choices to pursue STEM-related courses and the increased workforce required to remain competitive as a nation (United States Bureau of Labor and Statistics, 2015; United States Department of Commerce, 2011; United States Department of Education, 2016; STEM Education Coalition, 2016).

In addition to our national commitment to mathematics and science careers devoted to STEM from an economic perspective, it is also important to consider the influence of math anxiety on students' choices and performance in careers that are not primarily focused on mathematics or science. Although commonly overlooked, mathematics provides reasoning skills that are used in everyday life (Buckley, 2011; Grootenboer & Marshman, 2016). Later subsequent decisions in students' academic careers may have subtle negative consequences affecting others. For instance, high math anxiety may be prevalent among students enrolled in other traditional career choice settings that are not necessarily STEM focused. Hembree's (1990) study which surveyed attitudes among pre-service elementary school teachers, for example, revealed that this college sub-group scored the highest math anxiety rating on a scale that compared all other college majors surveyed, suggesting potentially negative long-term consequences for future generations of young children within a much broader educational system (Beilock, Gunderson, Ramirez & Levine, 2009). Moreover, this supports the importance of examining the relationship of teachers' instructional methods and students' mathematics anxiety.

Components of Math Anxiety

Math anxiety has frequently been described as being comprised of affective and cognitive components (Ashcraft, 2002; Ashcraft & Krause, 2007). Physiologically, fear of academic failure may trigger a negative reaction in an individual's affect that interferes with successful completion of a math task (Wigfield & Meece, 1988; Meece, Wigfield, & Eccles, 1990). Reactions vary, but nervousness may surface as a highly anxious individual feeling panicky or shaky when anticipating or engaging in mathematics (Wigfield & Meece, 1988; Meece, Wigfield, & Eccles, 1990). Negative affect, in the form of math anxiety, is described as a high value and low control emotion (Pekrun, 2006; Buckley, 2011). Moreover, a highly anxious student values mathematics that is taught in school because it represents a subject that is culturally associated with being smart (Grootenboer & Marshman, 2016), but perceives there is little control over achievement, resulting in a potentially negative emotional reaction to the situation

(Pekrun, 2006; Buckley, 2011). Not all individuals who struggle with math anxiety exhibit a visibly obvious emotional affect, which presents a challenging teaching opportunity for educators when identifying those students who are capable of achieving academically, but held back by anxiety. In fact, it has been suggested that there exists only a weak link between math anxiety and math intellectual potential (Ashcraft, 2002).

Dowker, Sarkar & Looi (2016), in reviewing 60 years of research, found that mathematics anxiety was frequently compared to general anxiety, although there is a uniqueness regarding deficits in working memory that sets math anxiety apart. For instance, an example of the cognitive component of the math anxiety is what a highly anxious student experiences when she is prepared to take a math assessment but then panics and is unable to retrieve the math concepts and skills necessary to successfully achieve when asked to complete the exam.

Ashcraft and Faust (1994) and others suggest that working memory is involved in the cognitive processes that are impeded by math anxiety (Ashcraft & Faust, 1994; Ashcraft & Kirk, 2001; Beilock & Maloney, 2015; Lyons & Beilock, 2012; Wigfield & Meece, 1988). Recognizing and understanding the uniqueness of math anxiety and how the brain short circuits when highly anxious individuals are presented with a problem that involves mathematics will help educators develop effective instructional strategies for promoting high quality learning for all students in the classroom.

Working Memory and Achievement

Cowan (2009) has described working memory as multi-faceted, and for purposes of this literature review, "…a multi-component system that holds and manipulates information in short-term memory". Working memory is compromised when anxiety acts as a distractor, limiting the capacity of working memory (Ashcraft & Kirk, 2001; Lyons & Beilock, 2012). For example, worrying or anticipating and focusing on failing an exam may act as a secondary, non-productive task and reduce space in the working memory for processing math concepts (Ashcraft, 2002). Most math tasks, with the exception of those that involve memory retrieval, require working memory to process problem solving needed for mathematics (Ashcraft & Krause, 2007). For instance, Faust, Ashcraft and Fleck (1996) reported that highly anxious individuals, capable of excelling at basic math tasks, compromised accuracy and speed when asked to complete tasks involving number operations. In this study, high math anxiety students demonstrated greatest difficulty and met with less success when asked to add with carrying and to identify false answers in a problem solving set (Faust, Ashcraft & Fleck, 1996). Both skills involve multi-step processing involving which extended beyond memory retrieval of math concepts.

Ashcraft and Kirk (2001) have suggested that math anxiety affects the accuracy and automaticity of math performance tasks (Ashcraft & Kirk, 2001; Dowker, 2016). The varying degree of an individual's math anxiety also influences performance outcomes (Ashcraft, 2002; Ashcraft & Faust, 1994). Ashcraft's (2002) research compared high, medium and low anxiety individuals' standardized test results and found no difference in whole number computation. However, there were significant discrepancies among the groups when math processes became more complex and students were asked to solve problems targeting mixed fractions, percentages and factoring expressions (Ashcraft, 2002). This is supported by Ashcraft and Kraus' research that has posited that 'strategy-based solutions' require more resources and complex processing from the working memory and is then more vulnerable to the negative consequences of math anxiety

(Ashcraft & Krause, 2007). Other research supports that variability in anxiety affects performance. Ashcraft and Faust (1994), when testing effects of processing speed and accuracy among college aged students, found that the low anxiety students demonstrated the fastest processing speed and were most accurate when completing multi-step math tasks. The medium math anxiety group completed the assessments last and the students with the highest math anxiety showed the poorest accuracy rate overall, even though all of the groups were initially tested to guarantee similarities in overall math ability and potential achievement standards (Ashcraft & Faust, 1994).

In addition to the degree to which a person feels anxious, the general capacity and limitations of one's working memory and math ability also influence overall math achievement (Passolungi, Caviola, DeAgostini, Perrin & Mammarella, 2016; Ashcraft & Krause, 2007). The importance of working memory to process mathematics may not be always obvious since, unlike language, a few symbols may represent a complex problem solving task (Ashcraft & Krause, 2007). Mathematics involves reasoning and understanding the meaning and vocabulary associated with symbols (Ball, Ferrini-Mundy, Kilpatrick, Schmid, & Schaar, 2005). Interestingly, Witt's (2012) research found that unlike anxiety related to verbal reasoning, highly math anxious elementary school students anticipated failure and showed compromised working memory and poor math performance from just a set of visual cues when presented with digits. In this case, complex problem solving was not necessary to trigger the anxiety and subsequent behavior (Witt, 2012). Other studies support the premise that math anxiety is 'stimulus- and situation-specific' judging from less neurological activity in the prefrontal cortex and other areas of the brain that control working memory and attention and increased emotional activity in the amygdala among highly anxious students (Young, Wu, & Menon, 2012).

Research by Hopko, Ashcraft, Gute, Ruggerio and Lewis (1998) revisited the premise that anxiety ‘crowds’ the working memory, resulting in less useable space to hold and process information. From their results, they suggested that rather than less working memory, individuals with high math anxiety are unable to shut out the distractors that inhibit processing complex thinking efficiently (Hopko, et al., 1998). Considering this, if there were strategies that highly anxious students could employ to anticipate and minimize math anxiety and thereby distractions, there would be better opportunities for all students to learn and assess knowledge successfully.

Lyons & Beilock (2012) have in fact, suggested that identifying, anticipating and developing strategies for how to control anxiety among highly anxious students is beneficial in order to improve achievement in mathematics. Research has documented the relationship between mathematics achievement and mathematics anxiety (Ma, 1999; Cates & Rhymer, 2003). An important consideration is to examine the relationship and degree of interconnectedness between math anxiety and math achievement in relation to whether high math anxiety drives poor mathematics achievement or vice versa.

Ma and Xu (2004) examined the casual priority between mathematics achievement and mathematics anxiety. Using longitudinal data following students from grades 7 – 12, the results of their study suggested that there was a correlation between students who were low achievers in mathematics in the earlier years of junior high school and subsequently high levels of math anxiety in high school (Ma & Xu, 2004). Interestingly, their results found that mathematics achievement is relatively stable throughout the secondary years beginning in grade 7, while math anxiety and students' perceptions about completing math successfully is stable beginning at grade 8 and throughout the high school years as well (Ma & Xu. 2004). These results lend merit to the importance of instilling confidence and shaping the early years of students' school experience carefully in order to minimize math anxiety, considering its long-term effects on mathematics achievement in high school.

Through review of recent research, Carey, Devine and Szucs (2015) have suggested that the relationship among math anxiety and academic performance is complex and bi-directional. This again raises serious considerations surrounding the importance of addressing math anxiety at a young age. Catching anxiety early will enable educators to effectively assess students' academic achievement and assist all students to reach their actual mathematical potential. In summary then, although conflicting views exist regarding the relationship of math anxiety and achievement, its impact regarding learning is significant. Moreover, understanding the underpinnings of an individual's self-efficacy towards mathematics, discussed in the following section, will provide an opportunity to research effective methods of easing mathematics anxiety.

Self-Efficacy

Research has discussed the negative influence of an individual's poor self-efficacy towards a mathematical task (Wigfield & Eccles, 2000; Harmes, 2012; Beilock, 2010; Beilock, Gunderson, Ramirez, & Levine, 2009; Gunderson, Ramirez, Levine, & Beilock, 2012; Meece, J., Wigfield, A., & Eccles, J., 1990). Perceived self-efficacy has been defined as, "… people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (p.71) (Bandura, 1994/1998). A student with good self-efficacy would approach solving a math problem as doable and embrace the challenge, while a student with poor self-efficacy would immediately assume failure prior to looking at the math task, even if skills matched the student's ability level.

Bandura (1977) has emphasized the importance of self-efficacy as follows: "…expectations of personal efficacy determine whether coping behavior will be initiated, how much effort will be expended, and how long it will be sustained in the face of obstacles and aversive experiences" (p.191). Moreover, the concept of perceived self-efficacy may influence the degree to which one is motivated to complete a task successfully, and perceived level of academic achievement (Bandura, 1993). Individuals with high self-efficacy have an optimistic view that they will be able to successfully complete a task and are more likely to exhibit persistence and accomplish goals (Bandura, 1994/1998). Highly motivated students with a good sense of self-efficacy will attribute failure to lack of effort, while students with a poor sense of self-efficacy may view failure as a lack of ability (Bandura, 1993).

Bandura (1993) has posited that individuals' self-efficacy influences motivation to accomplish goals through personally deciding and reacting to the goal itself and then making readjustments based upon perceived successes and failures. This presents important ramifications for math achievement. For instance, a highly anxious math student may anticipate failure and set goals that are artificially low considering the student's actual academic capabilities. If presented with failing at a task, even a minor one, the highly anxious student will give up rather than persist and move on to the next mathematical challenge. Motivation is associated with outcome expectations and cognized goals that are strongly influenced by an individual's sense of self-efficacy (Bandura, 1993). Bandura (1993) has commented, "By making self-satisfaction conditional on matching adopted goals, people give direction to their behavior…" (p. 130).

Perceived self-efficacy impacts and is a predicting factor contributing to actual achievement (Bandura, 1993). In fact, Pajares and Miller's (1994) research has suggested that an individual's view about successfully solving problems involving mathematics was a greater predictor of achievement than the individual's actual math ability. In their study, they found that high efficacy students were more likely to achieve in comparison to those with poor self-efficacy, even if both groups were equally capable of achievement (Pajares & Miller, 1994).

Both environmental and personal factors influence one's self-efficacy including one's prior success or failure rate of completing the given task and the performance and response by others that shapes our perceptions (Bandura, 1982). Subsequently, individuals with a poor self-efficacy tend to avoid tasks that appear threatening and have a weak commitment to goals (Bandura, 1993); which presents potential learning consequences. From an educator's perspective, a teacher may inadvertently tailor curriculum based upon students' beliefs about their math abilities, rather than recognizing the ability hidden behind the avoidance behaviors (Chinn, 2012). This again, provides an opportunity for both teachers and students to unknowingly perpetuate a cycle of non-achievement.

Bandura (1994/1998) has posited that self-efficacy is built around an individual's experiences, social modeling and positive or negative persuasion by others regarding a particular situation. For example, how we judge our capabilities to tackle a challenging word problem involving fractions, may hinge on our own past successes or failures, as well as the opinions and actions of those around us. Pajares (1995) has commented that, “Self-efficacy beliefs are important influences on motivation and behavior in part because they mediate the relationship between knowledge and action” (p. 4). Hackett’s (1985) findings supports this premise. Research regarding college students’ academic choices, found that students’ high or low self-efficacy towards mathematics, was a predicting factor of both the degree of students’ math anxiety and decisions pertaining to driving career choices with a focus in mathematics (Hackett, 1985).

Self-efficacy and its connectedness to mathematics impacts teachers’ choices as well as students’. Teachers socially model self-efficacy beliefs about their own successes or failures in math indirectly and may pass this on to children. Bates, Latham, and Kim (2013) found that early childhood pre-service teachers’ fear of teaching mathematics and their own negative math school experiences shaped their confidence and beliefs about their ability to teach mathematics. Other research has suggested girls are affected by female teachers’ poor self-efficacy regarding math ability and achievement which may affect female students’ inclination towards math anxiety in the classroom (Pajares & Miller, 1994). In fact, researchers have also explored the possible connection between gender and its possible effect on individual’s math anxiety (Pajares & Miller, 1994; Spencer, Steele, & Quinn, 1999; Devine, Fawcett, Szucs, & Dowker, 2011; Rubinsten, Bialik, & Solar, 2012), as well as stereotype threat and its role as well (Maloney, Schaeffer, & Beilock, 2013; Spencer, Steele, & Quinn, 1999). Developing an understanding about how to alleviate mathematics anxiety in children and adults will lead to better opportunities for learning by creating effective instructional strategies and frameworks for anxious students' achievement in mathematics.

Educational Technology and Math Anxiety

As discussed throughout this literature review, there appears to be a strong and relevant connection between mathematics anxiety and achievement as well as the influence of students' perceived self-efficacy as central to long-term mathematics achievement (Maloney & Beilock, 2012; Bandura, 1993; Chinn, 2012; Carey, et al., 2015; Dowker et al., 2016). Addressing mathematics anxiety early in school is important (Wigfield & Meece, 1988; Meece, Wigfield & Eccles, 1990), as there are potential benefits and consequences to examining this issue (Beilock & Maloney, 2015; Maloney et al., 2015). In fact, Bates, Latham, and Kim's (2013) findings mentioned above concerning pre-service teachers' mathematics self-efficacy and its negative effect on young children may present indirect consequences to students' potential achievement and learning. For example, since conceptual understanding of mathematics is socially constructed within the classroom, a teacher's grasp of concepts and the confidence to communicate effectively is critical to students' success (Steele, 2001). Employing test taking techniques like incorporating breathing exercises have been suggested to ease test anxiety in general (Brunyé, Mahoney, Giles, Rapp, Taylor, & Kanarek, 2013). However, there exists a consideration for the uniqueness of *mathematics* anxiety because of its working memory component which makes researching promising motivational strategies essential when addressing this type of anxiety.

Sun and Pyzdrowski's (2009) meta-analysis of literature has suggested that integrating technology in mathematics instruction as an instructional strategy reduces students' math anxiety in the classroom. Hellum-Alexander (2010) has posited that using technological tools may offer a variety of resources and timely feedback when helping students lessen tense feelings regarding math achievement. Sun and Pyzdrowski (2009) have also suggested that there are opportunities for further exploration as a result of their study. Although there is research that has focused on math self-efficacy (Beilock, Gunderson, Ramirez, & Levine, 2009; Meece, Wigfield, & Eccles, 1990; Pajares & Miller, 1994), a limited number of scholarly research exists about teachers' technology self-efficacy (Sun and Pydrowski, 2009; Tatar et al., 2015).

Using educational technology to alleviate mathematics anxiety is a fairly new approach to teaching mathematics (Marr & Helme, 1991; Flores, 2002; Taylor & Galligan, 2006). Educational technology has been defined in a variety of ways and different hardware and software resources have been documented and billed as such, and incorporated into teaching in order to supplement the learning process (p. 5) (Saettler, 2004). Of particular interest in this literature review, is exploring the research associated with educational technology from the perspective of using interactive online math resources. For the purpose of this study, educational technology does not include the use of calculators. It does include online interactive mathematics games and related mathematics software. Interactive software was chosen because of its potential motivational value for students.

In fact, Reidel (2014) reporting on the results of the 2013 Speak Up Survey which involved 9,000 school districts reported that mathematics was the subject where students expressed the greatest interest in pursuing online learning resources. It was also revealed that, “students’ expectations for the use of (social media) technologies far outpaced those of administrators, teachers and parents” (Reidel, 2014).

The positive findings about students’ general attitudes regarding technology reported by Reidel (2014) are consistent with recent research exploring the possible connection among technology and math anxiety. Sun and Pyzdrowski’s (2009) research has argued that fear of academic failure as demonstrated by students’ math anxiety and negatively impacting academic potential may be lessened by building confidence through the use of technological resources to teach mathematics. Their research has discussed two causes of math anxiety: internal (cognitive) and external (influence of others) which impact students’ academic performance (Sun & Pyzdrowski, 2009). Moreover, it has been suggested that internal causes resulting in students’ poor academic achievement and confidence may possibly be boosted through use of technology and non-traditional teaching platforms (Sun & Pyzdrowski, 2009).

Tatar, Zengin and Kagizmanli (2015) studied the effects on pre-service teachers’ use of technology to lessen their own anxiety about teaching mathematics. The research consisted of 481 elementary and secondary pre-service teachers who were asked about their perceptions of using technology to teach mathematics (Tatar, et al., 2015). Those who had high self-efficacy about using technology, demonstrated lower teaching anxiety, however the most interesting results were reported from the highly anxious group (Tatar, et al., 2015). Teachers who were anxious, showed a decrease in math teaching anxiety and a more positive outlook about teaching mathematics when they became more skilled at using the technology that supported instruction (Tatar et al., 2015). Moreover, this supports the importance of examining the relationship of teachers’ preconceived self-efficacy about using technology in mathematics instruction to lessen their students' own mathematics anxiety in the classroom.

These results show promise for using technology in a mathematics educational setting. Research in this area, however, is limited and it would be beneficial, given what is known about the early acquisition of math anxiety and its stability, to pursue research examining current teachers' views about using technology as well. It is essential, given the national focus on STEM and also many districts' long-term plans to allocate money dedicated to bringing more technology into schools, to research whether teachers' perceived self-efficacy towards using technology influences students' math anxiety in the classroom.

Chapter 3

Method

This study explored teachers' perceived self-efficacy about using educational technology and its influence on students' math anxiety. Building upon previous research by Sun and Pyzdrowski (2009), this study examined teachers' beliefs about their own ability to use online educational mathematics resources. This study explored the frequency and degree of critical thinking in mathematics that teachers use in their teaching when incorporating strategies which involve technology into classroom instructional practices. Addressing critical thinking addresses teachers' own self-efficacy about math and own levels of math anxiety that they bring into teaching mathematics to children.

The rationale for conducting this study was based upon Sun and Pyzdrowski's (2009) meta-analysis research which evaluated using educational technology to lessen students' math anxiety in the classroom. The results of their study suggested that using software to learn mathematics has a positive effect on students' learning (Sun & Pyzdrowski, 2009). For instance, Sun and Pyzdrowski (2009) have discussed that when highly anxious students engage in mathematics using educational technology, it provided the opportunity for strengthening gaps in knowledge through repeated skills practice as well as motivating students by building confidence using a non-threatening online learning platform (Sun & Pyzdrowski, 2009). Math self-efficacy seems to influence math achievement (Meece, Wigfield, & Eccles, 1990; Pajares & Miller, 1994; Ma, 1999; Maloney, & Beilock, 2012), and using educational technology appears to be a positive instructional teaching strategy to generally lessen students' anxiety about mathematics

(Sun & Pyzdrowski, 2009). However, Sun and Pyzdrowski (2009) also identified technology self-efficacy as an area that they have suggested warrants further research. Although the authors' meta-analysis supports earlier studies on the importance of students' perceived self-efficacy towards math ability and achievement, they concluded that additional research is needed targeting specifically teachers' own perceived self-efficacy towards using educational technology itself (Sun & Pyzdrowski, 2009).

At the time this study was conducted and now, there appears to be limited scholarly work that has focused on teachers' self-efficacy towards using educational software technology to lessen students' math anxiety in the classroom (Sun & Pyzdrowski, 2009). Bandura (1977) has suggested that engaging in and mastering skills are influenced by the degree people perceive how successful they will be prior to investing time in persisting in the learning process. Since technology is generally available and prevalent in today's society, is teachers' perceived self-efficacy about using *educational* technology relevant to its success as a teaching strategy for lessening students' math anxiety in the classroom? For instance, will teachers' high or low self-efficacy about using instructional online resources to reinforce learning mathematics be pivotal in influencing its regular use by students? Moreover, is Bandura's (1977) premise about self-efficacy situational and relevant to certain types of learning? And finally, will teachers' own self-efficacy about their own knowledge and anxiety of mathematics influence decisions about how educational technology is used to support critical thinking in the math classroom?

The rationale for this research study was based on Sun and Pyzdrowski's (2009) earlier identification for the need for future research related to teachers' own self-efficacy towards using technology as stated in the authors' original meta-analysis study. This rationale for this research study is also further viewed through the broader lens of current national and state expectations for school districts to readily adopt extensive technology initiatives supporting Science Technology Engineering and Mathematics curriculum (U.S. Department of Education, 2016; O'Dea, 2011). Understanding possible factors that may influence the success of school districts' technology initiatives may provide valuable information given the scope of those directives.

Considering the above stated rationale of this research study, the method I used was a qualitative research design (Maxwell, 2013; Creswell, 2014). I have triangulated the data collection process (Teddlie & Tashakkori, 2009) and collected data via teacher observations, teacher surveys and teacher semi-structured interviews to provide more in-depth and nuanced information (Rubin & Rubin, 2012) about participants' self-efficacy towards using technology and teaching mathematics. The rationale for choosing this methods design and the data collection instruments is discussed in further detail below.

A qualitative research design provides the opportunity of exploring the theoretical framework of self-efficacy through the lens of teachers' anxiety about using technology to teach mathematics and the influence of teachers' own math anxiety. The rationale of using a qualitative design is that it allows for inductive thinking; reasoning from the bottom up in order to identify initial patterns and trends (Creswell, 2014). Inductive reasoning by analyzing data from various sources will then lead to deductive reasoning based on the results of the study (Creswell, 2014). This exploratory qualitative design supports a narrative approach in grounded theory (Maxwell, 2013; Creswell, 2014). This qualitative study has allowed for the opportunity to examine nuances in teachers' instructional choices in the classroom through collecting data from observations, surveys and a semi-structured interviewing protocol (Rubin & Rubin, 2012). Although this study is based upon Sun and Pyzdrowski's (2009) meta-analysis, a qualitative research design has better suited this research study since it examined elementary teachers' beliefs and values associated with math anxiety and the use of educational technology.

It is now known that math anxiety, sometimes described as excessive worry about completing math tasks, affects students at a much earlier age than once identified (Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L., 2013; Beilock, 2010; Harmes, 2012; Maloney & Beilock, 2012). There are both internal and external factors that may influence a students' degree of anxiety (Sun & Pyzdrowski, 2009). This includes possibly an internal cognitive struggle academically or an external influence of others' views about mathematics (Sun & Pzydrowski, 2009). For example, a student may indirectly interpret poor attitudes about the ability to achieve in mathematics from others that in turn, negatively influences the student's own academic performance (Meece, Wigfield, & Eccles, 1990; Tobias, 1993; Pajares & Miller, 1994; Peker & Ertekin, 2011). Studying math anxiety is important because it is not only pervasive in our society (Beilock & Maloney, 2015), but also stable and long-lasting (Ma & Xu, 2004).

Considering its long-lasting effects, teachers also may be highly anxious about completing tasks that involve mathematics. Beilock, Gunderson, Ramirez, & Levine, S. (2009) reported a study where female teachers who were highly anxious about mathematics indirectly communicated their anxiety to female students. The impact of how teachers' perceive their own math ability and degree of their own anxiety plays an important role as an external factor affecting students' math anxiety in the classroom.

How teachers or students predict their ability to complete an impending mathematical task prior to attempting it refers to their degree of self-efficacy about the situation. Pajares and Miller (1994) have speculated that a person's self-efficacy about mathematics is a strong predictor of academic success. Bandura (1994) has suggested that self-efficacy is shaped, in part, by a person's experiences. It is important to study the influence of self-efficacy as a factor that contributes to successful academic practices.

Math anxiety and math self-efficacy impact students' academic progress (Bandura, 1994; Maloney & Beilock, 2012). Teachers' views about their own self-efficacy and level of anxiety towards teaching mathematics influences students' academic progress in the classroom (Pajares & Miller, 1994). It is relevant, as school districts push for more technology-driven initiatives, to research whether or not using on-line educational math resources help teachers deliver quality math instruction more effectively regardless of the level of the teachers' own math anxiety and self-efficacy towards using technology for this purpose.

The research questions are as follows: How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of using educational technology as an instructional resource tool to lessen students' math anxiety? How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of encouraging critical thinking tasks among students in mathematics classrooms? To what extent do the results of this qualitative study support previous research about factors affecting teachers' use of educational technology on teachers' self-efficacy related to the selection of instructional methods to lessen students' math anxiety? To what extent do the results of this qualitative study support previous research about factors affecting teachers' mathematics anxiety and self-efficacy about teaching mathematics to lessen students' math anxiety in the elementary school classroom?

A qualitative research design that has been chosen to be used in this study has provided opportunities for exploring a social issue (Creswell, 2014), in this case math anxiety, in a natural setting of the elementary school classroom (Teddlie & Tashakkori, 2009). Triangulating qualitative data collected from observations, interviews and surveys also provided information rich sources. The section that follows includes descriptions of setting, participants, data collection and data analysis of this research study.

Setting

This qualitative research study takes place in a suburban New Jersey town located centrally north in the state. The town is considered within the New York Metropolitan area, and is easily accessible to Manhattan by train. The town itself encompasses an area of approximately less than 5 square miles with a population exceeding 13,000; according to the 2010 Census. The town has recently experienced renewed growth and expansion in its downtown including the addition of an extensive upscale housing development and Whole Foods supermarket complex in the main street area. Additionally, there have been increasing trends in household income. Estimated median household income was approximately $76,000 in 2000 and $112,000 in 2015 as compared to the 2015 state median of $72,000 as reported by City data.com. The total number of free or reduced school lunches for 2016 – 2017 school year include 34 free and 7 reduced lunches at the elementary (grades 1 – 4) school, 42 free and 16 reduced lunches at the middle school and 54 free and 9 reduced lunches at the high school. At the elementary school, 6% of the students are from low-income households ("Greatschools", n.d.).

The school district is comprised of four schools all located within residential areas: one special education pre-k/typical half day kindergarten school, one elementary school grades 1 – 4, one middle school grades 5 – 8, and one high school, grades 9 – 12. For the 2016 – 2017 school year, there were 2,322 students in the school district: 169 pre-k/kindergarten students, 659 elementary students in grades 1 – 4, 751 and elsewhere middle school students and 649 high school students. The school district breakdown by race is as follows: 59.48% White, 21% Asian, 11.03% Hispanic, 4.39% Black, 3.79% Multi-Racial, 0.17% Hawaiian native/other Pacific Islander and .004% American Indian/Alaskan.

Academically, students in this district are ability grouped for language arts and mathematics beginning in the elementary school at third grade through high school. Mathematics is not departmentalized for third and fourth grade and all elementary teachers are expected to teach this core content subject. There are currently 18 third and fourth grade teachers responsible for teaching mathematics at the elementary school. Departmentalization for both language arts and mathematics begins at the middle school level beginning in fifth grade. Class size varies, however, at the elementary school level, the teacher to student ratio is 13:1. Also at the elementary school, 98% of full-time teachers are fully certified and 4% of teachers have fewer than 4 years teaching experience ("Greatschools", n.d.).

New Jersey School Performance Reports for 2015 – 2016 state that at the elementary school (grades 1 - 4), where the research data was collected, it was reported that 66% of students in the district met or exceeded expectations on the mathematics section of the state-wide assessment compared to the state-wide average of 78%. New Jersey School Performance Reports for 2015 – 2016 state that at the elementary school (grades 1 - 4), 66% of students in the district met or exceeded expectations on the language arts section of the state-wide assessment compared to the state-wide average of 68%. The breakdown by race for mathematics at the elementary school as reported by the New Jersey School Performance Reports for 2015 – 2016 are as follows: White 61% of the school district met or exceeded expectations compared to a state-wide average of 62%; Asian 88% of the school district met or exceeded expectations compared to a state-wide average of 58%; and Hispanic 67% of the school district met or exceeded expectations compared to a state-wide average of 93%.

The high school graduation rate for the school district is 96% and 47% of students participate in AP classes as reported by U.S. News & World Report (2017). The New Jersey School Performance Reports for 2014 – 2015 have reported that 0.3% of the school district compared to 18% average at the state level participate in Career and Technical Education and approximately 99% of the district's high school students take the SAT compared to 80% at the New Jersey state level.

This research study focused on collecting data from elementary mathematics teachers in a small suburban school district in New Jersey. New Jersey has been chosen because of its goal of following the United States Department of Education's plan: Transforming American Education – Learning Powered by Technology program (O'Dea, 2011). The state of New Jersey is also located where I was available to conduct research. This particular New Jersey district has been chosen because it is in the process of transitioning to a format where every student in the middle school and high school will have a personal computer to use in the classroom (1 – 1). The participants in this research study have access to devices for their students and themselves, but have not yet adopted the 1 – 1 technology initiative. In the beginning stages of a large four year technology long-term plan, this suburban district has provided valuable insight from its teachers regarding technology.

Participants

This research study focused on interviewing third and fourth grade elementary school mathematics teachers from a small suburban school district in New Jersey. A school district in the state of New Jersey has been chosen because the New Jersey Department of Education has reported that its goal is to encourage all districts in the state to move to one to one technology where all students would have 24/7 access to online educational technology (O'Dea, 2011). This aggressive initiative is aligned with the overall objective by the United States Department of Education's plan: Transforming American Education – Learning Powered by Technology program (O'Dea, 2011).

The focus was collecting data from the perspectives of third and fourth grade teachers from a small suburban school district. Mathematics is not departmentalized for these grades, but students are ability grouped (tracked) beginning in third grade. Third and fourth grade teachers in this particular district hold current elementary school certifications and not all of these teachers hold a specialization in math. The rationale of selecting this group of participants is that there may be varied educational perspectives and more in-depth data available about teaching math and participants' own level of math anxiety when not all teachers hold a specialization to teach mathematics.

A non-randomized, criterion-based sampling scheme (Onwuegbuzie & Collins, 2007; Patton, 2002) was used to target participants who will be able to provide in-depth knowledge of instructional techniques necessary for lessening elementary school students' math anxiety. Since the research objective is to explore how teachers' attitudes about their own abilities to use technology as an instructional tool help lessen math anxiety among students, a focused sampling of teachers who teach mathematics and have access to technology in their classrooms was appropriate for this study. A purposeful sampling scheme is also suitable considering the sample size (Rossman & Rallis, 2012). The small sample size chosen focuses on aligning it with the research questions and objectives (Onwuegbuzie & Collins, 2007; Patton, 2002) of this qualitative design.

In order to seek a balance of viewpoints (Rubin & Rubin, 2012) and avoid a potential misrepresentation of findings, teachers were asked to participate according to their professional assignment of teaching elementary school mathematics. A single-stage sampling procedure (Creswell, 2014) was used and the names of the participants were identified prior to the interviewing process in order to guarantee that both non-tenured and veteran elementary teachers who currently teach mathematics were included in this study. It was proposed that 18 third and fourth grade elementary teachers from a small suburban middle school in New Jersey be included in this research. From an academic perspective, these grades were chosen because of the curricular focus on multiplication and division of whole numbers and fractions that provides an important foundational basis for the later grades ("Achieve the Core", n.d.). Although the school district is in the process of moving to 1 (student) to 1 (device) technology and only fifth and ninth grade students are currently provided with their own devices, the third and fourth grade teachers in this study have daily access to technology use in their classrooms. The interviewing process was conducted in the participants' natural environment (Rossman & Rallis, 2012; Maxwell, 2013) which is within the elementary school district setting.

For my study, I conceptualized a collaborative rather than coercive role in regards to my interaction with the participants throughout the research process. There are a number of ways in which I have assured that this was possible. When considering developing interview questions, I formulated a set of questions that provided me with a deeper understanding of the problem rather than creating targeted or double-barreled questions that were coercive and one-sided (Fink, 2003;Maxwell, 2013). Setting the tone of a collaborative data collection process, including observations, surveys and interviews, allows for participant input and valuable information that I may not have anticipated otherwise (Maxwell, 2013). Observations were non-obtrusive in nature and I asked participants to identify the best place in the classroom to take field notes as well as not interrupting the teachers' classroom instruction. The data collection process also included semi-structured interviews, which built in opportunities to ask probing questions (Rubin & Rubin, 2012) based on trusting relationships and collaborative discussion. When delivering interview questions, I practiced asking the set of questions prior to the participant interview to assure that the interview tone is accepting and open-minded rather than coercive, mechanical, demeaning, and would have negatively affected the data collection process in this study.

As stated earlier, a purpose of this study was to explore teachers' perceived self-efficacy about using educational technology and its influence on students' math anxiety. Building upon previous research by Sun and Pyzdrowski (2009), this study examined teachers' beliefs about their own ability to use online educational mathematics resources. This study also explored the frequency and degree of critical thinking in mathematics that teachers use in their teaching when incorporating strategies which involve technology into classroom instructional practices. Addressing critical thinking indirectly addressed teachers' own self-efficacy about math and own levels of math anxiety that they bring into teaching mathematics to children. A qualitative research design was used in this research study (Creswell, 2014) and included data collection instruments: teacher observations of classrooms, teacher surveys and teacher semi-structured interviews that are described below.

Data Collection

The advantage of using a qualitative research design to study math anxiety is that it is an inductive approach which capitalizes on logical reasoning analyzed from the data collection process (Maxwell, 2013). This provided the opportunity to explore possible patterns and trends in data. The methodology chosen supports grounded theory, which is a narrative based approach, as well (Teddlie & Tashakkori, 2009).

Maxwell (2013) has discussed the benefit of triangulating data collection resources in qualitative research. Advantages of triangulation in the data collection process include reducing the risk of researcher bias based on collecting one source of data and creating a richer base that may uncover a wider scope of information about different aspects of the research topic (Maxwell, 2013). The data sources: observations, qualitative survey, and semi-structured interviews are described in the following section. I collected data sequentially. I first observed teaching practices in classrooms, then administered surveys and then interviewed participants. I chose a sequential protocol so that I was better informed and able to attend to nuances and details about teachers' espoused theories related to math anxiety and technology prior to interviewing participants. Surveys were administered in the middle of the process. This order was chosen to allow for opportunities to ask additional probing questions during the interviews that are based upon initial data collected from the observations and surveys.

Teacher observations. Observations have been purposefully chosen as a data collection instrument to enhance findings from interviewing teachers related to pre-conceived technology self-efficacy and math anxiety. Observations provided an opportunity to gather more detail about themes that may have surfaced during initial interviewing (Maxwell, 2013) as well as testing teachers' own theory-in-use compared to espoused theories (Maxwell, 2013). In this qualitative study, 12 of 14 third and fourth grade teachers who participated in this study from a small suburban New Jersey school district in close proximity to Manhattan were observed teaching mathematics in their own classroom settings. Since the purpose of this study was to examine the relationship of elementary mathematics teachers' self-efficacy related to technology and using technology as an instructional strategy to lessen students' math anxiety, it was important to not only interview teachers about their espoused view of using educational technology to teach mathematics, but also to have observed teaching to investigate actual practices. I followed the school's block scheduling for math instruction. I took field notes during the classroom observations and then subsequently included that information (via coding) as part of my data analysis protocol. I initiated a schedule which was mutually acceptable to administration (principals), participants and myself. The interviews followed the observations and in this way, I communicated that I was not monitoring their teaching practices. I also assured teachers of a collaborative rather than coercive situation by explaining honestly and openly about my exploratory study as well as my intent of sharing information collected and analyzed. I checked upfront whether it was acceptable for me to ask any follow up questions before data collection began and answered any protocol questions by the participants honestly and to the best of my ability. Investing in establishing a collaborative environment from the beginning inevitably produced the most effective data for this research study.

Teacher surveys. Surveys that are aligned with objectives provide an important tool for triangulating qualitative data collected during observations (Fink, 2003) resulting in collecting richer, more in-depth data (Teddlie & Tashakkori, 2009). Fink (2003) suggested, and I followed protocol in which questions written for surveys were unbiased, understandable and a length that was suitable for the participant in order to maximize the usefulness of the data collected during this process. Since the purpose of this research was to study self-efficacy, questions were crafted to effectively gather information about teachers' beliefs related to mathematics, educational technology and instructional strategies in the classroom. I distributed surveys to the third and fourth grade elementary teachers who teach mathematics and provide suitable time for participants to ask any additional questions about the questionnaire itself as well as time to respond to the survey. A list of survey questions that were used in this qualitative research study are included in the attached Appendix A.

Teacher semi-structured interviews. The interviews were audio taped which as Van Manen (1994) has suggested, allowed for an easier method for participants to share experiences than having to recount their experiences in writing. In addition to audio taping the interviews, I recorded field notes, which Rubin & Rubin (2012) have recommended in addition to audio taping in order to more accurately recall details after the interview process.

I interviewed 14 third and fourth grade elementary school teachers in the same small suburban school district that the observations and surveys are conducted. An interview protocol (Creswell, 2014) in a responsive semi-structured interviewing style was used which emphasized building a trusting relationship by allowing for flexibility when interviewing and establishing a supportive, mutual respectful environment (Rubin & Rubin, 2012). Maxwell (2013) has discussed that interviewer's style is an integral part of the overall decision making process. The set of semi-structured interview questions was used to collect data focusing on teachers' differentiated instructional practices related to instructional techniques that have been used to lessen students' math anxiety. As Maxwell (2013) has suggested, the interview questions reflected the intention of the research questions, and as other researchers have suggested have allowed for flexibility in questioning (Rubin & Rubin, 2012; Rossman & Rallis, 2012). A list of interview questions are included in the Appendix B. The interview questions focused on teachers' self-efficacy about technology and mathematics. The questions were delivered in an in-person semi-structured interview format (Rossman & Rallis, 2012). In order to maintain continuity and structure, I read the same initial questions to all participants. This allowed for a reliable and valid data instrument measure. Additionally, probing questions, as

Rubin and Rubin (2012) have discussed, were used to encourage participants to expand upon and share teaching experiences; allowing an opportunity to gather in-depth information related to self-efficacy, technology and math anxiety. Individual teacher face-to-face interviews were less than one hour in length at the elementary school in order to accommodate teachers' schedules.

Data Analysis

Process and pattern coding (Saldana, 2009) were used as methods for analyzing data in this research study. Data collected from teacher interviews were transcribed from audio taped interviews and written field notes and then coded following procedures for process and pattern coding (Saldana, 2009). Other sources of data including those from teacher observations, surveys, and field notes were coded as well.

Process coding was used as a first cycle coding technique in order to describe action through developing codes that reflected data collected from observations, surveys and interviews (Saldana, 2009). Pattern coding was used as a second cycle coding protocol to descriptively categorize individual process codes (Saldana, 2009). Coding provided the opportunity to think critically, presenting perspective during and after the data collection process (Saldana, 2009). Since the purpose of this study was to examine the relationship of how math teachers' self-efficacy related to technology influence using those tools as an educational instructional strategy to lessen students' math anxiety, coding provided the structure to identify nuances and patterns that may be evident after data collection. During the interview process, as potential themes become evident, subsequent questioning was used as a technique to follow-up in order to probe and research whether these themes are valid considering the data collected (Rubin & Rubin, 2012). Themes were examined through the lens of existing theoretical framework (Saldana, 2009) and current practice.

Maxwell (2013) has discussed the advantages of extracting meaningful data through the use of memos and narrative analysis. Throughout the data collection process, I reflected through actively taking observation notes, and conducting on-going analysis of the data through memo writing and narrative analysis of data as necessary, including reviewing the results from my observations (Maxwell, 2013; Creswell, 2014).

The interviews were recorded so that responses to questions were more reliably transcribed and coded. Since the purpose of this research study was to explore teachers' self-efficacy towards using technology and mathematics, understanding the degree to which teachers feel comfortable with instructional strategies in mathematics by analyzing interactions with students and measuring the degree to which critical thinking is encouraged in the classroom was essential.

Methodological Issues

Confidentiality. Throughout the research process, I maintained confidentiality of the participants and the information that was collected. Teddlie and Tashakkori (2009) suggested that participants in a study "… completely understand the purpose and possible outcomes of their participation (and noting that) vocabulary must be adjusted to best serve the participants' needs" (p.200). For example, when explaining the purpose of this qualitative study, I checked for understanding by asking participants if there were any questions and then rephrased the purpose and adjusted vocabulary as necessary to this process.

Considering that I work in the school district, I was particularly sensitive to maintaining confidentiality among participants. I communicated my commitment to collecting data confidentially with the participants at the beginning and throughout the research process. For example, I used encrypted letters for the teachers' names in this study. Moreover, I kept a confidential electronic log of that information in a separate word document file that was not to be disclosed as central to this research. As part of the follow-up protocol, I checked in with the teachers and provided an opportunity to answer any questions related to this research study.

Qualifications of the Researcher

I would like to disclose my own background and credentials regarding this qualitative study. I have taught mathematics at the middle school level for over 15 years and more recently have served as an instructional math coach to teachers. During the research process, I enjoyed the interaction of actively listening to participants' views and objectively collecting data. Building professional relationships throughout this process was essential to conducting authentic teacher interviews, observations and surveys.

Professionally, I have worked with both students and teachers extensively to achieve in mathematics. I have written articles for AMLE and ASCD on topics including differentiated instruction and encouraging students to take academic risks. These articles have focused on motivating students to engage in mathematics as well as offering teaching strategies from the field. I have presented for AMLE, AMTNJ and NJDOE Achievement Coaching initiative. I have been able to express my own teaching philosophy which targets linking real life application of mathematics to encourage math achievement through grants and awards. Highlights have included Middlesex County Teacher of the Year award, a districts' best practices award, Teacher of the Year on a middle school and district level, and a national Raytheon Math Heroes award for demonstrating creativity in mathematics.

As stated earlier in the method section, I promoted a collaborative rather than coercive researcher's role regarding my interaction with participants throughout the research process. In order to accomplish this, I interacted with participants honestly and collaboratively by asking questions that were in the best interest of collecting quality data from observations, surveys and interviews. I established a collaborative rather than coercive or condescending tone for the research study and welcomed participant input allowing for the opportunity to collect and analyze a rich set of data.

Summary

A qualitative research design was used for collecting and analyzing data for this research study. Since my goal was to collect information pertaining to elementary school teachers' self-efficacy about using educational on-line resources to lessen students' math anxiety in the classroom, a qualitative method provided the instruments: teacher observations, teacher surveys and teacher semi-structured interviews, to do so.

Chapter 4

Results

The purpose of this research study was to explore teachers' self-efficacy about mathematics and using educational technology and its influence on lessening students' math anxiety in the classroom. This study has reviewed and then built upon earlier research by Sun and Pzydrowski (2009) which focused on the value of using educational software to lessen students' mathematics anxiety. This research has explored teachers' own self-efficacy about mathematics and decisions to use various on-line educational software resources to lessen students' math anxiety and encourage math achievement at the elementary school level.

In order to meet the goal of exploring elementary school teachers' self-efficacy about mathematics, on-line technology and math anxiety, this dissertation has been organized to explore the following research questions:

1. How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of using educational technology as an instructional resource tool to lessen students' math anxiety?
2. How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of encouraging critical thinking tasks among students in mathematics classrooms?
3. To what extent do the results of this qualitative study support previous research about factors affecting teachers' use of educational technology on teachers' self-efficacy related to the selection of instructional methods to lessen students' math anxiety?

4. To what extent do the results of this qualitative study support previous research about factors affecting teachers' mathematics anxiety and self-efficacy about teaching mathematics to lessen students' math anxiety in the elementary school classroom?

As a prerequisite to exploring these research questions, the previous three chapters have provided an introduction to the educational topics relevant to this study along with a literature review which includes theoretical framework about self-efficacy and mathematics anxiety and finally, a methods section which outlines the research design that has been used in this study. The following chapter will present the results of this study. I will present findings about teachers' and students' self-efficacy about math and the relationship of educational technology and mathematics anxiety using the research questions as a guide throughout this chapter.

Four findings emerged during data analysis. The findings were in response to the research questions that framed this study and can be summarized as follows: 1) Teachers' self-efficacy about mathematics along with teachers' professional assignments contribute to decisions about how to best use educational technology as an instructional tool, 2) Educational math software provides opportunities to lessen teachers' and students' mathematics anxiety by acting as a valuable feedback mechanism and encouraging critical thinking related to mathematics, 3) Teachers self-reflect and use self-regulation strategies during mathematics instruction in order to overcome technology challenges in the mathematics classroom, and 4) Teachers' use of a combination and variety of technology and non-tech strategies to lessen students' mathematics anxiety in the elementary classroom.

The next section will summarize the participant population and review data collection measures in this study. The subtopics include 1) ability grouping designations, 2) summary of protocol, 3) teacher observation data, 4) teacher survey data, and 5) teacher interview data.

Participant Population and Data Collection

Ability group designations. The district groups students by math ability beginning in third grade through high school. Currently, there are five different math levels at the elementary school. This includes resource math which is at least one year below grade level, low average, average, high average and unique learners (UL) above grade level math. Current ability group assignments are listed in Table 1.

Table 1

Number of Participants by Grade and Ability Group Teaching Assignment

Ability Group	3rd Grade	4th Grade
Resource	0	1
Low	1	1
Average	2	1
High	2	2
Unique Learners	2	2
Total	7	7

The school district**'s** practice has been for administration to assign teachers' professional assignments. Teachers have generally not been involved with teaching assignment decisions and have not chosen the instructional level where they have felt most comfortable or knowledgeable about teaching mathematics. Although professional assignments can fluctuate each year, there was a consensus among the teachers in this study that the ability level in which they are assigned to teach usually remains constant long term. The demand regarding the number of math classes required per ability group has been driven by results from students' placement test criteria.

Summary of protocol. The triangulated data collected from the observations, surveys and interviews were analyzed in order to report teachers' choice of software used to reinforce learning mathematics. Teachers were 1) first observed teaching a third or fourth grade math class, then 2) asked to complete a survey, and then 3) interviewed either during or after the school day. This data collection protocol was followed in order to minimize influencing teachers to change their usual classroom routine during observations by reacting to survey and interview questions prematurely in the research process. Of the fourteen teachers who participated in this study, I observed twelve of the third and fourth grade teachers in their math classrooms.

Teacher observation data. Third and fourth grade teachers in this study are responsible for teaching mathematics in a block schedule from 1:25 p.m. to 2:45 p.m. daily. Teachers follow a Math Workshop Model where the teacher began the period with a guided lesson and transitioned to student engagement centered activities. I observed twelve teachers at the beginning of their math periods. The educational technology that I observed being used was primarily the Smart Board and online manipulatives. The teachers used the Smart Board for providing students with daily instructions, reviewing homework, and giving teacher-directed math lessons. It was evident that participants in this study employed a wide variety of teaching strategies to lessen students' math anxiety and create a positive learning environment. For example, students participated at the board, were given encouraging feedback and engaged in discussion. Of the twelve teachers that were observed, nine had the students collaborate with peers or worked in small groups with the teacher at the beginning of the period. There were more than twenty responses that involved small group or partner work at the third and fourth grade levels that I observed during my twelve visits to the mathematics classrooms.

Regarding other technology use, three of twelve classrooms that I observed had students involved in a technology station in the beginning of the period. Although students' participation in math technology stations were not evident during my visit to the other nine classrooms, those teachers communicated how they have organized their math instructional stations during the second half of the block, 2:00 - 2:45 p.m., in their daily block schedule.

Teacher survey data. Third and fourth grade teachers were surveyed about their self-efficacy beliefs about mathematics and using educational technology. Of the fourteen teachers, twelve participated in the observation, survey and individual teacher interviews. Two teachers participated in the survey and interview only. The following self-efficacy questions were included in the survey portion of the data collection process.

If someone asked you what being "good" in Math means, what would you say?

What topics in Math do you think are more challenging to teach than others and explain why?

If you asked your students if comparing to other subjects, how good are you at Math, what do you think that they will say?

If you asked your students what being good in Math means, what would they say?

How interested do you think your students are in Math compared to other subjects?

What topics in Math do you think students communicate are more challenging than others and why?

Teacher interview data. Third and fourth grade teachers were individually interviewed either during or after the school day about their self-efficacy beliefs about mathematics and using educational technology. All fourteen teachers participated in the interview process. The following interview questions related to self-efficacy were included in the interviews.

What has been your experience with students who have felt anxious about Math?

What do you think about Math that makes students anxious?

How would you describe your own math experiences when you were in school?

An important component of this research study targeted understanding teachers' own beliefs about mathematics. The next section will discuss the results focused on teachers' own self-efficacy about mathematics. The purpose of the following section is to describe how teachers viewed their own experiences along with their current beliefs about achieving in math and how they then view their third or fourth grade students' attitudes regarding achievement. The subtopics include 1) teachers' own experiences learning math, 2) teachers' own self-efficacy about math achievement, and 3) teachers' views about their students' self-efficacy regarding mathematics achievement. Refer to Table 2 for data related to teachers' self-efficacy beliefs.

Table 2

Number of Teachers by Mathematics Self-Efficacy and Professional Assignment

	Low Self-Efficacy		High Self-Efficacy	
Professional Assignment	Struggled	Achieved	Struggled	Achieved
Third Grade	3	1	0	1
Fourth Grade	2	2	2	3
Total (N = 14)	5	3	2	4

Note. "Struggled" and "achieved" refers to teachers' academic experiences with mathematics when younger as students. Low self-efficacy accounted for 57% of total participants and high self-efficacy accounted for 43% of total participants in third and fourth grades.

Teachers' Self-Efficacy about Mathematics

Teachers' own experiences learning math. For this research study, fourteen elementary school teachers were each interviewed one time about their beliefs and their students' beliefs about mathematics. Member checking was part of the data collection process as some of the teachers were asked to clarify answers after being interviewed. Teachers were asked to participate if they taught third or fourth grade mathematics. Most of the participants taught multiple subjects in either third or fourth grade, although two of the teachers were responsible for teaching multiple grades within the elementary school.

During the interview process, as part of data collection in this study, participants were asked to describe their own experiences learning math when they were students. About 51% of the participants reported feeling anxious about learning mathematics when they were younger. Within this group, responses included teachers whom, regardless of whether they achieved or struggled in mathematics, were anxious about learning the subject. Table 3 describes participants' prior experiences as math students.

Table 3

Participants' Interview Responses Describing Previous Math Experiences as Students

Codebook Category	Examples
Struggled in math and anxious when younger	Severe math anxiety
	Lost in the mix
	Wasn't my subject to connect with
	Really hard in middle school
	Seemed abstract
	Standardized tests
Achieved and anxious about math	Didn't think I belonged
	Pushed into the advanced class
	Got me a tutor
Struggled in math when younger and not anxious	Not a natural math student

Table 3 (continued)

Codebook Category	Examples
Achieved in math and not anxious when younger	Math was my better subject
	Memorizing
	Algorithm

Teachers' own self-efficacy about mathematics achievement. During the data collection process, participants shared a wide range of both positive and negative experiences as math students themselves. I grouped responses according to low self-efficacy and high self-efficacy beliefs. Although there are differences between the concepts of self-efficacy about mathematics and mathematics anxiety, for the purpose of clarifying terminology in this section, "low self-efficacy about math" in this study refers to anxious beliefs about mathematics and "high self-efficacy about math" refers to confident beliefs about mathematics, in context of whether taught or learned from the perspective of the participants in this study.

Of the teachers who identified as having low self-efficacy towards math when younger, 100% of this group were also unhappy with the way math was taught when they were students. Moreover, the reverse was true for teachers with high self-efficacy, who as a group were all happy with the way math was taught when they were students.

Participants were also asked to describe their beliefs about "what being good in math" means from their point of view. Interestingly, there were differences among the low self-efficacy and high self-efficacy groups. Responses about teachers' beliefs about excelling at mathematics were coded according to three major categories that became apparent after data collection. This included emphasis on understanding mathematical processes, being fluent and accurate, and being persistent when completing math tasks. The most common answer from teachers' point of view about their own beliefs for the low self-efficacy group was mention of "fluency and accuracy" with skills while there was a slightly more popular answer related to "understanding mathematical processes" for the high self-efficacy group.

Figure 3 illustrates teachers' beliefs about "what being good at math" means from a low self-efficacy perspective. In contrast, Figure 4 illustrates teachers' beliefs about "what being good at math" means from a high self-efficacy perspective.

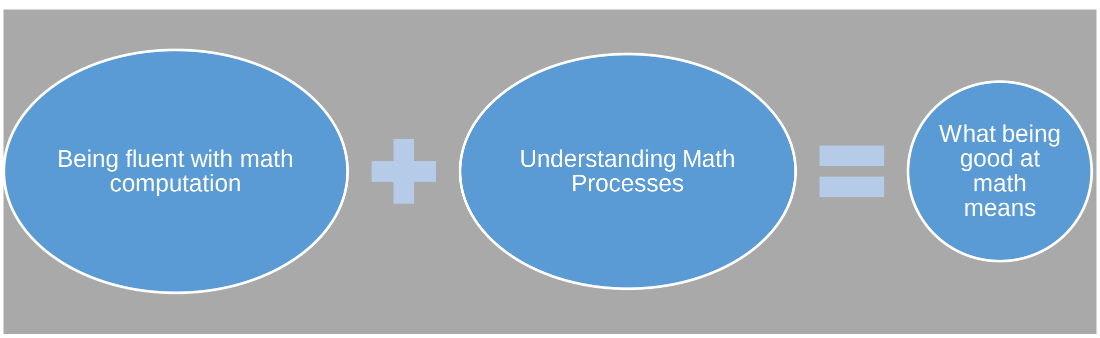


Figure 3. "What Being Good at Math" Means: Low Math Self-Efficacy Teachers' Beliefs

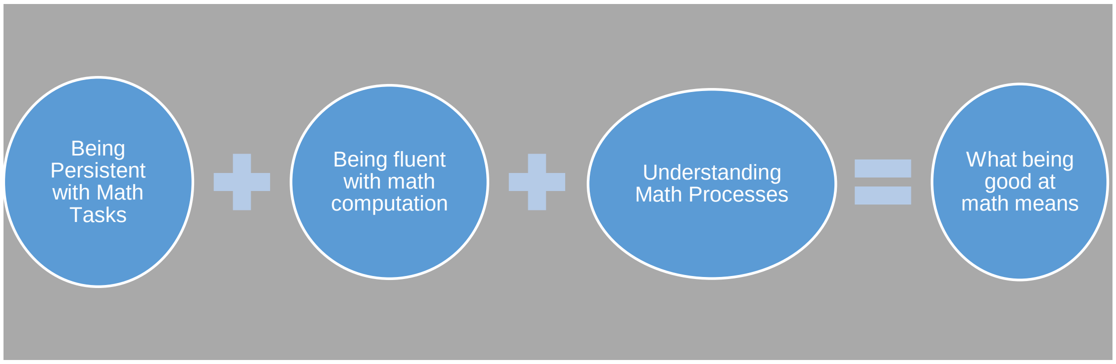


Figure 4. "What Being Good at Math" Means: High Math Self-Efficacy Teachers' Beliefs

Both the low and high self-efficacy teachers generally discussed the importance of being computationally fluent and understanding the processes related to solving a math task. However, 2 of the 6 high self-efficacy participants also mentioned persisting through completing a math task as important to generally defining what being good at math means. The impact of teachers' own self-efficacy, including the influence of teachers' beliefs on students' beliefs was previously discussed in the literature review. In this study, how did teachers' own self-efficacy influence how teachers described what their students' views would be about achieving in mathematics?

Teachers' beliefs about their students' views about achievement. All participants were also asked what their beliefs were about their students' views about "what being good at math" means. Answers from the surveys and interviews fit one of three categories: teachers believed that students identified being good at math as getting an answer correct (accuracy), teachers believed that students identified being good at math if they answer quickly (automaticity), or teachers believed that students identified being good at math if they get good grades (achievement). The most popular answers among teachers in the low self-efficacy group were that they believed that identifying students as being good in math was synonymous with either accuracy or achievement. Most teachers in the high self-efficacy group, a little over 75%, indicated that their students would relate being good at math with math achievement by correctly answering questions and successfully completing math tasks. Teachers' own perceptions of their students' attitudes towards math seemed to draw parallels to their own beliefs.

Teachers were not only asked what "being good in math means" but also from the viewpoint of their students. There appeared to be some consistency when comparing responses of what teachers' beliefs and teachers' beliefs are about what they believe students think 'being good' means in mathematics.

Figure 5 summarizes responses from teachers with both high and low self-efficacy about mathematics think that being good in math means and what the same teachers would say being good in math means from the perspective of their students. Figure 5 illustrates priorities expressed by teachers sorted by levels of self-efficacy. Responses are prioritized for each category.

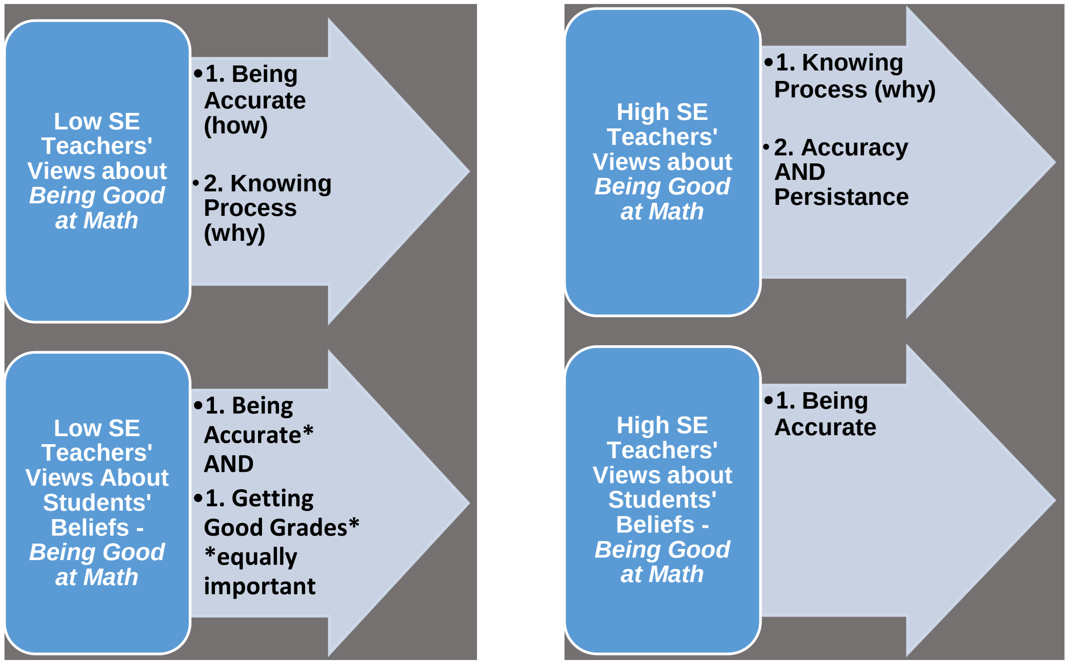


Figure 5. Teachers' Beliefs Regarding "What Being Good At Math" Means According to Priority and Sorted By Teachers' Self-Efficacy

As illustrated in Figure 5, teachers' own self-efficacy beliefs were generally aligned with their beliefs about their students' self-efficacy about learning mathematics as well. For example, low self-efficacy teachers viewed the mechanics of how to solve a problem as what they and their students would consider the most important aspect regarding excelling in mathematics. Moreover, teachers with weak background experiences not only emphasized being accurate and fluent as how they would define being good at mathematics, but those participants also appeared to have projected those beliefs to include how their own students would answer the same question. There were some similarities among the high self-efficacy teachers and those teachers' views of their students, as illustrated in Figure 5. Regarding students' actual beliefs, it should be noted that data was collected from the teachers' viewpoint only and may or may not be what students actually value regarding achievement.

As these findings describe how third and fourth grade teachers discuss their students' beliefs about mathematics achievement, then how do teachers use these views to articulate their relationship of using technology as an instructional resource tool to lessen students' math anxiety? The following section will explore the relationship of teachers' self-efficacy and educational technology. The subtopics include 1) technology use in the mathematics classroom, 2) teachers' attitudes about using technology, 3) educational technology and critical thinking, 4) educational technology and effective feedback, and 5) teaching strategies used to overcome challenges of using technology.

Teachers' Self-Efficacy and Educational Technology

Technology use in the mathematics classroom. Currently, the district in this study is implementing a long-range technology plan. This includes providing 1-1 Chromebooks for students beginning in grade 5. When the plan has been completed, existing Chromebook carts which are now housed at the middle school will be reallocated to the elementary school in order to better support classes for the younger grades. This year, students in grades 5 and 9 have access to 1-1 technology in all their classes.

Each third and fourth grade classroom is currently equipped with a Smart Board, Smart Board software resource tools and at least two desktop computers. One third grade high ability group math classroom and two fourth grade Unique Learners (highest level math) classrooms also have a Chromebook cart housing about 24 computers each that they share within their own grades. Additionally, there are Chromebook carts housed in the library and teachers have access to that technology through a sign out sheet protocol. A typical third grade classroom may have a physical layout as illustrated in Figure 6.

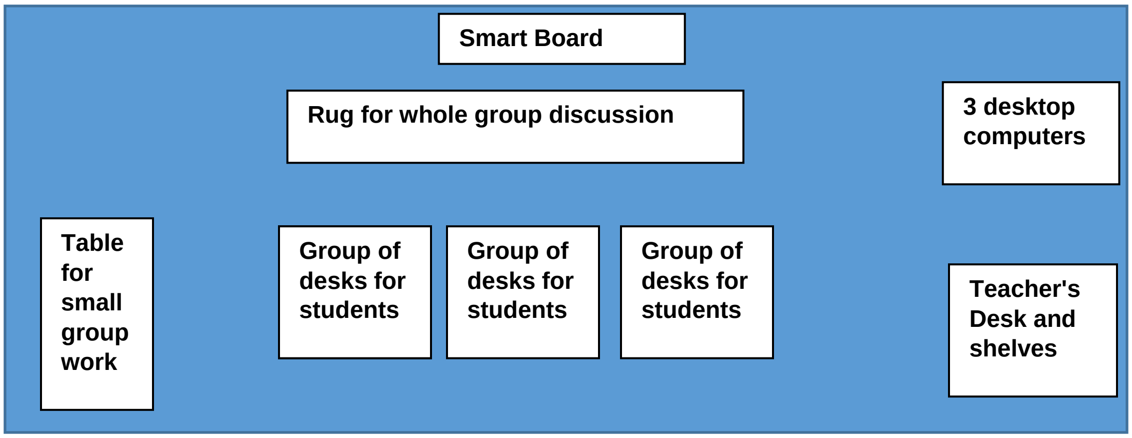


Figure 6. Teacher H's Classroom Layout

As a matter of practice, all participants in this study used Smart Boards and related interactive software to communicate directions, teacher-led instruction and provide students practice "at the board". Adopting a district-wide Math Workshop Model, all teachers during the interviews reported that they set up various centers throughout the room. Teachers' responses varied as to the frequency of using technology as a center. Math centers allow for differentiation of instruction where small groups of students are able to receive more individualized lessons from the teacher. Generally, most teachers reported including a math technology center into their routine where students work either independently or with a partner.

As central to the protocol for third and fourth grades, teachers administer benchmark testing using Study Island software three times during the school year as a means of assessment and preparedness routine for the standardized PARCC exam administered annually. Study Island software is also available and used by some of the teachers in differentiated stations. During follow up conversations with ten of the teachers individually regarding Study Island software, none of the teachers reported using students' Study Island results as a formative assessment contributing to report card grades. Although the data is available to administration, it has not been formally reviewed with staff this year and teachers generally examine their own class statistics without peer collaboration. Moreover, four of the five third grade teachers expressed that Prodigy Math offers more useable data and easier for teachers to manipulate since it can be designed to pinpoint a particular skill more easily. Teachers generally commented that Prodigy Math's game format is more engaging to students than Study Island software. Of the ten teachers, only two fourth grade teachers teaching high ability math share their students' strengths and weaknesses during parent conferences. Generally, teachers reported using the data from the Study Island benchmark assessments as an opportunity to look at trends and patterns in class data that should be addressed rather than focusing on weaknesses of particular students, although there is no formalized accountability protocol to do so.

In this study, the types of software that teachers used regularly were coded according to intended purposeful use by teachers in the math classroom. The categories included continuous video game format, non-continuous game format, timed software focused on fluency and software focused on fluency and tracks progress. Software that monitors students' progress and pacing is available in various formats. Examples are Study Island and Ten Marks software programs as well as continuous video game format software like Prodigy Math and Ready Math.

Teachers' attitudes about using technology. Teachers' software choices were driven by self-reflective practices and beliefs about incorporating choice and differentiated instructional methods to teach mathematics to elementary school students of different ability levels. Teachers conveyed advantages of using technology from the perspective of effectively facilitating their own teaching practices. For example, this included helping to manage the pace of the class, providing students with academic choices for more challenging math problems or offering students different formats for practicing math skills. Refer to Table 4 for a description of teachers' comments.

Table 4

Teachers' Comments Regarding Use of Technology

Teacher	Interview Comments Regarding Technology Use
F	I do push them and sometimes if I do, I probably push them too hard or too fast, and I try and watch my own pacing. But, I feel that (that) definitely causes anxiety for those who are borderline. Yeah, it's the pacing that I have to watch the most, which is why I try to lay out as much with Ten Marks and Study Island (websites).

Table 4 (continued)

Teacher	Interview Comments Regarding Technology Use
H	Less anxiety from having choice. So if they decide what they'd like to play or what kind of game to practice their multiplication facts, then maybe it's not as competitive a game then they feel a little bit better about it.
T	The (multiplication) program that they did was (that) they could go up like four or five digits. And so the kids who felt more comfortable passing two digit by two digit, they then could move on and do three by four. And the program would allow them to increase their digits once they found success.

Teachers reported differentiating one of the centers as technology-based in class. By differentiating mathematics in this way, students were given more freedom to independently self-regulate the pace at which they acquired and reinforced skills, thereby building confidence, lessening anxiety and steering their own learning process. For example, I observed two students in the fourth grade low math class working enthusiastically in the tech center on Prodigy Math. The students were seated next to each other yet one student was using visual models to solve a math task while the other student was engaged in solving computational based problems. The students were clearly invested in the center and as they met with success, the students seemed to gain confidence and embrace further practicing of the math concepts displayed on the screens.

Teacher V commented:

> I think also that the technology nowadays that it's leveled in such a way (that) it builds up the confidence of the students. So you're having these kids start out with concepts at a very low level… building up their levels…so it doesn't make them over anxious. It makes them feel like they can manage it more. It makes them calmer and it makes them relax because it's also non-judgmental.

Teacher Q commented:

> What I like about that particular aspect of having students work by themselves or a partner, is that the computer often times will give you that feedback. I don't need to be the feedback mechanism for all 23 of those students.

During the interview process, teachers commented about the advantages of using educational technology as an instructional tool to teach mathematics. Both having technology as a motivating resource for learning as well a convenient tool for teachers were popular comments shared during interviews.

Table 5 organizes this data and reports the number of teacher responses for each category by teachers' professional assignment. Teachers commented during interviews about their beliefs about the advantages of using technology.

Table 5

Number of Teachers' Responses Regarding Their Beliefs About the Advantages of Using Technology Sorted by Professional Assignment

Professional Teaching Assignment	Motivational Tool	Easier to Teach
Teaching Average or Below Grade Level Math	8	1
Teaching High or Above Grade Level Math (UL)	1	8
Total Number of Responses	9	9

Educational technology and critical thinking. In this research study, data were collected in order to analyze how third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of encouraging critical thinking tasks among students in mathematics classrooms.

For the purposes of this study, I have referenced Garrison's (1992) model of critical thinking (Newman, Webb, & Cochrane, 1995). Of the five stages that Garrison outlined, I have focused on the first two stages for this research. At the base level of critical thinking, individuals are able to identify a problem and are motivated to learn and then at the second stage, understand the "assumptions which underlie the statement of the problem" (Newman, Webb, & Cochrane, 1995).

Evidence of critical thinking during observations generally occurred most often during the first ten minutes as the teacher presented the daily lesson on the Smart Board.

For example, Teacher H first enthusiastically modeled and then asked her third grade students when they would find an exact answer versus an estimate during the school day or at home. Students were asked to brainstorm and then justify their answers as the teacher encouraged using math reasoning in the process. By modeling an example on the Smart Board, students understood the problem and were guided to successfully participate in the opening class discussion. Another participant, Teacher J, used collaboration to encourage both cohesiveness within the group and taking risks to think critically when he asked his students to "turn and talk" and use manipulatives to solve an involved "do now" problem on the Smart Board. In this situation, students were given a small pile of block manipulatives and asked to work with a partner to visually represent the problem and then strategize how to solve the math task. Students were then encouraged to share and justify their answers. Since the scope of this study allowed for data collection during a limited time period, the content of both visits related to the math topic of estimation. However, it was interesting to investigate which topics the math teachers in this study find that were both most challenging to teach as well as best taught using technology.

Overall, third and fourth grade teachers reported in survey data that fractions followed by division were the most challenging math topics to teach elementary school students. Moreover, 75% of the participants who reported prior anxiousness about math also commented that math skills related to fraction concepts were the most difficult to communicate to students. Responses from third and fourth grade teachers who experienced little anxiousness when younger were varied and did not highlight teaching a particular math concept. Both understanding fractions and basic computation involving fractions are important foundational skills in mathematics (Lortie-Forgues, Tian, & Siegler, 2015). Learning fractions involves applying critical thinking skills which present formidable challenges including "opaqueness of rational number arithmetic procedures" "understanding fraction notations" and "number of distinct procedures" (Lortie-Forgues, Tian, & Siegler, 2015). I will be revisiting and discussing critical thinking, self-efficacy and use of educational technology in chapter 5.

Teachers were also interviewed and surveyed regarding their views about the math topics that are best supported by technology. The majority of third and fourth grade teachers, about 57%, suggested that using educational technology for the purpose of general review best fit the instructional needs of their students. General review includes online practicing of a variety of mathematics skills learned in third and fourth grades. During interviews, 42% of participants commented that on-line practice also supports learning multiplication by providing varied and extra practice opportunities for their students. There were no notable differences in responses among the high and low-efficacy groups regarding math topics best supported by educational technology.

Educational technology and effective feedback. Participating with students by reviewing their on-line learning has the potential of building teachers' own self-efficacy through exposure to supporting students on these software platforms. For example, IXL and similar fluency-based programs offer academic feedback by providing an explanation when a question is answered incorrectly that can be reviewed independently by the student or with the teacher for more understanding of a particular math skill. Explanations identify the incorrect answer and then provide math strategies for solving the question correctly. The role of the student is to answer the initial question on the computer screen. When answered incorrectly, the solution with an explanation is displayed for the student to read. It is unclear as to whether or not this was a passive task in this study since my observations happened during the first half of the class and there was little evidence of using IXL or similar software during my visits. However, this type of computer format offers the opportunity to draw from a solution to apply math strategies to similar subsequent questions for the student to solve. Implications are discussed in chapter 5. See IXL example in Figure 7.

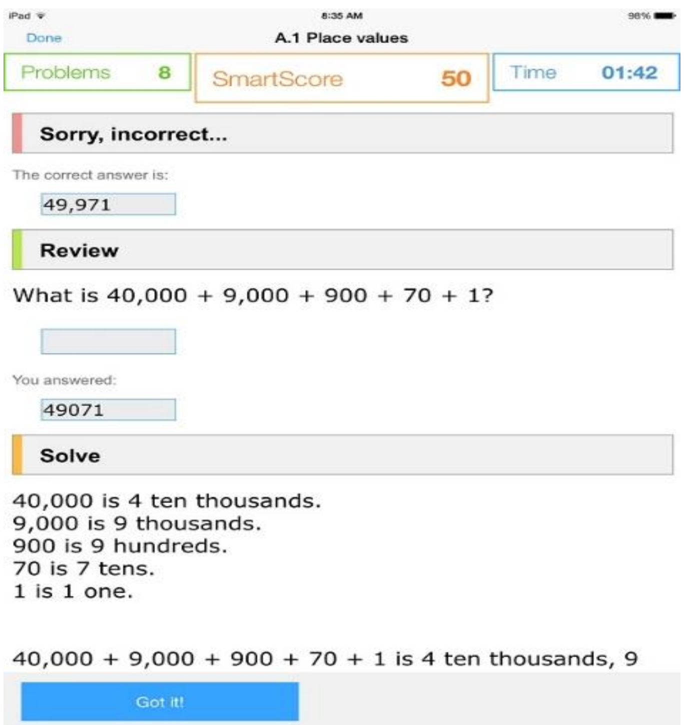


Figure 7. IXL Example

To summarize, math software sites presented opportunities for students, and indirectly to teachers, to feel more comfortable with the grade level math concepts and foundational skills while gaining knowledge through supplemental online practice and instruction.

Teaching strategies used to overcome challenges of using technology. As central to the data collection process, teachers were asked to describe any technology challenges that they have experienced and share how they were able to overcome these challenges. The pattern evident from the feedback received from the group of 13 teachers who responded to the interview question was the concern about daily access. About 62%, 8 out of 13 participants, suggested that availability of Chromebooks was an issue. Some teachers expressed acknowledgement about the district's plan to add more technology in the near future.

When asked to describe how they overcome the challenge of Chromebook availability, teachers discussed how they self-reflect and adjust instructional plans about how to best tailor the math lesson within the limitations of available technology. As illustrated by the comments below, most teachers quickly reassessed their instructional situation and then either reassigned the original assignment to include collaborative learning with peers, readjusted differentiated centers for students or created a sign in schedule protocol for technology.

Teacher A commented:

> So then everybody is signing them out, so then if you're like, "Oh man, I really wanted to do this today," but then if you needed that extra computer… So basically, then that's why I love the centers. So then we do that movement. We

> still have those lovely computers over there which is fantastic, so everybody has the opportunity to jump on it, and it is very motivational, because the kids love to go on.

Teacher H commented:

> Yeah, so we're spread pretty thin (regarding access to technology). But, we've been told there will be more (chrome books available to teachers). So I'm optimistic… We double up on things like that. I'll have them work with a partner.

Teacher B commented:

> So, the only challenge I mean is having access to the laptops all the time. They're okay with it… I have a checklist now with their names, so they know that I'm keeping track of who's going on. And, I think they understand that so they know "Okay, if I didn't go today, I'll go tomorrow". So I think they know what to expect.

Interestingly, on the surface it seemed as though the only challenge was availability and teachers would use Chromebooks more readily if the technology was available. However, in addition to that limitation, there were critical assessments expressed about concerns about the motivational value of particular fluency based and tutorial educational software. This included teachers' comments about incorporating Pearson, Ten Marks, Study Island and Khan Academy websites into instructional routines. Generally, teachers' concerns were about students' lack of engagement with this type of software.

Teacher L commented:

> I mean Ten Marks is free but I wish that I had something else that I had to differentiate. Sometimes we go on Study Island but it's not as fun. They don't like it as much.

Teacher V commented:

> I do some of the manipulatives that come with Pearson, but I don't really think it's that great. The kids get pretty bored by it.

Teacher R commented:

> I think it's (Khan Academy) kinda boring, but I guess it's good… I think (that) I really don't like that. I think it's annoying how it repeats itself all the time.

Teacher W commented:

> I use Study Island. This year… I've only used it when we've had to use it …
> The question that arises is whether these comments are reflective of using technology in general. I will discuss this implication in detail in the chapter 5.

One other secondary pattern emerged regarding challenges using educational technology. Of the group of participants in the study, four out of fourteen participants, a little less than 30%, were concerned about how the software aligned with teachers' instructional pace. How reliable was the software to support a teacher's learning objectives? In this situation, participants frequently reflected on why the technology was causing issues regarding students' learning and subsequent anxiety about learning, and then readjusted the routine and computer use to better fit the academic needs of the students in the classroom. This occurred in a range of ability grouped classes. For example, some teachers expressed that the reading component of the online program was too difficult for students while others were concerned about the math skills content itself. Regardless of prior self-efficacy, teachers adjusted current practices and use of online resources as necessary. The comments below highlight how teachers self-reflect and then self-regulate their own instruction in order to minimize anxiety, and maximize student learning and math achievement.

Teacher E commented:

> Then we do Ten Marks and that's more… I'll do it with them to show, to read it with them and to show that they can do it. Ten Marks can be overwhelming with all the reading and these students aren't readers, so I'll read it with them to make them feel successful in it.

Teacher L commented:

> I always try to explain to them that like I have a plan and sometimes it's the first time I'm trying it… Last week we watched a Brain Pop and I said, "We're going to try to make a map and you can show me all the different ways you can do multiplication"… It was a disaster. I had two kids in tears. And, I said, "Maybe we'll do it in partners (instead)".

Teacher R commented:

> I'll assign an assignment on Ten Marks or Study Island but it's asking them things that they haven't learned yet…I just say this is practice, we will learn it. And then it seems to be fine, but I feel like using it as practice is much better and letting them know it's practice, rather than an assessment. And we can learn from our mistakes. And that seems to lessen their anxiety and frustration.

To summarize, participants in this study overcame technology challenges by adjusting routines related to differentiated centers, collaborative assignments and scheduling changes. Teachers' use of online technology was customized to students' learning when technology challenges were not sufficiently met. This included concerns expressed by teachers related to the reading portion included in a computerized math task or the combination of mathematical concepts included in a software program.

In the following section, I will explore teachers' choices regarding educational technology. The subtopics include 1) game technology and the motivation to learn and 2) preparing students for the PARCC exam.

Teachers' Choices Regarding Educational Technology

Game technology and the motivation to learn. Of the fourteen participants in this research study, a little less than half or 43% of the teachers use continuous video game software such as Prodigy Math, as a differentiated learning center during the math instructional period. Of the teachers that use Prodigy Math in their classrooms, about two-thirds or 67% teach low or average ability levels and suggest that one of the benefits of this type of software is its engagement value as a motivational learning tool. The teachers that use Prodigy Math reported that their students enthusiastically embraced learning math with this online resource tool. An equal number of teachers with high or low self-efficacy background in mathematics use Prodigy Math software in his/her classrooms.

Teacher V commented as follows:

> Well, what happens is, I think that technology it presents it in a story mode for these kids and it relates it to real life to things that the kids can actually make connections to, and it's interactive. And these days, kids are so into the video games and so into the interactive that their attention is held longer…So I think it makes a connection with these kids on their level to something they already like. So it holds them longer.

Teacher B commented as follows:

> The kids right now are really gravitating towards Prodigy Math. I think that's really what they've been doing consistently. I think because they kind of have success with it. It's not too hard, but it's not too easy. And, it kind of builds their confidence.

About 86% (n=12) of teachers reported using non-cumulative game format or timed software focused on fluency as a differentiated math technology learning station. Examples of these types of sites include Math Playground, Cool Math, Fun Brain, Multiplication.com and Xtra Math. These games are not designed to cumulatively track students' progress and although students receive feedback whether an answer is correct or not, these sites do not typically provide explanations and strategies associated with the game. This provided students with practice opportunities but not in-depth critical feedback. There was no evidence as reported by teachers that students were asked to self-reflect in writing about their own thinking while participating at the game software technology station. As communicated through teacher observations and interviews, the intended purpose was focused on strengthening fluency in an engaging format different from teacher directed instruction.

Interestingly, similar to assigning continuous math video game format software, teachers communicated that their decisions for choosing one math game versus another was in response to developing appropriately engaging instructional methods based on their beliefs about particular class dynamics and the academic needs of the students that they teach. Of the total number of teachers, the 14 % (n = 2) of participants who do not use game software teach an above grade level ability group of students for mathematics and have expressed that games serve as a distraction to instruction.

Along with extra practice, teachers used game software for its motivational value. Teachers' preconceived self-efficacy about mathematics and the role of technology regarding learning was sometimes evident.

Teacher V (observation and interview) commented:

> Let's get through this (learning multiplication) and then yes, we are going to play a game.

Students were able to independently practice using engaging games on sites such as Math Playground or Sheppard Software format to test accuracy of skills. Teachers reported assigning math games as a center activity, however, there was little evidence that the teacher assessed students' progress on non-continuous game software. Moreover, teachers communicated that the purpose was to promote engaging learning through repeated practice.

Teacher L commented:

> I always try to find games for them and I put the links up on my website. So then if they're done like that sometimes it's an option they can get a Chromebook and play a game or they can practice at home.

Teacher A commented:

> It's really nice because a lot of games now come with the differentiated levels…every day it's like we're always looking for games on the computer.

Teacher H commented:

> They can also play different games that I have on my website that provide multiplication practice and reinforcement and things like that…But, there are a number of problem solving websites. Math Playground. We like Red Block…Maybe they're more in a problem solving mood, or a multiplication mood. There are different multiplication games on Math Playground.

Preparing students for the PARCC exam. Teachers expressed the value of lessening students' anxiety by not only motivating to learn through use of game software but also as an opportunity to prepare students for taking state standardized tests by using on-line programs for practice. A third grade teacher within this school has created a website that contains links to on-line practice tests that are available to teachers within the school. Teachers also commented about using websites like Study Island, IXL and Ten Marks which focus on fluency, track progress and incorporate rigorous reading passages similar to the structure of the standardized PARCC exam.

Teacher T commented:

> I think that doing programs that are familiar to them, such as doing online programs like Study Island, Ten Marks, those kind of things to help lessen the anxiety when they go and see the PARCC. So things that make them more familiar, so when it comes time to take those kind of overwhelming tests, they're more comfortable and less anxious.

Teacher E commented:

> If I give them Ten Marks, sometimes I'll give them a third or second grade activity and they don't even know. They can't see what grade it is, but so they are successful…It's to show them that they can do it. I guess if you want to believe you can do things, it does lessen anxiety in return.

Teachers use a variety of educational technology in the classroom to motivate and encourage academic achievement. In the following section, I will report about teachers' views on lessening students' math anxiety. The subtopics include 1) teachers' views about the sources of their students' math anxiety, 2), teachers' strategies using technology to lessen students' math anxiety, 3) teachers' non-tech strategies to lessen students' math anxiety and 4) comparing frequency of tech and non-tech methods to lessen students' anxiety.

Teachers' Views on Lessening Students' Math Anxiety

Teachers' views about the sources of their students' math anxiety. The sources of students' mathematics anxiety were explored from the participants' point of view. Students were not interviewed about their anxiety. The teachers in this study were generally keenly aware of their students' anxiety about learning mathematics as expressed in observations, surveys and interviews. Initially, second cycle process coding resulted in the following codes: getting good grades, coming from home or culture, getting it right, knowing math skills, feeling uncomfortable, lacking confidence and predicting math will be hard.

The following highlighted comments in Table 6 describe sources of students' math anxiety from teachers' perspectives of teaching students and interacting with the community.

Table 6

Teachers' Comments Describing Sources of Students' Math Anxiety

Teacher	Source of Students' Anxiety	Comment
E	Knowing the math skills	We're doing multiplication right now and I'm showing them all the different ways you can multiply…they don't understand…they just get overwhelmed with all the different choices that they have.
B	Getting it right	They are more anxious about getting an answer wrong, because it's more right or wrong. If they don't understand, it's hard for them to explain what they're having trouble with.

Table 6 (continued)

Teacher	Source of Students' Anxiety	Comment
L	Pressure from home	A lot of these parents at conference time have sent me emails that they want their child in UL math and that is their goal…that they are not happy with them in high math.
Q	Cultural value of math	Well, one of the things about math that makes students anxious is the fact that I think it's just very prevalent attitude in our society. It is okay not to be good at math… nobody brags that they're illiterate. They won't think twice about saying, "Gee, I'm terrible at Math".
E	Predicting it will be hard	That they just shut down. It overpowers them and they just become so anxious and they just can't move forward. They don't even try to break it down. They just say, "I just can't do it. It's just too hard".
R	Feeling uncomfortable	Maybe the one or two who obviously don't fit into this (accelerated group). It's very obvious. And I think they feel, I know it. And then I find that they're making like they come up to me and let me know right away. I could only do one of these and they're so aware.

Based on teachers' responses during data collection, three general patterns emerged related to teachers' beliefs about sources of students' mathematics anxiety. Understanding how teachers interpret causes of students' math anxiety may help to also understand teachers' perceptions of how best to alleviate students' poor self-efficacy and encourage achievement in mathematics. The patterns apparent from teachers' views of their students' anxiety focused on attitudes about achievement, cultural values and students' internal beliefs. Refer to Table 7 for data collected. See Figure 6 for a diagram illustrating these patterns.

Table 7

Number of Teachers' Interview Responses about Sources of Students' Math Anxiety by Teachers' Professional Assignment

	Teachers' Professional Assignment (Ability Grouping)		
Source of Anxiety	Resource/Low	Average	High/Unique Learners
Getting good grades	0	0	4
Home/Culture	0	0	2
Getting it right	3	0	3
Knowing math skills	3	3	2
Feeling uncomfortable	0	0	3
Lacking confidence	0	2	0
Predicting math will be hard	0	2	0
Total (N = 27)	6	7	14

The data in Table 7 were collected from responses during the teacher interviews. Specifically, the questions I asked were as follows:

What has been your experience with students who have felt anxious about math?

What do you think about math that makes students anxious?

Of the 27 interview responses, there were differences among responses from teachers who taught lower ability groups and higher ability groups about what they thought makes their students anxious related to learning mathematics. Getting good grades and outside pressure were unique to responses from higher level math teachers. Lacking confidence and predicting that math will be hard were unique responses from average level math teachers.

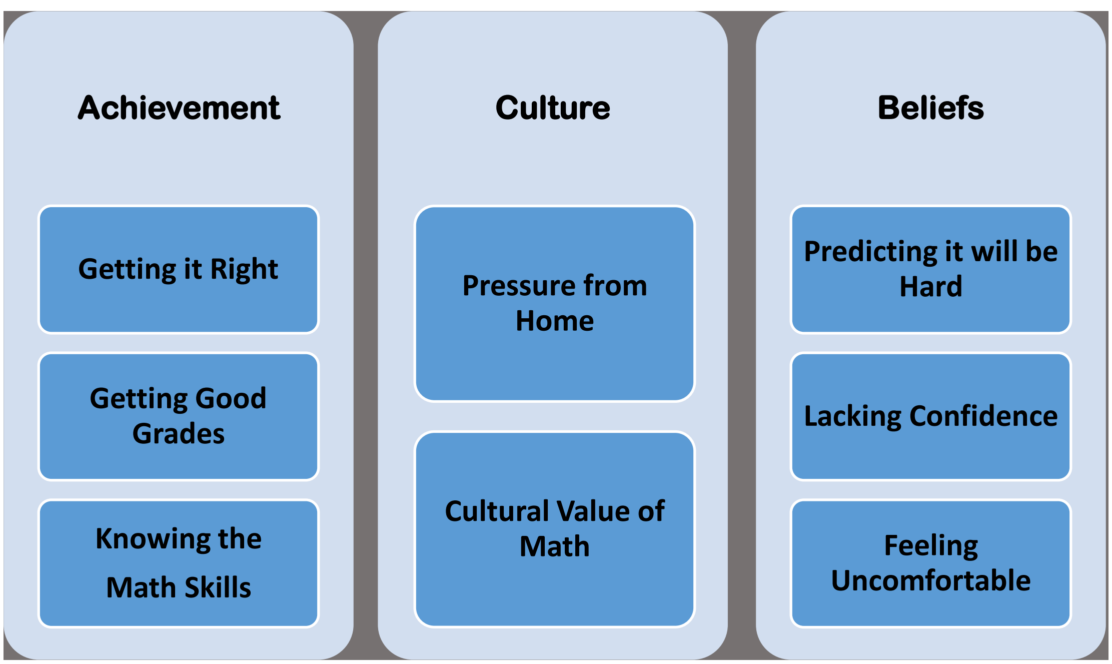


Figure 8. Three Patterns Emerging Relating to Sources of Students' Math Anxiety

Teachers' strategies using technology to lessen students' math anxiety.

Teachers in this study used a combination of non-tech and tech resources to encourage and build upon their students' self-efficacy in the classroom. Table 8 highlights teachers' comments regarding helping students build self-efficacy about math achievement using educational technology resources.

Table 8

Teachers' Comments on Students' Self-Efficacy using Online Resources

Teacher	Strategy	Comment
J	Differentiated centers	I found that using centers and using technology in a positive way, and meeting with the kids often and checking in with them often has worked for this group in particular.
E	Format of software	(About piloting new software) There's cool videos as a lesson that you could use that's interactive… That's what we'll do as a whole group because it's so engaging that they all sit there.
V	Objectivity	It (computer software tool) doesn't have a face where a kid can read into the emotions of the person giving them the feedback. It's very straightforward….I have a clue, do you want a clue? They don't feel like someone is judging them. I think that technology is a really great aid to help build confidence level of the students…

Teachers' non-tech strategies to lessen students' math anxiety. As described earlier in this section, teachers' preconceived self-efficacy influenced their own beliefs about what their students' views were about learning mathematics. The findings in this study suggest that teachers' poor past experiences positively impact how teachers view the best way to lessen their students' math anxiety and promote achievement. The idea that teachers with poor self-efficacy may expect different markers of achievement and hold different beliefs about how to best encourage students to reach academic potential will be discussed further in chapter 5. Table 9 describes teachers' responses from the interview data which emphasized the importance of collaboration and small group instruction to motivate students to learn mathematics.

Table 9

Number of Teachers' Responses Supporting Using Collaboration /Small Group Instruction to Motivate Students to Learn Mathematics by Self-Efficacy and Professional Assignment

Teaching Assignment	LSE Teachers	HSE Teachers
Third Grade	22	10
Fourth Grade	18	12
Total (N = 62)	40	22

Note. Of the total 62 responses, LSE (low self-efficacy) accounts of about 65% and HSE (high self-efficacy) accounts for 35%.

Referring to Table 9, the total number of teachers with poor self-efficacy about mathematics describing the importance of peer collaboration and small group instruction to motivate students to learn mathematics about two times as frequently commented in interviews as the third and fourth grade teachers who described themselves as having positive experiences learning math when they were younger.

Other non-tech strategies that teachers use every day to lessen students' math anxiety include reassuring students, trying mindfulness type exercises, and adjusting assessments accordingly. Table 10 highlights teachers' comments regarding helping students build self-efficacy about math achievement.

Table 10

Teachers' Comments Regarding Building Students' Self-Efficacy in Mathematics

Teacher	Strategy	Comment
Z	Changing language	I try to make it where it's *not*, "You're right. You're wrong". I try to change the language… just kind of redirect them. Just making them feel comfortable. 'Cause when you hear that, you feel like I got the answer wrong. I'm gonna put my hand back down. I'm not participating anymore. That's it.
Q	Mindfulness	I establish my classroom climate at the beginning of the year. I want to make sure that students feel comfortable not knowing something. Some of the mindfulness techniques that I use for tests, I have the students...do some deep breathing exercises. I have several affirmations on the board.

Table 10 (continued)

Teacher	Strategy	Comment
V	Feedback	(Students) are anxious (so I am) providing positive feedback all the time no matter whether the kids are making the smallest improvements or not.
R	Extra help	Just small group is very helpful. If you feel like you're struggling, meet me on the rug. Or, if I find that that's embarrassing for kids… I'll pull everyone so it's not obvious that these kids need the extra help.
T	Adjusting tests	In the beginning of the year, I do more like fact timed tests just to see and get them practicing. I always have one or two who just shut down. And…I go over to them and I'll say, "I want you to do the first 20, but you're not timed. Just take your time. Or pick any ones you wanna do that you feel comfortable with".

Teachers employed a variety of non-tech strategies as well as techniques that involve technology to build students' understanding of math fostering achievement and lessening students' math anxiety in the elementary classroom.

Comparing tech and non-tech methods to lessen students' anxiety. Third and fourth grade teachers frequently focused on strengthening students' preconceived self-efficacy beliefs by employing tech and non-tech strategies that involved building students' confidence in math. One popular strategy was to encourage partner work. Refer to Figure 9.

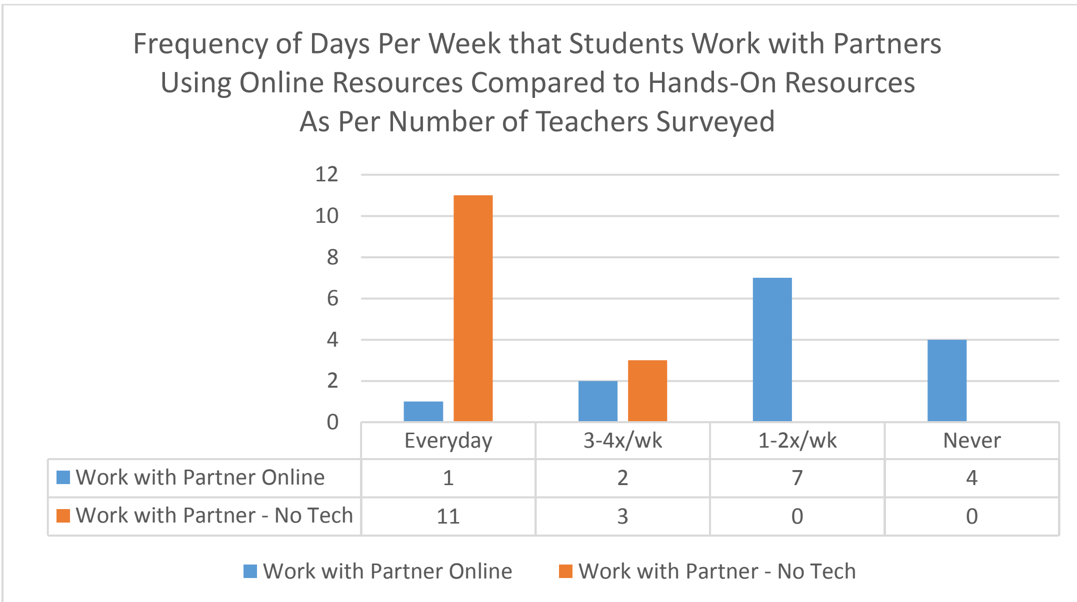


Figure 9. Frequency of Days Per Week That Students Work with Partners

As illustrated in the bar graph above, the majority of the elementary school teachers surveyed found partner work using hands-on print resources rather than online games and programs more effective regarding lessening students' math anxiety. Many teachers in this study suggested that having students share a computer to complete an engaging computer game was more distracting to classmates and themselves than building confidence by working on the online game independently.

As reported earlier, teachers' own self-efficacy beliefs were generally aligned with their beliefs about their students' self-efficacy about learning mathematics. Teachers with poor self-efficacy tended to discuss that they had trouble connecting with the subject or that the instruction that they received was boring and meaningless. The findings in this study suggest that teachers' poor past experiences helped to shape how those same teachers view the best way to lessen their students' math anxiety and evaluate how to positively support and encourage students' achievement. As previously mentioned, teachers' poor self-efficacy and their expectations of achievement along with their views about how to best support students to reach academic potential will be discussed further in chapter 5. Table 11 describes teachers' responses from the interview and observation data about the importance of using engaging games to motivate students to learn mathematics.

Table 11

Number of Teachers' Responses Suggesting the Importance of Using Engaging Games to Motivate Students to Learn Mathematics by Self-Efficacy and Professional Assignment

Teaching Assignment	LSE Teachers	HSE Teachers
Third Grade	13	2
Fourth Grade	13	4
Totals (*N* = 32)	26	6

Note. Of the total 32 responses, LSE (low self-efficacy) accounts of about 81% and HSE (high self-efficacy) accounts for about 19%.

Referring to the table above, the total number of teachers with poor self-efficacy about mathematics describing the importance of using engaging activities to motivate students to learn was about four times as frequently commented as the teachers who described themselves as having positive experiences learning math when they were younger. I will explore the implications of teachers' self-efficacy and its effect on instructional decisions and strategies used in the classroom in chapter 5.

Summary

This study has explored teachers' own self-efficacy about mathematics and decisions to use various on-line educational software resources to lessen students' math anxiety and encourage math achievement at the elementary school level. The findings of this research suggest that teachers, through their own previous experiences, hold self-efficacy beliefs about mathematics that influence how they view their students' own self-efficacy regarding mathematics achievement. Drawing from their own experiences, teachers embrace technology use and choose different software programs and websites based upon perceptions of ability, class dynamics and engagement value. Especially among teachers whose professional assignments are to teach the average and below average students, math game software, both continuous (tracking) and non-continuous formats were used as a motivational resource to encourage students to persist through difficult math tasks and encourage achievement.

Teachers employed a variety of methods to lessen students' math anxiety in all classrooms, regardless of ability level. Differentiating the specific math content by adjusting students' grade level work, helping students with the reading portion of on-line tasks and providing opportunities to master skills through repeated practice in a game format were all strategies using technology. Teachers also used non-tech strategies to lessen math anxiety including small group instruction and collaborative work. In the final chapter, I will discuss the implications of these research findings and suggest future areas of exploration as well as directives for educational leadership.

Chapter 5

Discussion

There has been continued debate about how to equitably teach mathematics in our schools (Cobb, et al., 1992; Ellis, 2003; Ladson-Billings, 1997; Loveless, 2001; Oakes, 1985; Price & Ball, 1997). This has been reflected in conceptual shifts in educational focus and greater accountability for quality education through increasingly standardized testing protocol (Conley, 2003; Epstein, 2004). Considering mounting political pressure for U.S. students to compete globally as measured by international PISA assessments (PISA, 2012) and focus on achievement through STEM education (STEM Coalition, 2016), the overriding educational issue is how to improve students' academic potential and encourage students to pursue math related careers (STEM Coalition, 2016; U.S. Department of Education, 2016). This is a realistic and justifiable goal as jobs in the STEM field are projected to increase at almost two times the rate of growth of non-STEM jobs (U.S. Department of Commerce, 2011). Considering growth in science, technology, engineering and math job markets, it is essential that U.S. students are prepared for future careers. However, students' outlook about mathematics discussed earlier in this paper is alarming. Only 25% of U.S. students continue to study math as an educational requirement for future careers (Scarpello, 2007). As previously discussed, when students are worried or anxious about math, they may avoid taking elective classes in this subject in high school and college (Ashcraft, 2002; Ashcraft & Krause, 2007). Moreover, students who avoid mathematics classes in high school then avoid pursuing STEM-related careers (Chipman, Krantz, & Silver, 1992).

One of the topics of concern that has been discussed in depth in the first two chapters is the emphasis about math anxiety. Considering its impact on academic potential, career choices and long-lasting effects, searching for solutions to lessening math anxiety is central to strengthening and sustaining a quality educational experience by teachers and for all students. Although previous research by Sun and Pzydrowski (2009) confirmed that technology use in schools lessens students' math anxiety, it was important to investigate this issue in more depth.

Given both the emphasis on math achievement and wide availability of technological resources in education today, there was a need to examine how teachers reflected on using strategies involving technology to lessen students' anxiety and encourage math achievement by exploring teachers' own insights about their self-efficacy related to mathematics anxiety. Research has suggested that an individual's poor self-efficacy about mathematics negatively influences one's own math achievement (Wigfield & Eccles, 2000; Harmes, 2012; Beilock, 2010; Beilock, Gunderson, Ramirez, & Levine, 2009; Gunderson, Ramirez, Levine, & Beilock, 2012; Meece, Wigfield, & Eccles, 1990). Moreover, as discussed in the literature review, teachers socially model self-efficacy beliefs about their own successes or failures in math indirectly and may pass this on to students (Bates, Latham & Kim, 2013). Exploring teachers' self-efficacy in this study has contributed to understanding teachers' instructional choices regarding using technology to best teach mathematics in third and fourth grades.

The purpose of this study was to examine teachers' beliefs about mathematics and their students' mathematics anxiety. This study also explored the use of educational technology to lessen students' mathematics anxiety in the elementary school classroom.

Four research questions that I addressed were as follows: 1) How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of using educational technology as an instructional resource tool to lessen students' math anxiety? 2) How do third and fourth grade teachers describe their own self-efficacy for teaching mathematics and the relationship of encouraging critical thinking tasks among students in mathematics classrooms? 3) To what extent do the results of this qualitative study support previous research about factors affecting teachers' use of educational technology on teachers' self-efficacy related to the selection of instructional methods to lessen students' math anxiety? and 4) To what extent do the results of this qualitative study support previous research about factors affecting teachers' mathematics anxiety and self-efficacy about teaching mathematics to lessen students' math anxiety in the elementary school classroom?

I addressed these research questions by analyzing data collected from first observing, then surveying and finally interviewing third and fourth grade teachers from an elementary school in a suburban setting in New Jersey. All teachers currently have access to technology in their classrooms. I reviewed these findings to explore whether a relationship exists between teachers' self-efficacy about mathematics and using educational technology to lessen students' math anxiety in the younger grades. In this final chapter, I will present my key findings and implications drawing from existing theoretical framework. I will then conclude by discussing limitations of this study along with suggestions for educational leadership and future directions in the area of mathematics anxiety and educational technology.

Key Findings

I focused my study on three areas of interest: teacher self-efficacy about mathematics, students' self-efficacy from the perspective of the teachers, and teachers' choices when using technology to teach mathematics. The key findings are in response to the research questions which address these areas of interest and were stated previously. Based on the research questions and the data analyzed from the observations, surveys and interviews, I was able to conclude the study with four themes about my topic of study. These themes are organized according to the order of the research questions and are summarized as follows: 1) Teachers' self-efficacy about mathematics along with teachers' professional assignments contribute to decisions about how to best use educational technology as an instructional tool, 2) Educational math software provides opportunities to lessen teachers' and students' mathematics anxiety by acting as a valuable feedback mechanism and encouraging critical thinking related to mathematics, 3) Teachers self-reflect and use self-regulation strategies during mathematics instruction in order to overcome technology challenges in the classroom, and 4) Teachers use of a combination and variety of technology and non-tech strategies to lessen students' mathematics anxiety in the elementary classroom.

The results of this research study discussed in the previous chapter suggested that, third and fourth grade teachers taught mathematics following a Math Workshop Model protocol that included providing opportunities for student engagement primarily through the use of differentiated learning stations. In the following section, I will discuss the findings and implications of contributing decisions to using educational technology. The subtopics include 1) teachers' self-efficacy about mathematics, 2) Students' self-efficacy about mathematics from their teachers' perspectives and 3) relevance of findings.

Contributing Decisions to Using Educational Technology

Teachers' self-efficacy about mathematics. The findings from my research study suggest that teachers' own prior experiences about learning mathematics coupled with the teachers' professional assignment influence decisions about what types of educational software teachers chose to use in the math classroom. Teachers' descriptions of their own previous experiences in mathematics in this study were categorized according to whether or not they were anxious about mathematics when they were younger. It is suggested that teachers' past experiences and beliefs shaped how they interpreted their students' views and needs regarding learning mathematics. For example, a teacher who was anxious about learning math when younger then assumes that her students will also feel anxious if met with similar experiences. The results in this study showed evidence of a strong link among teachers' own beliefs about achievement and what teachers reported how their students would value achievement. The results also supported the premise that teachers subsequently interpret and deliver instruction for their students that has been shaped by the teachers' own past situation. Technology choices are included in teachers' teaching strategies and affected by elementary teachers' self-efficacy about mathematics.

Students' self-efficacy about mathematics from their teachers' perspectives. The results of this study support Bandura's (1993) self-efficacy research, from both a teachers' perspective about their own perceived beliefs and their beliefs about their students' attitudes about mathematics. Consistent with Bandura's (1993) research, the findings in this study suggest that teachers' own self-efficacy towards mathematics affects goal setting for students. Moreover, teachers use their understanding of content knowledge to adapt to their teaching environment, impacting the learning experiences and beliefs of their students in their math classroom (Remillard, 1999). For example, there were various situations during the interview process where teachers who had previously communicated a low efficacy towards mathematics expressed how their own beliefs were a motivating factor for designing different instructional methods in order to lessen students' mathematics anxiety. In one instance, a fourth grade teacher commented how she extensively incorporated math games and other related technology because she felt uncomfortable and struggled with the rote math that she learned as a student. In a different situation, a third grade teacher expressed how she enjoyed math as a student because it involved memorizing facts for which she has previously experienced success. When I observed her class, students were practicing drill and practice type skills. Subsequently, regardless of the teachers' background, students own attitudes are impacted and shaped to form what it means to learn mathematics from the teachers' classroom decisions, practices and beliefs (Goodykoontz, 2008; Grootenboer & Marshman, 2016).

Relevance of findings. Considering the vast amount of instructional resources currently available, teachers have the challenging task of deciding what software to use in their classrooms to effectively deliver math instruction. Analyzing data collected from observations, surveys and interviews, it appears that the teachers' expectations of their students and how to best deliver instruction to meet academic goals were often influenced by the teachers' own past math experiences. This is consistent with previous research which has discussed the powerful relationship of the impact of teacher's self-efficacy about mathematics and students' math anxiety (Bates, Latham, and Kim, 2013). Moreover, this is especially relevant considering the increasing number of technology resource choices teachers are faced with and the pressures to deliver math curriculum which will encourage students to pursue more extensive math in their school careers. Teachers' beliefs about defining effective learning as evident within the context of using educational technology effectively is an area that may warrant further research in the future.

Teachers also reflected on and considered their own professional teaching assignment when planning for lessons which involved different math ability groups of students. Consistent with research regarding the positive impact of socially constructing cognitive experiences (Rogoff, 2003; Vygotsky, 1978), and the relationship of motivation and self-efficacy, teachers chose software which maximized the engagement value of the task and students' learning experiences, especially among those who taught average and low math ability groups. Again, teachers' own beliefs about how their own students regard achievement influenced technology and instructional choices. In the following section, I will discuss how educational math software provides opportunities to lessen teachers' and students' mathematics anxiety by acting as a valuable feedback mechanism and encouraging critical thinking related to mathematics. Subtopics include 1) providing feedback, and 2) alternate explanations to consider.

Teachers' Self-Efficacy and using Technology

Providing feedback. As previously stated, third and fourth grade teachers taught mathematics using a Math Workshop Model protocol that provided opportunities for student engagement primarily through the use of differentiated learning stations. Drawing from Vygotsky's (1978) research regarding zone of proximal development, a differentiated station format supports a platform for developing a socially constructed learning environment within the math classroom. Moreover, the active use of incorporating technology provides instantaneous feedback, along with encouraging academic growth within the students' reach. During one of my elementary classroom visits, I observed students working in pairs on a computer program designed to practice the math skill of over and under estimation. Pairs of students were working together on a non-continuous fluency-based site, AAA Math, and took turns solving and explaining math questions. The computer program indicated whether a question was correct, but did not provide an explanation; that was the responsibility of students in each group. I observed most pairs of students following these directions. Specifically, as one student answered a question incorrectly, the other commented about why it was incorrect and how to correctly answer the question. It was evident during my math visit that the teacher had clearly previously practiced this protocol in class with his students. Additionally, the teacher checked in with students asking specific questions and sharing targeted feedback. Wiggins (2012) has suggested that in order for feedback to be effective, it should be "tangible, transparent and timely" which this study demonstrates is possible with the use of technology in the math classroom. The software program that the third grade teacher selected displayed grade level content material. The teacher rotated among pairs at each desktop, informally assessing students' knowledge and giving additional feedback.

The use of educational software, regardless of the format, also functions to provide both the students and teacher with feedback about students' academic progress through on-going assessment. For example, by gradually building content, both students and teachers have the opportunity to potentially build on their self-efficacy through strengthening skills, socially constructing knowledge (Rogoff, 2003; Vygotsky, 1978) and reviewing material together. Moreover, the objective feedback provided through a computer-generated task is immediate (Hellum-Alexander, 2010) and actionable (Wiggins, 2012) since it provides multiple opportunities for teachers and students to acquire new knowledge and strengthen existing skills by responding to questions through computer generated tasks. Tatar, Zengin and Kagizmanli's (2015) research supports the advantage of strengthening teachers' self-efficacy about mathematics online as they reported a decrease in math teaching anxiety when teachers who were initially anxious about teaching mathematics became more skilled at using the technology that supported instruction. In this study, a third grade math teacher within the elementary school created and maintained his own website that includes practice tests and links to useful third and fourth grade online non-continuous math games. Other teachers that were interviewed discussed how the website and this teacher's expertise served as valuable resources to effectively teaching mathematics. There are positive implications as a result of this situation. Third and fourth grade math teachers became more comfortable differentiating instruction using a Math Workshop Model as a result of knowing that they have the online and peer resources that they need readily and consistently available. Additionally, teachers now have access to online tools that they may not have been aware of previously which provides opportunities to increase their own knowledge about technology that they can use in their own lesson planning and instruction.

Research has discussed the value of developing teachers' critical thinking and general expertise in math (Ball & Forzani, 2009; Ball, Thames, & Phelps, 2008; Hill and

Ball, 2004; Ball, Hill, & Bass, 2005). In fact, shifts in mathematical focus as reflected by the Common Core Standards emphasize the importance of understanding math within the rigorous context of both process and fluency (Alberti, 2012/2013). Considering that 57% of the teachers in this study reported poor self-efficacy about mathematics when they were younger, and that math anxiety remains relatively consistent during the teenage years (Ma & Xu, 2004), it is essential to discuss the research findings related to opportunities to improve teachers' and their students' mathematics self-efficacy using educational technology.

The findings in this study related to mathematics anxiety and achievement in the context of using educational technology in the classroom can be explained using Eccles' (1983) Expectancy-Value Model. In this theoretical framework, students' choices of tasks are determined by "…expectancies for success on those tasks and the subjective value they attach…" (Wigfield & Eccles, 2002). Moreover, students are motivated to complete a math assignment based on a personal assessment of how important the task itself is regarding skills knowledge along with the degree of success that the student foresees as possible. During the interview process, some teachers in this study commented about the value of having educational technology available as another "tool in the toolbox" to explain and motivate elementary school students to learn mathematics. This is helpful to teachers from the perspective of both instructional planning and delivering effective math lessons to third and fourth grade students.

The use of educational technology in a differentiated center generally provides an opportunity for teachers to motivate students to achieve by boosting students' expectations for success. For example, as communicated during interviews in this research study, third and fourth grade teachers discussed how they tailored specific software programs to the students' needs without calling attention to the grade level work that the student was assigned. This was particularly helpful for customizing mathematics instruction for students who were above or below grade level. For example, one teacher discussed how her students were poor readers and struggled with word problem formats. Adjusting the level of the Ten Marks, a continuous fluency based software program, students were motivated to try to solve the word problem type questions rather than demonstrate the typical reaction of shutting down when assigned a mathematics task. This observation is aligned with Eccles' (1983) Expectancy-Value Model in that it illustrates how students' subjective value on a task is fluid and can show positive change (Wigfield & Eccles, 2000). Motivation to complete a task is important and is reflective of an individual's self-efficacy about learning new mathematics concepts (Bandura, 1993).

Educational software provides opportunities to lessen teachers' and students' mathematics anxiety by acting as a valuable feedback mechanism for critical thinking. Technology offers situations to build the students' confidence by fostering success in math class. In fact, the teacher is able to keep a pulse on encouraging critical thinking among students using computer resources as a learning and planning tool. As Eccles' (1983) model (Wigfield & Eccles, 2000) and my findings suggest, students were motivated to complete tasks as they perceived that the skills were valuable to learning and that they held an expectation based on experience, of being successful as well.

Alternate explanations to consider. Considering the results of this study, to what degree is critical thinking actually happening through the use of technology in the classroom? Technology in this study appears to act as a "tool in the toolbox" and teachers' resource opportunity for students' immediate feedback and possible critical thinking depending upon the software program that the students are using and how students are instructed to self-reflect during practice and learning. Eccles' (1983) Expectancy Value Model has discussed the importance attaching a value to expecting success and subsequently motivating individuals to learn (Wigfield & Eccles, 2000). The results of this study suggest that teachers may indirectly guide how students expect to be successful based upon how the teachers themselves value the technology that they are asking their students to use to achieve in mathematics. Teachers' enthusiastic embrace of Prodigy Math in this study best illustrates this point. Prodigy Math is a fluency based software program that is designed in a video game format and tracks students' progress. The reverse is true as well. During a follow-up visit to a fourth grade classroom, I observed a fourth grade teacher discussing how "Study Island software was boring to use" and students readily agreed. Unlike Prodigy Math, Study Island is a fluency based software program that tracks students' progress but is not formatted in a continuous video game format. Teachers' perceptions of using technology are powerful to effective learning. In fact, this is an important consideration regarding developing professional development for teachers. When school administrators are designing long range planning and support in the area of math and technology use in the elementary classroom, the results of this research study suggest that teacher involvement is essential.

In the following section, I will discuss how teachers self-reflect and use self-regulation strategies during mathematics instruction in order to overcome technology challenges in the classroom. Subtopics in this section include 1) overcoming challenges using self-regulation, and 2) unexpected findings.

Self-Regulation and the Challenges of Technology

Overcoming challenges using self-regulation. The findings in this study indicated that teachers reflected about their situation and used self-regulation strategies during mathematics instruction in order to overcome technology challenges in the classroom. As indicated in the previous results chapter, about 62% of the participants commented that the availability of Chromebooks was an issue that impacted planning for math instruction. About 29% of the participants were concerned about how well the software aligned to curriculum and instructional methods.

Zumbrunn, Tadlock, and Roberts' (2011) research related to self-regulation suggests that individuals who self-regulate readjust their goals and progress through a series of stages in order to successfully complete a task. This was also true for the participants in this study. Teachers who were faced with not having enough Chromebooks available for whole class instruction, would then quickly reflect on how to best deliver the lesson planned by changing the format to a differentiated learning station format. Additionally, when assigning online activities where the content was too challenging for students, teachers in this study then readjusted the purpose of the assignment. For example, if the task was originally going to be assessed, it would be reframed as a valuable practice opportunity. Teachers commented that they would informally monitor and reflect on the decisions in the classroom in order to plan for better future instructional strategies.

Unexpected findings. A surprising finding about overcoming technology challenges were teachers' critical assessments shared during observations and interviews. Regarding challenges, there were some teacher concerns focusing more on the motivational value of software choices rather than availability of technology. Some teachers expressed concern about searching for more engaging math online resources for students. Additionally, although teachers use benchmark assessments as directed by the school's policy, follow-up to the interviews suggested that the results from benchmark assessments are not consistently used by all and some teachers prefer other online math software choices currently available which provide more specific data about their students. Considering that teachers are responsible for teaching different ability levels, this may or may not be an important issue, and provides opportunities for further discussion.

Various Strategies to Lessen Students' Math Anxiety

Throughout this research study, teachers employed a variety of technology and non-tech strategies to lessen students' mathematics anxiety in the elementary classroom. Teachers reported that poor self-efficacious students in their classes have generally displayed defeatist attitudes about mathematics prior to beginning a task, which is consistent with Bandura's (1991) research. Individuals set goals based on one's own self-efficacy beliefs. Casual attributions, how observable behavior is interpreted, are influenced by one's own self-efficacy (Bandura, 1993). Students' math anxiety as described by teachers in this study and how teachers employed strategies to lessen that worrisome behavior is supportive of Weiner's (1985) Attribution Theory framework. In Attribution Theory, individuals interpret observable behavior by deciding its level of stability, degree of causality and if the behavior is within an individual's locus of control (Weiner, 1985). From teachers' perspectives, students who are anxious about math will anticipate that failing at a math task is predictable, due to one's own poor ability and lack of control to make a positive impact. Motivation to succeed at math is intentionally driven by one's own self-efficacy about preconceived views about whether success is possible (Bandura, 1993). Recognizing anxious students' beliefs, the teachers in this study used a variety of both technology-based and non-technology strategies to lessen their students' anxiety in the mathematics classroom.

Within the context of this research study, data collected and analyzed from observations, surveys and interviews suggest that teachers employed instructional strategies to maximize their students' success in math that focused on building achievement and subsequently developing a student's sense of control over their own learning; which is supportive of Weiner's (1985) research. Teachers encouraged their students to persist through mathematics tasks and the process was relational as the more that students would persist through a task, the greater likelihood that they would experience better success and more confidence in their own math abilities to continue to persist when faced with mathematics tasks. Ma (1999) and others (Faust, Ashcraft, & Fleck, 1996; Cates & Rhymer, 2003; Ma & Xu, 2004; Carey, Devine and Szucs, 2015) have discussed and suggested an interconnected relationship among mathematics achievement and mathematics anxiety. Investing in lessening students' anxiety regarding subsequent achievement was expressed as worthwhile by teachers in this study and also supported by research (Lyons & Beilock, 2012; Maloney, & Beilock, 2012; Maloney, Sattizahn, & Beilock, 2014; Beilock, & Maloney, 2015).

Teachers frequently discussed their own class dynamics, the degree to which classes vary, and the importance of teaching to the instructional and emotional needs of their students. Regardless of a particular year or professional ability group assignment, it should be noted that all teachers in this study discussed the frequency of having students in their classrooms each year who are anxious about math achievement; which is consistent with research describing the prevalence of math anxiety in our society today (Meece, Wigfield, & Eccles, 1990; Beilock, 2010; Harmes, 2012; Maloney & Beilock, 2012; Ramirez et al., 2013; Beilock and Maloney, 2015). As stated earlier, teachers used a combination of strategies which involved technology and non-tech approaches to lessen their students' math anxiety.

This research study explored further the original findings of Sun and Pzydrowski's (2009) study which suggested that educational technology positively affects students' learning by lessening anxiety in the mathematics classroom. Since there is currently greater availability of educational technological resources than when Sun & Pzydrowski's (2009) research was originally published, it was interesting to investigate in what capacity online tools are currently being used to improve students' self-efficacy in mathematics.

Teachers in this study found using computer software, primarily in a differentiated station format, as most effective regarding lessening students' anxiety about math. It was reported that students frequently worked independently at computer technology stations. In fact, about 79% of the teachers in this study commented that they assign students to work alone or work in pairs only once or twice per week. Students mostly sit physically in front of a computer screen by themselves. Although teachers cited that using computer resources are motivational to students, many suggested that they experienced that it was a distraction to others if groups of elementary school students were taking turns playing computer games together. Interestingly, teachers who assigned Prodigy Math, commented that the benefit of using this type of software was that although students worked independently, they also had the ability of connecting with other students remotely while still strengthening current skills, tracking academic progress and building confidence about math. Prodigy Math is a software program structured for continuous game format practice. Although physically working alone, in this situation, students were able to socially construct learning (Vygotsky, 1978; Rogoff, 2003) by communicating remotely with their peers.

This also supports Vygotsky's cultural-historical theory stating that individuals learn through "engagement in sociocultural activities" (Rogoff, 2003); which is certainly true of math video game activities. In this study, students' academic achievement using this type of online tool provided anxious students with guided support of their peers in a remotely social environmental context. In addition to game formats, teachers reported using non-game, fluency-based math software to build skill competence. Teachers most commonly suggested that students' use of computers to practice math skills in a differentiated station format functioned to build academic achievement and motivated students to continue to practice assigned math skills and prepare for classroom assessments.

Teachers reported a variety of non-technology strategies that they used to lessen students' math anxiety in the elementary school classroom. This included methods previously supported by research: using targeted effective feedback (Brookhart, 2012; Hattie, 2012; Wiggins, 2012; William, 2012) and modeling positive classroom climate including mindfulness techniques like adding breathing exercises (Brunyé, Mahoney, Giles, Rapp, Taylor, & Kanarek, 2013). Interestingly, teachers' verbal approaches to giving feedback to lessening students' anxiety support the premise of addressing linguistic capital (MacLeod, 1995). MacLeod (1995) discussed the importance of recognizing that students come to school with diverse linguistic patterns as experienced through culturally different backgrounds. Especially among teachers in this study who taught low and average math classes, teachers remarked about the importance of delivering feedback so that it wouldn't be misinterpreted. For example, one teacher commented that she avoided using "You're right. You're wrong" as it has a culturally negative connotation. Teachers also emphasized customizing the physical structure of instruction by offering more opportunities for small group and individualized extra help along with different formats for skills assessment based on students' level of academic progress and math anxiety.

As previously stated in this chapter and drawing from Vygotsky's (1978) research which has discussed the importance of socially-constructing learning, all elementary school teachers in this study capitalized on encouraging students to actively share ideas and work together with partners or in small groups as part of a regular instructional approach to teaching mathematics to young children. Teachers commented that there were tangible benefits to having students learn from each other and this strategy was used often when lessening students' mathematics anxiety. Moreover, using different approaches to building students' confidence was an advantage to encouraging students to work to their academic potential. In fact, it was observed that it would be insufficient to rely on computer technology alone to ease students' worrisome attitudes. In summary, teachers found it beneficial to employ a variety of technology *and* non-tech strategies to lessen students' mathematics anxiety in the elementary classroom.

Conclusion

In this section, I will address limitations of this study that include discussion about the location site and sample size and then suggestions based upon these recognized limitations. I will also discuss the role of educational leadership and the implications for additional research in educational technology and self-efficacy in mathematics as well as future directions for practice, policy and educational leadership.

Limitations

The purpose of this study was to explore teachers' perceived self-efficacy about mathematics and using educational technology and its influence on lessening students' math anxiety in the classroom. I used a qualitative approach (Maxwell, 2013) in my research design. I triangulated my data collection process by conducting observations, surveys and interviews of third and fourth grade math teachers. This approach was used in order to provide a rich set of data and to reduce the risk of researcher bias (Maxwell, 2013). Limitations of this study include various sampling decisions in the research process. In the following section, I will describe each limitation, reflect on the reasoning behind my choices during data collection and briefly discuss how these limitations could be overcome in the future along with suggestions for future research.

Location site. Data was collected in a suburban school district in New Jersey. New Jersey uses the New Jersey Student Learning Standards (NJSLS) in Mathematics which provides rigorous curriculum which aligns with the Common Core State Standards. States that adopt different guidelines other than the Common Core or New Jersey Student Learning Standards may also adhere to different academic standards and criteria for math curriculum. When reviewing this research study, the reader should consider that the mathematics standards that the school district's teachers have adopted reflect their own instructional strategies based on the parameters they follow as dictated by the NJSLS standards. Future suggestion for further research would be to expand this study to include additional districts with varying socioeconomic and size demographics in other states.

The elementary school for this study was specifically selected for research, due to the district's commitment to a long-range technology plan. Currently, in this study there exists an uneven distribution of computers available to third and fourth grade teachers. For example, some classrooms house a Chromebook cart which holds about 24 devices while other rooms have three desktop computers and share a cart stored in the library or other central location. Considering the financial investment in hardware and software, it was particularly valuable to research actual use of computer resources and tools in the elementary classroom setting. Limitations include districts that are not equipped with technology yet or have a different set up in their schools. Suggestions for future research would be to again expand this study to examine various technology configurations and teachers' instructional use for lessening students' mathematics anxiety.

Sample size. Of the 18 possible participants, 16 originally agreed to participate and 14 third and fourth grade teachers actually took part in this research study. The sample size represented teachers who taught a variety of professional teaching assignments and every ability group in relation to the total number of participants was represented in the research design. Although the sample size was relatively small, the data collection process included adopting a triangulated approach (Teddlie & Tashakkori, 2009; Maxwell, 2013) in which teacher observations, surveys and semi-structured interviews (Rubin & Rubin, 2012) were conducted at the elementary school. The result of this in-depth data collection protocol was a rich set of data responses available, valuable to analyzing the relationship among teachers' preconceived beliefs about mathematics, students' math anxiety from the teachers' perspective, and using educational technology for instruction. Future suggestions would be to recreate this study using a larger sample size in order to compare and contrast findings from this research study. Additionally, recreating this study to include different configurations regarding tracking students by ability as well as including a heterogeneous format to teaching math at the elementary school would produce potentially interesting findings.

Educational Leadership

Participating in an educational leadership doctoral program, I chose a topic of current relevance within our schools today. Given the emphasis on our standing regarding mathematics on a global scale, it is essential that we encourage students to achieve academically to remain competitive in the future. Researching the implications of students' mathematics anxiety from teachers' perspectives and the relationship of using educational technology to encourage achievement has provided a window into understanding how supplemental resources are used to improve mathematics instruction at the elementary school level.

Implications for research. Originally, Sun & Pzydrowski (2009) reviewed literature spanning from 1996 - 2009 to determine if computer programs lessened students' math anxiety in the classroom. They suggested that there was a benefit to using online software in this capacity (Sun & Pzydrowski, 2009). This research study expanded upon this topic further by examining the relationship of teachers' preconceived beliefs about mathematics, lessening students' mathematics anxiety and the role of educational technology in schools. Generally, technology available for learning has rapidly increased in recent years (Dankbaar & DeJong, 2014; Sun & Pzydrowski, 2009) and consequently, allocation of online academic resources has been discussed (Reidel, 2014; Tatar, Zengin and Kagizmanli, 2015).

Although there is ample availability of online educational resources in mathematics, research regarding examining the relationship of using technology and math anxiety is limited (Sun and Pydrowski, 2009; Hellum-Alexander, 2010; Tatar et al., 2015). Using online resources as a tool in a teacher's toolbox to alleviate mathematics anxiety is a fairly new instructional strategy to teaching mathematics (Marr & Helme, 1991; Flores, 2002; Taylor & Galligan, 2006). Moreover, Beilock and Maloney (2015) and others (Wigfield, & Eccles, 1990; Beilock, Gunderson, Ramirez, & Levine, 2009; Maloney & Beilock, 2012) have stressed the importance of focusing on improving self-efficacy of both teachers and students in mathematics and its impact on academic achievement.

This study has focused on exploring how third and fourth grade teachers' own beliefs which they bring to teaching mathematics shapes their views about what their students' anxiety and beliefs are about mathematics achievement. As educators, this has presented opportunities for further discussion about what academic expectations teachers then have for encouraging critical thinking based upon teachers' views about students' own attitudes towards mathematics. The findings from teacher observations, surveys and interviews in this study suggest that using educational technology is beneficial to lessening students' math anxiety in the classroom. This was a relatively small sample focused on third and fourth grade math teachers in an elementary school environment. I suggest that additional research is necessary in order to explore this link between online resources and self-efficacy from a teachers' perspective about teaching mathematics. Understanding how to best support teachers in their role in providing quality education to all students using online resources is essential and possible by advocating for additional research in the area of math anxiety and educational technology.

Implications for policy and practice. During data collection, it became apparent that third and fourth grade teachers informally collaborate among others on their grade teams as they managed busy teaching routines. Dictated by coordinating a relatively large group of teachers responsible for teaching different ability group levels, the schedule currently allows for teachers meeting in a professional learning community (PLC) according to grade level to discuss curriculum about once per month during the teachers' lunch period. According to DuFour and Eaker (1998), professional learning communities collaborate about a common vision, share ideas and reflect on change. Especially since teachers are already trying to coordinate resources within the school day, allowing designated time for the third and fourth grade teachers to meet would be helpful regarding creating a platform for sharing ideas related to educational resources and instructional strategies. Recently, there has been a proposal presented by the mathematics and technology district supervisor to consolidate some of the levels (skills/low) at the elementary and middle schools. If this proposal is adopted, then there would be an opportunity for administrators to better coordinate teachers' schedules to allow for more regularly scheduled teachers' PLCs among like ability group assignments. Additionally, it is suggested that math coaching support along with administrative support be available to the PLCs as necessary. Ball, Thames and Phelps (2008) have emphasized the importance of targeted curricular support to teachers which not only includes strengthening subject matter and specialized content knowledge, but also pedagogical knowledge regarding effectively using available educational resources. Finally, an area of possible future exploration is looking into departmentalizing teaching math in third and fourth grades, thereby fostering further expertise in this content area at the elementary level.

Implications for leadership. Considering the recent state and national emphasis on mathematics achievement and the pressures that teachers face delivering curricula that is standards-based, meaningful and motivating to students, it is essential to advocate for positive change so that those who make policy and those who are responsible for carrying it out are in sync with pre-determined goals and objectives.

Argyris and Schon (1974) have discussed the importance of interpersonal communication for implementing change policies which effectively represent individuals' espoused beliefs. In the context of this study, delivering new protocol routines that realistically address both the technology resources needs as well as specific mathematics instructional strategies as communicated by *all* stakeholders in this process are important to promoting lasting change in the district. Moreover, Fullan (2011) has argued that in order to be an effective leader, one has to be able to communicate a shared vision by effectively motivating others and creating buy-in for the purpose of change.

Authentic leadership theorists (George, 2003) perhaps best speak to leadership implications of this particular research study. Authentic leadership focuses on a set of five dimensions (George, 2003). The authentic leader is one whose professional relationships with staff incorporates unified purpose for change along with adding meaningful values, self-discipline, and a passion for change (George, 2003). In this context, administrators reach out to teachers to help develop realistic and meaningful educational policies which reinforce the changing technological and math educational needs of both elementary school teachers and their students.

Recognizing that a focal point of proposed change is centered on teachers' own self- efficacy in mathematics, it is critical that administrators, such as principals and supervisors, establish positive working relationships among teachers and other administrators in order to sustain workable support in the area of educational technology and instructional math practices. Authentic leadership in practice is fluid and circular in its approach to change (George, 2003). Understanding that teachers may be invested in shifting the focus of PLC's and professional development at the elementary school for the specific purpose of supporting their own math practices related to academic resources is essential, especially as technology continues to be integrated into the district's academic culture. By doing so, all stakeholders will be invested in change as they act as problem solvers in this process (Fisher & Ury, 2011). Additionally, providing opportunities for collaboration and establishing consistent math coaching support is important. Ultimately, understanding and valuing teachers' own beliefs and experiences will help shape educational best practices to lessen students' math anxiety, encourage achievement and effectively use technology to sustain positive transformational change in math education.

References

Achieve the Core. (n.d.). *Achieve the core mathematics*. Retrieved December 20, 2017 from https://achievethecore.org/

Adkins, R. C. (2012). America desperately needs more STEM students. Here's how to get them. *Forbes Leadership Forum.* Retrieved from https://www.forbes.com/sites/forbesleadershipforum/2012/07/09/america-desperately-needs-more-stem-students-heres-how-to-get-them/#5b0e2dd74976

Alberti, S. (2012/2013). Making the shifts. *Educational Leadership, 70*(4), 24-27.

Argyris, C., & Schon, D. A. (1974). *Theory in practice: Increasing professional effectiveness.* San Francisco, CA: Jossey-Bass.

Arnowitz, S., & Giroux, H. A. (1993). *Education still under siege.* Westport, CT: Greenwood Publishing Group.

Ashcraft, M. (2002). Math anxiety: Personal, educational and cognitive consequences. *Current Directions in Psychological Science – American Psychological Association*, *11*(5), 181-185.

Ashcraft, M., & Faust, M. (1994). Mathematics anxiety and mental arithmetic performance: An exploratory investigation. *Cognition and Emotion, 8*(2), 97-125.

Ashcraft, M., & Kirk, E. (2001). The relationship among working memory, math anxiety and performance. *Journal of Experimental Psychology*, *130*(2), 224-237.

Ashcraft, M., & Krause, J. (2007). Working memory, math performance and math anxiety. *Psychometric Bulletin*, *14*(2), 243-248.

Ball, D., Ferrini-Mundy, J., Kilpatrick, J., Milgram, R. J., Schmid, W., & Schaar, R. (2005). Researching for common ground in K–12 mathematics education. *Notices of the AMS*, *52*(9), 1055-1058.

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education*, *60*(5), 497-511.

Ball, D. L., Hill, H., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade and how do we decide? *American Educator, 29*(1), 14-17, 20-22, 43-46.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389-407. doi:10.1177/0022487108324554

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*(2), 122-147.

Bandura, A. (1991). Social-cognitive theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50*(2), 248-287.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117-148.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York, NY: Academic Press. (Reprinted in H. Friedman [Ed.], *Encyclopedia of mental health*. San Diego, CA: Academic Press, 1998).

Bates, A., Latham, N., & Kim, J. (2013). Do I have to teach math? Early childhood pre-service teachers' fears of teaching mathematics. *IUMPST: The Journal, 5*(Teacher Attributes), 1-10.

Beilock, S. (2010). *Choke*. New York, NY: Simon & Schuster.

Beilock, S., Gunderson, E., Ramirez, G., & Levine, S. (2009). Female teachers' anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences, 7*(5), 1860-1863. Retrieved from http://www.pnas.org/content/107/5/1860.full.pdf

Beilock, S., & Maloney, E. (2015). Math anxiety: A factor in math achievement not to be ignored. *Behavioral and Brain Sciences, 2*(1), 4-12.

Brookhart, S. M. (2012). Preventing feedback fizzle. *Educational Leadership, 70*(1), 24-29.

Brookings Institute. (n.d.). Brown Center Report on American Education. *Brookings*. Retrieved January 2018 from https://www.brookings.edu/research/2013-brown-center-report-on-american-education-how-well-are-american-students-learning

Brunyé, T. T., Mahoney, C. R., Giles, G. E., Rapp, D. N., Taylor, H. A., & Kanarek, R. B. (2013). Learning to relax: Evaluating four brief interventions for overcoming the negative emotions accompanying math anxiety. *Learning and Individual Differences, 27*, 1-7.

Buckley, S. (2011). Deconstructing maths anxiety: Helping students to develop a positive attitude towards learning maths. *Australian Council for Educational Research*. Melbourne, Australia: ACER. Retrieved from https://www.acer.org/occasional-essays/deconstructing-maths-anxiety-helping-students-to-develop-a-positive-attitude

Carey, E., Hill, F., Devine, A., & Szucs, D. (2015). The chicken or the egg? The direction relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology, 6,* 1987. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4703847/

Cates, G. L., & Rhymer, K. N. (2003). Examining the relationship between mathematics anxiety and mathematics performance: An instrumental hierarchy perspective. *Journal of Behavioral Education, 12*(1), 23-34.

Chinn, S. (2012). Beliefs, anxiety and avoiding failure in mathematics. *Child Development Research*, *2012*, 1-8. doi:10.1155/2012/396071

Chipman, S. F., Krantz, D. H., & Silver, R. (1992). Mathematics anxiety and science careers among able college women. *Psychological Science*, *3*(5), 292-295.

City Data. (n.d.). Demographic city data. Retrieved January 2018 from www.city-data.com/

Cobb, P., & Jackson, K. (2011). Towards an empirically grounded theory of action for improving the quality of mathematics teaching at scale. *Mathematics Teacher Education and Development*, *13*(1), 6 - 33.

Cobb P., Yackel, E. & Wood, T. (1992) A constructivist alternative to the representational view of mind in mathematics education. Journal for Research in Mathematics Education, *23*(1): 2-33.

Common Core State Standards Initiative. (n.d.). *Common core state standards in mathematics*. Retrieved January 2018 from http://www.corestandards.org/Math/

Conley, D. T. (2003). *Who governs our schools? Changing roles and responsibilities.* New York, NY: Teachers College Press.

Cowan, N. (2009). What are the differences between long-term, short-term, and working memory? *United States National Library of Medicine, 169,* 323-338. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2657600/

Creswell, J. (2014). *Research design*. Thousand Oaks, CA: Sage Publications.

Dankbaar, M. E. W, & DeJong, P. G. M. (2014). Technology for learning: How it has changed education. *Perspectives on Medical Education, 3*(4), 257-259.

Das, R., & Das, G. C. (2013). Math anxiety: The poor problem solving factor in school mathematics. *International Journal of Scientific and Research Publications*, *3*(4), 1-5.

Devine, A., Fawcett, K., Szucs, D., & Dowker, A. (2011). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions*, *8*(33), 1-9. Retrieved from http://behavioralandbrainfunctions.biomedcentral.com/articles/10.1186/1744-9081-8-33

Dill, K. (2014, July 3). The top paying STEM jobs for recent grads. *Forbes*. Retrieved from https://www.forbes.com/sites/kathryndill/2014/07/03/the-top-paying-stem-jobs-for-recent-grads/#3c266539ef34

Dowker, A., Sarkar, A., & Looi, C.Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology*, *7*, 508. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4842756/

Dream Box Learning. (n.d.). Conceptual understanding definition. Retrieved February 2018 from www.dreambox.com/conceptual-understanding/

DuFour, R., & Eaker, R. (1998). *Professional learning communities at work: Best practices for enhancing student achievement.* Bloomington, IN: Solution Tree.

Educational Technology. (n.d.). In *MacMillan Dictionary*. Retrieved from https://www.macmillandictionary.com/us/dictionary/american/educational_technology

Ellis, M. W. (2003). Constructing a personal understanding of mathematics: Making the pieces fit. *Mathematics Teacher*, *96*(8), 538-542.

Ellis, M. W., & Berry, R. Q. III. (2005). The paradigm shift in mathematics education: Explorations and implications of reforming conceptions of teaching and learning. *Mathematics Teacher*, *15*(1), 7-17.

Epstein, N. (Ed.). (2004). *Who's in charge here? The tangled web of school governance and policy.* Denver, CO: Education Commission of the States.

Erbas, A. K., & Aydogan Yenmez, A. (2011). The effect of inquiry-based explorations in a dynamic geometry environment on sixth grade students' achievements in polygons. *Computers and Education*, *57*(4), 2462-2475.

Esroy, Y. (2005). Movements for innovations of mathematics education – 1: Technology supported mathematics teaching. *The Turkish Online Journal of Educational Technology*, *4*(2), 51-63.

Faust, M., Ashcraft, M., & Fleck, D. (1996). Mathematics anxiety effects in simple and complex addition. *Mathematical Cognition, 2*(1). doi:10.1080/135467996387534.

Fink, A. (2003). *How to ask survey questions.* Thousand Oaks, CA: Sage Publications.

Fisher, R., & Ury, W. (2011). *Getting to yes: Negotiating agreement without giving in.* New York, NY: Penguin Group.

Flores, A. (2002). Learning and teaching mathematics with technology. *Teaching Children Mathematics, 8*(6), 308-310.

Fullan, M. (2011). *Change leader: Learning to do what matters most.* San Francisco, CA: Jossey-Bass.

Furner, J., & Duffy, M. L. (2002) Equality for students in the new millennium: Disabling math anxiety. *Intervention in School and Clinic, 38*(2), 67-74.

Gafoor, K. A., & Kurukkan, A. (2015). *Trends and challenges at Farook Training College*. Paper presented at the National Seminar on Pedagogy of Teacher Education, Kozhikode, Kerala.

Geist, E. (2010). The anti-anxiety curriculum: Combating math anxiety in the classroom. *Journal of Instructional Psychology,* 37(1), 24-31. Retrieved from https://www.andrews.edu/sed/gpc/faculty-research/montagano-research/the-anti-anxiety-cur.pdf

George, B. (2003). *Authentic leadership: Rediscovering the secrets to creating lasting value.* San Francisco, CA: Jossey-Bass.

Gerstenberg F. X. R., Imhoff R., Schmitt M. (2012). "Women are bad at math, but I'm not, am I?" Fragile mathematical self-concept predicts vulnerability to a stereotype threat effect on mathematical performance. *European Journal of Personality, 26(6),* 588-599.

Great Schools (n.d.). *Campbell Elementary School data*. Retrieved December 2017 from http://www.greatschools.org/new-jersey/metuchen/1143-Campbell-Elementary-School/#Teachers_staff

Goodykoontz, E. (2008). Factors that affect college students' attitude toward mathematics (unpublished dissertation). Morgantown, WV: College of Human Resources and Education at West Virginia University.

Grootenboer, P., & Marshman, M. (2016). *Mathematics affect and learning: Middle school students' beliefs and attitudes about mathematics.* Singapore: Springer Science and Business Media Publishing.

Gunderson, E. A., & Levine, S. C. (2011). Some types of parent number talk count more than others: Relation between parents' input and children's number knowledge. *Developmental Science, 14*(5), 1021-1032.

Gunderson, E., Ramirez, G., Levine, S., & Beilock, S. (2012). The role of parents and teachers in the development of gender related math attitudes. *Sex Roles*, *66*(3-4), 153-166.

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math- related majors of college women and men: A path analysis. *Journal of Counseling Psychology*, *32*(1), 47-56.

Halat, E., & Peker, M. (2011). The impacts of mathematical representations developed through Web Quest and spreadsheet activities and motivation of pre-service elementary teachers. *The Turkish Online Journal of Educational Technology, 10*(2), 259-267. Retrieved from http://files.eric.ed.gov/fulltext/EJ932244.pdf

Harmes, W. (2012, September 12). Math anxiety causes trouble for students as early as first grade. *University of Chicago News.* Retrieved from https://news.uchicago.edu/article/2012/09/12/math-anxiety-causes-trouble-students-early-first-grade

Hattie, J. (2012). Know thy impact. *Educational Leadership*, 70(1), 18-23.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*(1), 33-46.

Henri, F. (1991) Computer conferencing and content analysis. In O'Malley, C. (Ed.) *Computer supported collaborative learning*. Heidelberg, Germany: Springer-Verlag.

Hellum-Alexander, A. (2010). *Effective teaching strategies for alleviating math anxiety and increasing self-efficacy in secondary students*. (Unpublished master's thesis). Evergreen State College, Olympia, WA. Retrieved from http://archives.evergreen.edu/masterstheses/Accession89-10MIT/Hellum-Alexander_AMIT2010.pdf

Hill, H., & Ball, D. (2004). Learning mathematics for teaching: Results from California's mathematics professional development institutes. *Journal for Research in Mathematics*, *35*(5), 330 -351.

Hom, E. (2014). STEM definition. Retrieved February 2018 from https://www.livescience.com/43296-what-is-stem-education.html

Hopko, D., Ashcraft, M., Gute, J., Ruggerio, K., & Lewis, C. (1998). Mathematics anxiety and working memory: Support for the existence of a deficient inhibition mechanism. *Journal of Anxiety Disorders*, *12*(4), 343- 355.

Hurrell, D. P. (2013). What teachers need to know to teach mathematics: An argument for a reconceptualised model. *Australian Journal of Teacher Education*, *38*(11), 51-64.

Klein, D. (2003). A brief history of American K-12 mathematics education in the 20th century. In J. Royer (Ed.) *Mathematical cognition* (pp. 175-225). Greenwich, CT: Information Age Publishing. Retrieved from http://www.csun.edu/~vcmth00m/AHistory.html

Lackner, A., & Nuckles, M. (2016). Tell me why! Content knowledge predicts process-orientation of math researchers' and math teachers' explanations. *Instructional Science, 44*(3), 221-242.

Ladson-Billings, G. (1997). It doesn't add up: African American students' mathematics achievement. *Journal for Research in Mathematics Education, 28*(6), 697-708.

Lortie-Forgues, H., Tian, J., & Siegler, R. S. (2015). Why is learning fraction and decimal arithmetic so difficult? *Developmental Review*, *38*, 201-221. doi:10.1016/j.dr.2015.07.008

Loveless, T. (1998). *Making sense of tracking and ability grouping debate*. Retrieved from http://edexcellencemedia.net/publications/1998/199807_trackingandability/Loveless%20Final%20Copy.pdf

Loveless, T. (Ed.) (2001). *The great curriculum debate: How should we teach reading and math?* Washington, DC: Brookings Institution Press.

Loveless, T. (2013). *The 2013 Brown Center report on American education: How well are American students learning?* Washington, DC: Brown Center on Education Policy at Brookings. Retrieved from https://www.brookings.edu/research/2013-brown-center-report-on-american-education-how-well-are-american-students-learning/

Lyons, I. M., & Beilock, S. L. (2012). Mathematics anxiety: Separating the math from the anxiety. *Cerebral Cortex*, *22*(9), 2102-2110.

Ma, X. (1999). A meta-analysis of the relationship between anxiety towards mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 30*(5), 520-540.

Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. *Journal of Adolescence, 27*(2), 165-179.

MacLeod, J. (1995). *Ain't no makin it: Aspirations and attainment in a low-income neighborhood.* Boulder, CO: Westerview Press.

Maloney, E. A., Ansari, D., & Fugelsang, J. A. (2011). The effect of mathematics anxiety on the processing of numerical magnitude. *The Quarterly Journal of Experimental Psychology, 64*(1), 10-16.

Maloney, E. A., & Beilock, S. L. (2012). Math anxiety: Who has it, why it develops, and how to guard against it. *Trends in Cognitive Sciences*, *16*(8), 404-406.

Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science, 26*(9), 1480-1488.

Maloney, E. A., Risko, E. F., Ansari, D., & Fugelsang, J. (2010). Mathematics anxiety affects counting but not subitizing during visual enumeration. *Cognition*, *114*(2), 293-297.

Maloney, E. A., Sattizahn, J. R., & Beilock, S. L. (2014). Anxiety and cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, *5*(4), 403-411.

Maloney, E. A., Schaeffer, M. W., & Beilock, S. L. (2013). Mathematics anxiety and stereotype threat: Shared mechanisms, negative consequences and promising interventions. *Research in Mathematics Education, 15*(2), 115-128.

Marr, B., & Helme, S. (1991). *Breaking the maths barrier: Language, Literacy & Asian Studies Projects (LLASP).* Adelaide, Australia: Centre for Professional Communication, University of South Australia.

Marx D. M., Monroe A. H., Cole C. E., & Gilbert P. N. (2013). No doubt about it: When doubtful role models undermine men's and women's math performance under threat. *Journal of Social Psychology, 153(5),* 542-559.

Maxwell, J. A. (2013). *Qualitative research design*. Thousand Oaks, CA: Sage Publications.

Meece, J., Wigfield, A., & Eccles, J. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*(1), 62-70.

National Center for Education Statistics. (n.d.). *Trends in international mathematics and science study*. Retrieved December 2017 from https://nces.ed.gov/timss/

National Council of Teachers of Mathematics. (n.d.). *NCTM*. Retrieved from https://www.nctm.org/

New Jersey Department of Education. (2015-2016). *2015-2016 school performance report*. Retrieved from: https://rc.doe.state.nj.us/report.aspx?County=23&District=3120&School=060&SchoolYear=2015-2016&SY=1516

Newman, D. R., Webb, B., & Cochrane, C. (1995). Content analysis method to measure critical thinking in face-to-face and computer supported group learning. *Interpersonal Computing and Technology, 3*(2), 56-77.

Oakes, J. (1985). *Keeping track: How schools structure inequality*. New York, NY: Yale University Press.

O'Dea, C. (2011, May 31). No more pencils, no more books: Technology-driven education in NJ schools. *NJ Spotlight.* Retrieved from http://www.njspotlight.com/stories/11/0530/2255/

OECD (2012). *Education at a glance 2012: Highlights*. Paris, France: OECD Publishing. Retrieved December 2017 from http://dx.doi.org/10.1787/eag_highlights-2012-en

One-To-One Technology (2013). In *Educational Glossary*. Retrieved from www.edglossary.org/one-to-one.

Onwuegbuzie, A. J., & Collins, K. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report, 12*(2), 1-38.

Pajares, F. (1995). *Self-efficacy in academic settings*. Paper presented at the meeting of the American Educational Research Association, San Francisco, CA.

Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concepts beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*(2), 193-203.

Passolungi, M. C., Caviola, S., DeAgostini, R., Perin, C., & Mammarella, C. (2016). Mathematics anxiety, working memory, and mathematics performance in secondary school children. *Frontiers in Psychology, 7,* 42. http://doi.org/10.3389/fpsyg.2016.00042

Patton, M. Q. (2002). *Qualitative research and evaluation methods.* Thousand Oaks, CA: Sage.

Peker, M. (2016). Mathematics teaching anxiety and self-efficacy beliefs towards mathematics teaching: A path analysis. *Educational Research and Reviews, 11*(3), 97-104.

Peker, M., & Ertekin, E. (2011). The relationship between mathematics teaching anxiety and mathematics anxiety. *The New Educational Review, 23*(1), 213-226.

Peker, M., & Halat, E. (2009). Teaching anxiety and the math representations developed through Web Quest and spreadsheet activities. *Journal of Applied Sciences, 9*(7), 1301-1308.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18*(4), 315-341.

Pentin, S. (2014, March 17). Motivation [Blog post]. Retrieved from http://sianpentinsportpsychology.blogspot.com/2014/03/motivation.html

Pew Research Center. (n.d.). *Pew research*. Retrieved from http://www.pewresearch.org/

Price, J. N., & Ball, D. L. (1997). There's always another agenda: Marshalling resources for mathematics reform. *Journal of Curriculum Studies, 29*(6), 637-666.

Programme for International Student Assessment. (2012). *PISA results*. Retrieved from http://www.oecd.org/pisa/keyfindings/pisa-2012-results.htm

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development*, *14*(2), 187-202.

Reidel, C. (2014, February 3). 10 Major technology trends in education. *THE Journal.* Retrieved from https://thejournal.com/articles/2014/02/03/10-major-technology-trends-in-education.aspx

Remillard, J. (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. *Curriculum Inquiry*, *29*(3), 315-342. Retrieved February 2018 from http://mathed.net/wiki/Remillard_(1999)

Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counselling Psychology*, *19*(6), 551-554.

Robbins, J., & Bauerlein, M. (2013, April 16). The common core state standards: Two views. *Academic Questions, 26*(1). Retrieved from https://www.nas.org/articles/the_common_core_state_standards_two_views

Rogoff, B. (2003). *The cultural nature of human development*. New York, NY: Oxford University Press.

Rossman, G. B., & Rallis, S. F. (2012). *Learning in the field*. Thousand Oaks, CA: Sage Publications.

Rubin, H. J., & Rubin, I. S. (2012). *Qualitative interviewing: The art of hearing data*. Thousand Oaks, CA: Sage Publications.

Rubinstein, O., Bialik, N., & Solar, Y. (2012). Exploring the relationship between math anxiety and gender through implicit measurement. *Frontiers in Human Neuroscience, 6*, 1-11.

Saettler, P. (1990). *The evolution of American educational technology*. Englewood, CO: Libraries Unlimited, Inc.

Saldana, J. (2009). *The coding manual for qualitative researchers*. Thousand Oaks, CA: Sage Publications.

Scarpello, G. (2007). Helping students get past math anxiety. *Techniques: Connecting Education and Careers*, *82*(6), 34-35.

Schein, E. H. (2010). *Organizational culture and leadership*. San Francisco, CA: Jossey-Bass.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Schultz, W. (2005, April). *Mathematics self-efficacy and student expectations: Results from PISA 2003*. Paper presented at the Annual Meeting of the American Educational Research Association in Montreal, Canada.

Seitchik A. E., Jamieson J., Harkins S. G. (2012). Reading between the lines: subtle stereotype threat cues can motivate performance. *Social Influence, 9(1)*, 52-68.

Sharma, Y. (2016). Alleviating mathematics anxiety of elementary school students: A situated perspective. *International Journal of Research in Education and Science (IJRES)*, *2*(2), 509-517.

Sherman, B., & Wither, D. (2003). Mathematics anxiety and mathematics achievement *Mathematics Research Journal*, *15*(2), 138-150.

Skiba, A. (1990). Reviewing and old subject: Math Anxiety. *Mathematics Teacher, 83*(3), 188-189.

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, *35*, 4-28.

Spicer, J. (2004). *Resources to combat math anxiety*. Washington, DC: Eisenhower National Clearinghouse. Retrieved July 12, 2004: http://www.enc.org/features/focus/archive/mathanxiety/document.shtm?input=FOC-003455-index

State of New Jersey Department of Education. (n.d.). *Partnership for assessment of readiness of college and careers* (PARCC). Retrieved December 2017 from http://www.state.nj.us/education/assessment/parcc/

Steele, D. (2001). Using socio-cultural theory to teach mathematics: A Vygotskian perspective. *School Science and Mathematics, 101*(8), 404-418.

STEM Education Coalition. (2016). Retrieved from http://www.stemedcoalition.org/

Sun, Y., & Pyzdrowski, L. (2009). Using technology as a tool to reduce mathematics anxiety. *Journal of Human Resource and Adult Learning, 5*(2), 38-44.

Tatar, E., Zengin, Y., & Kağızmanlı, T. B. (2015). What is the relationship between technology and mathematics teaching anxiety? *Educational Technology & Society, 18*(1), 67-76.

Taylor, J. A., & Galligan, L. (2006). Mathematics for maths anxious tertiary students: Integrating the cognitive and affective domains using interactive multimedia. *Literacy and Numeracy Studies*, *15*(1), 23-42.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Los Angeles, CA: Sage Publications.

TIMSS & PIRLS. (n.d.). Summary of TIMSS and PIRLS international study center reports. Retrieved from https://timssandpirls.bc.edu/

Tobias, S. (1993). *Overcoming math anxiety*. New York, NY: W.W. Norton & Company.

United States Bureau of Labor and Statistics. (2015, May). STEM crisis or STEM surplus? Yes and yes. *Monthly Labor Review.* Retrieved from http://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm

United States Census Bureau. (n.d.). Census information. Retrieved January 2018 from https://www.census.gov/

United States Department of Commerce. (2011). STEM: Good jobs now and for the future. *ESA Issue Brief #03-11.* Retrieved from http://www.esa.doc.gov/sites/default/files/stemfinalyjuly14_1.pdf

United States Department of Education. (2016). *Science, technology, engineering and math: Education for global leadership*. Retrieved from http://www.ed.gov/stem

U.S. News & World Report. (2017). *Metuchen high school.* Retrieved from: https://www.usnews.com/education/best-high-schools/new-jersey/districts/metuchen-public-schools/metuchen-high-school-12636

Vahedi S., Farrokhi F. (2011). A confirmatory factor analysis of the structure of abbreviated math anxiety scale. *Iran Journal of Psychiatry, 6*(2), 47-53. Retrieved from http://ijps.tums.ac.ir/index.php/ijps/article/view/283

Valencia College (2016). *Help for managing math anxiety: A discussion board assignment.* Retrieved from http://libguides.valenciacollege.edu/c.php?g=358909&p=2423153

Van Manen, M. (1994). *Researching lived experience*. Albany, NY: SUNY Press.

Venkatesh Kumar, G., & Karima, A. (2010). Math anxiety, math performance, and overall academic performance in high school students. *Journal of the Indian Academy of Applied Psychiatry, 36*(1), 47-50.

Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Wang, Z., Lukowski, S., Hart, S., Lyons, I., Thompson, L., Kovacs, Y., Mazzocco, M. M., Plomin, R., & Petrill, S. (2015). Is math anxiety always bad for math learning? *Psychological Science, 26*(12). Retrieved from http://journals.sagepub.com/doi/pdf/10.1177/0956797615602471

Weiner, B. (1972). Attribution theory, achievement motivation, and the educational process. *American Educational Research Education, 42*(2), 203-215.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review, 92*(4), 548-573.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*, 68-81.

Wigfield, A., & Meece, J. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology, 80*(2), 210-216.

Wiggins, G. (2012). Seven keys to effective feedback. *Educational Leadership, 70*(1), 10-17.

William, D. (2012). Feedback: Part of the system. *Educational Leadership*, *70*(1), 30-35.

Witt, M. (2012). The impact of mathematics anxiety on primary school children's working memory. *Europe's Journal of Psychology*, *8*(2), 263-274.

Wong, W. K., Yin, S. K., Yang, H. H., & Chang, H. H. (2011). Using computer-assisted multiple representations in learning geometry proofs. *Educational Technology and Society*, *14*(3), 43-54.

Young, C. B., Wu, S., & Menon, V. (2012). The neurodevelopmental basis of math anxiety. *Psychological Science, 23*(5), 492-501.

Zimmerman, B. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82-91.

Zumbrunn, S., Tadlock, J., & Roberts, E. D. (2011). *Encouraging self-regulated learning in the classroom: A review of the literature.* Richmond, VA: Metropolitan Educational Research Consortium (MERC).

Appendix A

Interview Questions

1. How long have you been a teacher?
2. How long have you taught math at this school?
3. What is your current ability group assignment?
4. How many students are in each of your math classes by ability level?
5. Overall, what has been your experience with students who have felt anxious about Math?
6. What it is about math that makes students anxious?
7. How would you describe your own math experiences when you were in school?
8. Describe how and when you use technology to differentiate instruction in the classroom.
9. Describe how you set up your classroom instructionally? For example, how do you use educational technology, differentiated instruction, etc.?
10. What guides your decision to use one way of teaching over another on a particular day? * *delivering lesson material using the methods described in #s 8 & 9 above
11. Tell me about the challenges of using educational technology to differentiate instruction to lessen a student's math anxiety.
12. Describe how you have tried to overcome these challenges.

Appendix B

Survey Questions

1. Have you used technology in any of your math classes during this school year? If yes, describe in what format (teacher led instruction, differentiated stations, independent practice, etc.) you typically use technology.

2. Typically, how often in the class period do you currently have your students complete in-class assignments and activities with others? Would you say, in a school week: not at all, 1 – 2 times per week, 3 – 4 times per week or every day?

3. Typically, how often in the class period do you currently have your students complete in-class assignments and activities with others that are in an on-line format? Would you say, in a school week: not at all, 1 – 2 times per week, 3 – 4 times per week or every day?

4. Typically, when you currently have the students in your class complete in-class assignments and activities on-line, about how much of the time do students choose or are assigned by you?

5. What type of technology software and websites are you using to teach math? How long have you used this software?

6. What math concepts are best supported by using technological resources? Why?

7. What is the most effective teaching strategy of lessening math anxiety in your students when using online resources?

8. If someone asked you, what being ‘good’ in math means, what would you say?

9. What topics in Math do you think are more challenging to teach than others and why?

10. If you asked your students if comparing to other subjects, how good are you at math, what do you think that they would say?

11. If you asked your students what being good in math means, what would they say?

12. How interested do you think your students are in Math compared to other subjects?

13. What topics in Math do you think students communicate are more challenging than others and why?

14. How many school years, including this year, have you used technology for teaching math in any of your classes? ________ years

15. How many years have you been a teacher? _______ years

16. How many school years, including this year, have you been teaching math at this school? _______ years

17. How many school years, including this year, have you been teaching math in this grade? _______ years