Math is Like a Spider:
Alleviating Math Anxiety in the Pre-Service Teacher

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Abstract

Math anxiety, mental and/or physical unease associated with the performance of mathematics, has far-reaching implications radiating from personal struggle to the realms of national economic strength (Chernoff & Stone, 2014; Richards, 2014; Tobias, 1993; Sells, 1973). This qualitative case study examined the experiences of four educators who have overcome this anxiety. The study used a semi-structured interview to inquire about the process shift from anxiety to confidence and how this experience could lead to changes in pre-service teacher education as well as the role of cross-curricular instruction on anxiety levels. The findings of this research are located in 3 themes: (1) Teacher Preparation for math instruction, (2) Pedagogical Approaches, and (3) Benefits of Cross-Curricular Planning. The findings reveal the importance of math anxious teachers developing deep conceptual knowledge, re-teaching themselves the subject and using manipulatives to help gain understanding. The study also finds that educators perceive a positive correlation between cross-curricular instruction and the lowering of anxiety within math anxious students. Given these findings that study urges anxious teachers towards the practices listed to gain confidence and teacher educators to explicitly teach concepts, anxiety reducing pedagogy and the application of cross-curricular integration.

Keywords: Math Anxiety, Pre-Service Teachers, Math-Art, Qualitative Study, Cross-Curricular Lessons
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Chapter 1: Introduction

In a mathematics class for Pre-Service Teachers, an instructor enquired, “Which image would you use as a visual metaphor to represent mathematics?” One student selected the image of the spider, pointing to the intricate web designs of the insect’s craft and commenting on the beauty of its construction, comparing it to the intricacies of math. Another student also selected the spider, presenting a vastly different rational. “Math is like a spider, it traps its prey, incapacitates it and then feasts on its blood!”

1.0 Research context

There are some subjects for which there are few in the middle ground; I would argue that math is one such subject. Ken Robinson (2006), in his much-lauded TED Talk, notes that everyone seems to have an opinion on education. In recent years there has been much debate and study surrounding math education, with the discussion shifting fluidly between the studies of university professors, the action research of teachers, the headlines of newspapers and, offhand conversations amongst family and friends.

1.1 Research problem

Amid the dialogue there appears to be a prevalent cultural story that mathematical ability is innate, a gift, a divide fashioned by one’s very DNA between those who ‘get it’ and those who do not (Mighton, 2007). Canadian math scores on international tests, such as the Program for International Student Assessment (PISA) administered by the Organization for Economic Cooperation and Development (OECD), continue to decline (Richards, 2014). These declines have led policy think-tanks such as the C.D Howe Institute to forecast concerning economic predicaments for Canada in the years to come; Richards (2012) writes, “There is solid evidence that economic growth in any country is a function of the academic abilities of the country’s
workers” (p.2). With a view to these troubling indicators, the Federal Government has undertaken initiatives to bolster the number of students opting to pursue the fields of science, technology, engineering, and mathematics, known collectively as STEM (Government of Canada, 2013). In Ontario, the Provincial Government has introduced reforms such as the subsidizing of professional development math courses for teachers, in an effort to bring about much needed change (Rushowy, 2014).

Amidst the dire predictions and disappointing international results, research continues on a key factor influencing mathematical achievement, math anxiety. Math anxiety can be described as “feelings of tension … that interfere with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations” (Richardson & Suinn, 1972, p.551). Though various study authors highlight different facets of the phenomenon in their definition, commonalities include sentiments of insecurity, apprehension, tension and an avoidance of math related activities (Beilock & Willingham, 2014; Boyd et al., 2006; Bursal & Paznokas, 2006; Harper & Daane, 1998). Harper and Daane (1998) showed a significant portion of math anxious people trace the origin of their anxiety to their school years. Poor experiences of mathematics in elementary school have been linked to a lowering of one’s perceived self-efficacy in the subject and this in turn escalates as the student progress through school (Harper & Daane, 1998; Boyd et al., 2006).

Within the classroom, math anxious teachers have been shown to teach differently than their math confident peers; focusing their instruction on whole-class lectures on skills rather than underlying math concepts. These teachers are more likely to assign individual seat work in place of small group work, games, or problem-solving activities (Aslan, 2013). It has even been stated that math anxious teachers are “carriers of math anxiety” (Sloan, 2010). Yet even before the
classroom, further upstream, math anxiety, effects education. Within teacher training programs the levels of math anxiety should be noted, Hembree’s (1990) meta-analysis of a number of studies found that amongst college majors, Pre-Service elementary Teachers (PSTs, also referred to as Teacher Candidates) had the highest instances of math anxiety. It is crucial to train effective, engaged elementary teachers who teach mathematics well, to help stem the tide of decreasing math competence, change the cultural dialogue, and provide Canada with the math competent workforce required to thrive.

It should be noted that as early as the 1950s there have been studies on teacher attitudes and mathematics education (Harper & Daane, 1998). Since these initial research forays there have been a number of studies focusing specifically on math anxiety, among the most influential the work of Richardson and Suinn (1972) who define math anxiety and provide examples for the usage of the quantitative tool, the Mathematics Anxiety Rating Scale (MARS). Further studies examined the attitudes of PSTs towards mathematics (Aslan, 2013; Boyd et al., 2006; Bursal & Paznokas, 2006). Research has also queried the efficacy of mathematics preparation courses for PSTs in relation to math anxiety (Gierdien, 2012; Harper & Daane, 1998; Milford, Hellaby, & Strang 2013; Tooke & Lindstrom, 1998). Yet there is an exceptionally small body of research that has addressed the potential links existing between mathematics and cross-curricular lesson planning, such as math-art lessons, as it pertains to the training of PSTs (Uğurel, Tuncer, & Toprak, 2013). There is certainly a need to learn more to combat the imminent consequences of math anxiety in teacher education programs.
1.2 Research purpose

The purpose of this qualitative case study was to access the lived experience of seasoned teachers in relation to math anxiety. The study explored their initial struggles with math, as well as their growing comfort with math instruction. The study then looked to glean their thoughts on PST math education and the role cross-curricular education in their classrooms.

1.3 Research questions

The main question explored:

- How do experienced teachers transition from a history of math anxiety to increased confidence with mathematics?

Under this key question the study inquired:

- What changes to teacher training, would experienced teachers recommend to promote reduction of math anxiety among PSTs?
- How have experienced teachers used cross-disciplinary approaches to math instruction and is there a perceived link to math anxiety reduction?

1.4 Research methods

This qualitative study used an instrumental case study approach (Stake, 1995, p.3). The case study method allows one to thoroughly investigate events, phenomena, issues and perspectives at a micro level (Lapan, Quartaroli, & Riemer, 2011). This approach creates an opportunity for “a holistic and lifelike description that … readers normally encounter in their experiencing of the world, rather than being mere symbolic abstractions” (Lincoln & Guba, 1985, p.359). In his influential qualitative research book, Stake (1978), discusses the ability of the case study approach to construct “harmony with the reader’s experience and thus to that person a natural basis for generalization” (1978, p. 5). The intent of this case study is to act as an
instrument to more deeply understand the phenomenon of math anxiety and how it can be effectively reduced within the PST population. The study interviewed veteran teachers to better understand their perspectives on this issue through their lived experience and expertise; through these discussions and insights themes have been gleaned. These themes provide a natural basis for the type of personal generalization of which Stake speaks (1978).

1.5 Positionality

As I progressed through the teacher education program at the Ontario Institute for Studies in Education (OISE), I became aware of best practices, current research and key discussion topics that affect the world of education. It is into this atmosphere that the research paper finds its roots. Chief among influences, have been my experiences as a student in the Ontario public school system. I have suffered with math anxiety throughout my school career. Reflecting on this, I can personally attest that math anxiety often begins in elementary school. I have found math anxiety to be a pervasive and crippling concern, as it builds on itself from year to year. What began as insecure concepts attainment in my early years led to poor marks, which in turn negatively affected my self-efficacy, which can be thought of as “confidence in [one’s] competence” (Jameson, 2009, p.48). The self-efficacy work of Bandura in the 1990s and the later work of Warwick (2008) informs this study as it aligns to my own experience of this anxiety. My lowered self-efficacy, created by minimal success, comparison with peers, feedback of teachers, led to a gradual shying away from the subject (Warwick, 2008). I began to expect to do poorly regardless of my considerable efforts, and my expectations became realized time and again. The old adage ‘an ounce of prevention is worth a pound of cure’, rings true. Rather than remedy the effects of math anxiety, it is preferable to teach elementary students in such a manner as to minimize or eliminate feelings of anxiety associated with math. Teachers are key disseminators
of mathematical knowledge, and so must become competent and comfortable with the subject.

As a graphic designer, I am interested in the intersection of design and art with math. Could math be made more accessible, anxiety reduced, and competency increased through the deliberate intersecting of these two disparate fields? It is these experiences and questions from which I designed this study.

1.6 Overview of the study

This study contains five chapters the Introduction, Literature Review, Methodology, Findings and lastly Discussion. In chapter two of this study the reader will find a review of the literature surrounding math anxiety, education, teachers and teacher education math courses, from which this study finds its origin. Chapter three provides the methodology that has been undertaken to gather the data, needed to explore the research questions. This chapter also introduces the reader to the study participants through whom will came the knowledge I have detailed, explored, and analyzed. Chapter four contains the discussion of the research findings, exploring the themes gained from the participants as well as the links to the seminal and current research in the field of math anxiety. Chapter five concludes the study presenting suggested practices in light of the findings and proposes new research explorations for the future as well as cites the limitations of this work. These five chapters will be followed by the reference list, the participant consent form and the interview protocol.
Chapter 2: Literature Review

“28.3495 grams of prevention in elementary school are worth .45359 kilograms of cure in the high school or college remedial classroom.” (Martinez, 1987, p.1)

Mathematics is ubiquitous; it is knowledge that one must use to successfully navigate the world, from shopping at the supermarket, to calculating a store discount, to figuring out the amount of flooring required for a given room. Yet for some math causes intense negative sensations and emotions (Lyons & Beilock, 2012). This literature review has drawn on research studies, popular books, as well as first-hand accounts from math anxiety sufferers to examine different facets of this phenomenon. This review also introduces the contribution this paper will look to make to this growing and significant field of study.

2.0 What is Math Anxiety?

Richardson and Suinn (1972), pioneers in the field and creators of the Math Anxiety Rating Scale (MARS), describe math anxiety as “a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (p. 551). Ashcraft (2002), another key researcher, describes a negative attitude and lack of confidence associated with performing mathematical processes. A further definition focuses on the performance aspect that is often associated with mathematics; which can be particularly useful when thinking about this anxiety within the classroom. Citing the early work of Cemen, Trujillo and Hadfield (1999) write that math anxiety is, “a state of discomfort that occurs in response to situations involving mathematical tasks that are perceived as threatening to self-esteem” (p.219). Tobias (1993), a leading popular author in the field of math anxiety, describes the phenomena as having the right ‘hardware’ (prior knowledge, memory, strategies, formulas, etc.) yet being interrupted by the debilitating ‘static’
of negative emotions. In this moment, she writes, one’s ‘hardware’ becomes inadequate as problem-solving pathways are blocked, self-confidence depletes and finally “you can’t think because you have stopped working” (1993, p.7). For the purposes of this research, math anxiety, also known as, math fear, math phobia or math panic, will use a broad definition: math anxiety is mental and/or physical unease associated with the performance of mathematics.

2.1 Sources of Math Anxiety

Studies continue to examine factors involved in this phenomenon. These factors can be understood as having an external as well as an internal root.

2.1.0 Internal Factors: Cognition. Among the factors studied in the field, the role of cognition and behavior are significant topics. Specifically working memory is widely studied in math anxiety research. “The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning and reasoning” (Baddley, 1992, p.1). A useful way to think about working memory is as a “mental scratch pad” (Beilock & Willingham, 2014, p. 3). Processing Efficiency Theory was developed by Eysenck and Calvo (1992), which proposed that cognitive manifestations of anxiety, such as negative thoughts and concerns, act deleteriously on one’s working memory, co-opting its limited capacity, when attempting a cognitive task. Math anxiety has been shown to disrupt cognitive processes, including working memory, which is required to solve math problems (Ashcraft, 2002, p.181). The deleterious effects on math performance have been demonstrated by Ramirez et al. (2013) in a study with children as young as six. These two interrelated pieces, working memory and the Processing Efficiency Theory can be seen clearly in the Tobias (1992) popular culture metaphor of ‘hardware’ malfunctioning due to a barrage of anxiety laden thoughts and negative emotions. Hembree (1990), who conducted
one of the most extensive meta-analyses of math anxiety, found that in large part math anxiety is a learned condition, which is behavioral in nature (p.45). These findings illustrate the need to examine the external factors that lead to this ‘learning’ of anxiety.

2.1.1 External Factors: Culture. We exist and function within culture and so it is in this milieu that our attitudes, aptitudes and deficits (both perceived and actual) are formed. In 1993, Tobias wrote, “American culture is somewhat ambivalent about mathematicians as role models” (p.5). Though this observation may seem trivial, consider that those whom culture selects to tell stories about are often whom we choose to model. Another prevalent factor within culture is the ‘math gene’ argument, the notion that some individuals have a “head for math” and others simply do not (Jameson, 2009; Mighton 2007; Tobias, 1993; Zaslavsky, 1995). There is social acceptance in stating one is simply “not a numbers person”, where there is less cultural comfort in owning to an inability to read (Beilock & Willingham, 2014). When interviewed for the book Overcoming Math Anxiety, some respondents said that as a child they were led to reason that they could be competent in numbers or words but not both (Tobias, 1993). There is, within culture, a false divide that has affected the math landscape within and without the family and the classroom.

2.1.2 External Factors: Family. It widely understood that one’s family of origin has significant bearing on an individual. Giest (2010), a prolific researcher in the field, writes that individuals originating from families with a low socio-economic base are disadvantaged in mathematics as their parents often have not had the education to support them and may themselves not have a positive outlook toward the subject. Popular author Claudia Zaslavsky (1995), found that parents who themselves avoid math are often modelled by their children. Negative or dismissive remarks about a child’s ability, such as, ‘you’re just not a numbers
person, it’s okay I wasn’t either’, oft weigh heavily on the mathematical future of a child greatly affecting their perceived self-efficacy and values concerning the subject (Hembree, 1990; Zaslavsky, 1995, Warwick, 2008). Self-efficacy can be thought of as one’s “confidence in his or her competence”, in the case of math anxiety it is the feeling that one can succeed at a mathematical task (Jameson, 2009, p.48). Parental expectations often tempered by ethnicity, culture and differing gender biases, and these also factor into early experiences and sentiments surrounding mathematics and can lead to math anxiety (Tobias, 1993; Zaslavsky, 1995). The role of gender in beliefs and conversations about mathematics has long been “math is for boys”; that the gender has an innate superiority where this is subject is concerned (Tobias, 1994; Zaslavsky, 1995). In one study conducted by Parsons et al. (1982), parents of girls were shown to believe that their child had to exert more effort to do well in mathematics. The study went on to show children’s self-efficacy was influenced more by their parents’ estimation of their abilities than their own past performance (Parsons et al., 1982). These beliefs are not without consequence to educational systems.

2.1.3 External Factors: School. Perhaps most troubling of the external causations is one’s school experience. It is within school environments that mathematics is primarily actively taught; yet it also ranks highly in the memories of those suffering with math anxiety as being the beginning of their struggles (Aslan, 2013; Hembree, 1990; Jameson, 2010; Zaslavsky, 1995). In their examination of math anxiety research, Chernoff and Stone (2014), citing Stodolsky, write that math anxiety is caused by how the student learns math. Therefore, the question becomes how are students learning, or not learning, mathematics in school?

There are numerous overt and covert actions of teachers, that have been found to promote math anxiety including timed tests and responses; a focus on right answers; forcing students to
write on the board; using handouts to teach math concepts; lack of debate or discussion; negative or hostile responses to questions, competition and speed-based answers in place of understanding (Ashcraft, 2002; Geist, 2010; Jackson & Leffingwell, 1999; Tobias 1993; Zaslavsky, 1995). Teachers can also perpetuate the cultural story that math ability is inborn (Tobias, 1993). Lastly, the attitude with which the teacher approaches mathematics can be an influencer. A teacher who appears to dislike the subject, will also greatly impact the outlook of students (Jackson & Leffingwell, 1999; Tobias, 1987).

2.2 Consequences to students

There are many personal, educational and professional consequences of math anxiety. Among the unpleasant physical symptoms are a rise in heart rate, trembling hands, sweating, tears, unease, stomach disorders, confusion, nervous laughter, nausea and even panic (Ashcraft, 2002; Chernoff & Stone, 2014; Furner & Burman, 2004). Perhaps most startling is the study conducted by Lyons and Beilock (2012) which found that, “highly math-anxious individuals show neural responses in regions known to be involved in experiencing pain … in anticipation of an upcoming math task” (p.1). Given the potential severity of a math anxious person’s response to the subject it is clear that math competence scores are lowered (Hembree, 1990). Ashcraft (2002) found, “When the anxiety was relieved, a truer picture of their competence emerged” (p.183). All of these negative responses in the math anxious, “…ultimately undercuts their math competence and forecloses important career paths” (Ashcraft, 2002, p.182). Perhaps unsurprisingly the moderate to highly math anxious individual is likely to avoid mathematics, in the classroom, when selecting courses, choosing activities and unfortunately career paths. 1970s thinker Sells, argued that mathematics is a “critical filter”; separating the quantitatively literate from those who are not, thereby blocking the later from attaining well-paying careers paths
(1973, p.1). As technology continues to grow as the medium through which economic strength is achieved, those who cannot compete, as they do not have the necessary skills, may well be left behind. Aside from limits to educational and career paths, math anxiety interferes with everyday life pursuits (Chernoff & Stone, 2014). Researchers have outlined the typical cycle of anxiety and its effects on the math anxious. The majority avoid the subject, lack self-confidence and motivation, hold negative attitudes towards mathematics and their self-efficacy, go on to receive lower grades, which in turn leads again to an avoidance of math electives (Ashcraft, 2002; Chernoff & Stone, 2014). The self-concept regarding one’s intelligence can be severely affected by the condition as eloquently stated by former sufferer, who became a university math educator, Mary Jo Cittadino:

I became so terrified that I was on the verge of withdrawing from college. I felt I would never succeed. The fear caused mental paralysis. The more I attempted to overcome the fear, the more “blocked” I became. The more “blocked,” the more futile the attempt. I dreaded the exams. I became hysterical and then self-loathing set in; “I was a failure, and I failed because I was stupid” (Zaslavsky, 1995, p.8)

2.3 Consequences of math anxious teachers

The self-efficacy and comfort level of math teachers does affect the classroom, be it through lessons or more subtly through oral or emotional responses. Researchers are not unanimous regarding the transmittal of math anxiety from teacher to student, though the majority agree that teacher outlook and approach significantly impact students of mathematics (Aslan, 2013; Beilock et al. cited by Beilock & Willingham, 2014; Bulmahn & Young, 1982; Bush, 1989; Boyd et al., 2006; Chernoff & Stone, 2014; Martinez, 1987). Researchers have shown there does appear to be a traditional style of teaching, with an emphasis on seatwork, drills,
memorizing formula, emphasis on the right answer and lectures, among math anxious teachers (Aslan, 2013; Bush, 1989; Harper & Daane, 1998). Bulmahn and Young (1982) postulate that this maybe the case as teachers with math anxiety may wish to limit factors that could lead to conceptual conversation they feel maybe out of their depth. Meta-analysis of 151 math anxiety studies found that college students taking math for elementary teaching had the highest rating of math anxiety, when administered the quantitative instrument of the Math Anxiety Rating Scale (MARS) (Hembree, 1990). A recent study conducted by Boyd et al., showed that elementary PSTs recalled difficulties with math in elementary school, they therefore suggest that this may raise their level of anxiety as they prepare to be elementary teachers (2014).

2.4 Alleviating math anxiety in the classroom

To limit the transmittal of math anxiety, Harper and Daane advocate for teachers to become self-aware of their level of math anxiety (1998). Chernoff and Stone write that reflective teaching on one’s practice can lead to a coming to terms with and navigating past one’s own negative emotions towards mathematics (2014). Many researchers have examined the causes of math anxiety, and much work has also been done to suggest and test means for the reduction if not its alleviation. Some of the recommendations include: the use of technology, fewer drills, more math manipulatives, class discussions, practical ‘real life’ math problems, teaching estimation, creating a supportive class environment, small group and self-paced work, and ensuring fundamental numeracy skills (Beilock & Willingham; 2014; Furner, 1996 as cited by Furner & Berman, 2003; Tobias 1993; Tooke & Lindstrom, 2014). One novel recommendation from the research is to have students journal their thoughts regarding an upcoming math event (such as a test) this allows students space to begin to change their outlook and unburdens their
mind allowing for the more working memory to be made available (Park, Beilock, and Gunderson, 2014).

2.5 Math courses and alleviating of math anxiety

There is variance in the literature regarding the efficacy of math courses in the reduction of anxiety in teacher training (Boyd et al., 2014; Gresham, 2007; Tooke & Lindstrom, 2014). Among the math courses that some researchers do detect some reductions are those in which PSTs are required to venture out of class to practice teach math lessons, and courses which focused on math pedagogy (Tooke & Lindstrom, 2014). Gresham’s mix-methods study involving PSTs taking a math course fashioned from the work of Bruner (a 1960s mathematics education theorist), which focused on manipulatives, small group work, literature based activities and math lesson practice did result in a reduction of anxiety (2007). There is research to suggest that a layered approach involving, math pedagogy, content and behaviour-cognitive interventions could yield positive results. Researchers, Beilock and Lyons, write “… educational interventions emphasizing control of negative emotional responses to math stimuli (rather than merely additional math training) will be most effective in revealing a population of mathematically competent individuals…” (2011, p.1). Hembree’s meta-analysis showed that group discussions designed to remove the negative emotion present in the math anxious were not effective (1990). The most successful of the cognitive approaches to math anxiety treatment, found Hembree, was a ‘systematic desensitization’, removing the feelings of dread and fear associated with math, confidence building activities, and anxiety limitation techniques (1990).

2.6 Noting a gap

Increasingly connections are being formed linking math and art in an educational context, yet this researcher could find only one journal article that spoke on a course designed to help
Teacher Candidates build a Math-Art Practice. Uğurel, Tuncer, & Toprak’s qualitative case study investigates the lesson plans of 43 Teacher Candidates, taking an elective course, “Mathematics and Art” (2013). This article is of great interest, as this research paper seeks to ask questions about math anxiety reduction effective techniques in light of cross-curricular activities and lessons. There has been some coverage highlighting specific educators with a Mathematics and Art (M-A) practice, featured in the news media (Kennedy, 1994; Seidman, 2012). Seidman, writes about a math fair held to promote math through art, created by a mathematics professor and teacher educator and run by pre-service teachers. In another report, the M-A practice of teacher Frances Tucker, is highlighted. Another article written by teacher, Tim Granger, outlines his combination of best practices found in the research with an M-A focus (2000). This paper will seek to add to the bridge of qualitative study writings connecting the silos of math, math anxiety, cross-curricular lessons and teacher education.

While much has been studied, written, and analyzed regarding this crucial field, the research body can still be strengthened. Math anxiety, as this literature review has shown, is a significant challenge for individuals, communities, economies and countries. Teachers play a significant role, either supporting students towards a healthy relationship and knowledge of mathematics or, perhaps more frequently, leading to a fear and avoidance of this necessary subject. Faculties of Education are in the position to stem the tide of math anxious teachers, dispel false cultural dialogues and remedy the missteps of past educators. Math anxiety in an individual is cyclical in nature, and I would argue given the literature, that math anxiety is cyclical in a culture and educational system. New approaches, consistent with the latest research can be the change that is required to shift the cultural dialogue and open previously shut pathways for students. This study has examined:
• How do experienced teachers transition from a history of math anxiety to increased confidence with mathematics?

• What changes to teacher training, would experienced teachers recommend to promote reduction of math anxiety among PSTs?

• How have experienced teachers used cross-disciplinary approaches to math instruction and is there a perceived link to math anxiety reduction?
Chapter 3: Methodology

3.0 Introduction

In this chapter the present study discusses the methodology used. Examining the key question, how do experienced teachers transition from a history of math anxiety to increased confidence with mathematics?

This chapter begins with a discussion about qualitative research, addressing in particular the case study research approach and relevance to this study. This chapter also states and explores the research instrument, semi-structured interviews, used for Data Collection and provides the procedures through which the data has been analyzed. This will be followed by a section outlining the sampling criteria and rationale for participants selected in this study. Following this section the present study outlines the ethical review procedures including such areas as confidentiality and consent. The chapter then addresses methodological limitations and strengths, and concludes with an overview and an outline of the succeeding chapter, focused on the study findings.

3.1 Approach and procedures

There has long since been a history of the usage of qualitative research in the field of education. Broadly, qualitative research can be thought of as a, “way of knowing in which a researcher gathers, organizes, and interprets information obtained from humans using his or her eyes and ears as filters” (Lichtman, 2013, p.7). Qualitative research, when compared to the arguably better known, quantitative research, is interested in the ‘whys?’ and ‘hows?’ of human experience (Lichtman, 2013; Yin, 1984). Given the present study’s aim to examine the lived experience of in-service teachers, it fitting to use the qualitative approach. Within qualitative research there exist a myriad of research strategies, this paper uses the Case Study Approach.
Case Study research can be understood as “an empirical inquiry” concerned with investigating “contemporary phenomenon within its real-life context” (Yin, 1984). Case study method was selected due to my desire to deeply explore how experienced teachers have lessened their anxiety to teach the subject effectively. I questioned their thoughts on teacher education in light of this troubling phenomenon and the links they have made to other curriculum strands they found had reduced math anxiety. Case Studies exist within a “bounded instance”, a series of parameters that span then particular case in question, for this study I partnered with experienced teachers, working in the public school system within the province of Ontario.

3.2 Instruments of Data Collection

Education is personal, so is the way in which we make sense of our world and experiences in it, as John Berger says “The way we see things is affected by what we know or what we believe” (Lichtman, 2013). The present study explored the first hand voices of participants in four semi-structured (or focused) interviews. In the semi-structured interview, the researcher creates a series of “open-ended” questions posed in a “conversational manner” (Yin, 1984). This instrument was selected because it provided the focus required to hone in on the topic of inquiry, whilst still allowing for the “respondent to propose his or her own insights into certain occurrences … [used as a] basis for further inquiry” (Yin, 1984). This method of data collection, was also selected because participants, “actions and words are used to determine what is important”, and this instrument increases the likelihood that data novel to myself could be revealed (Coles, McGrath, 2010).

The semi-structured interview protocol began with questions that helped establish rapport and the personal educational math history of each respondent; the proceeding questions followed to hone in on addressing the first two study questions regarding teacher education, and current
math experiences, followed by questions that focused on the cross-disciplinary applications of math education. Questions posed to participants included, “When would you say you begun to experience math anxiety (MA)? What were your thoughts/feelings regarding teaching mathematics as a new teacher? For a complete listing of questions please see Appendix B.

3.3 Participants

Undoubtedly the chief resource in any qualitative case study are the participants, it is they who provide the data, shed light on the lived experiences central to the research question and provide further avenues of thought and inquiry. Subsequent paragraph outline the sampling criteria, procedures and provide a brief biography of each of the participant contributors of this study.

3.3.0 Sampling criteria. In qualitative research, sampling refers to the process of selecting individuals, who hold key understandings on the issues in question (Gay, Mills, Airasian, 2012). These individuals can be thought of as expert collaborators. For this study I interviewed experienced teachers, who self-identified as having bouts of mathematics anxiety in the past, and who had used cross-curricular approaches to combat this anxiety.

Experienced educators. Time brings knowledge and the opportunity to harness the two, to form wisdom. In this study I sought out the wisdom of teachers with 10 years or more of teaching experience. I sampled from this cohort due to their knowledge acquired over the school years. These teachers have had the opportunity to develop their craft, formulate beliefs on the field.

History of math anxiety. In this study it was crucial to hear the perspectives of those who have experienced math anxiety first-hand. Personal experience can lead to empathy and if harnessed productively can inform the way in which one responds to others experiencing the
same phenomenon. Educators who themselves had struggled with mathematics in their education, and had found strategies to counter-act and overcome the anxiety, are a wealth of potential knowledge.

**Cross-Curricular.** The final sampling criteria was important to help further math anxiety research through my study, by examining the links educators have made between mathematics and other curriculum strands. Of particular interest was the growing work of Math-Art instruction. Their insights and practical knowledge can help establish, practical ways this type of teaching is impacting math education in Ontario.

3.3.1 **Sampling procedures.** As a Pre-Service Teacher, I have not yet developed an extensive network of contacts within the educational field; this does bare on the way in which I proceed with sampling. I have used convenience and chain sampling to locate participants. Convenience sampling is sampling from those who are willing to be participants (Gay, Mills, & Airasian, 2012). Chain sampling works by using participants as informants, who provide access to other potential participants, who meet the sampling criteria. (Lichtman, 2013). I requested recommendations for possible participants from teachers in the field, and colleagues at the Ontario Institute of Studies in Education (OISE).

3.3.2 **Participant biographies.** As stated a qualitative study is formed by the dialogue between study author and participant and then further hone and meaning extracted by the author. Each of the educators interviewed provided key insights into this phenomena and a brief introduction of their educational history follows. Please note that each participant was given a pseudonym, in accordance with the ethical review process which is outlined below.

**Beatrice,** has been an educator for 36 years, teaching primary, junior and intermediate grades and working as a school administrator. She is currently a principal in a school in the
Greater Toronto Area (GTA). Beatrice cites her anxiety as beginning during her intermediate grade school education. She was very candid during the interview, suggesting many possible reforms to the math pedagogy within Faculties of Education.

Frank, is a grade five teacher, who completed his teacher education outside of Canada. He has a wide array of educational experiences including teaching summer school and afterschool programs but the majority of his experience has been teaching kindergarten. He recalled a favourable math experience that became overwhelming as he entered high school. During the interview Frank provided a useful point of reference due to his experience of teacher education in another British Commonwealth.

Pamela, has been a teacher for 20 years, currently Pamela is a grade four teacher working in the GTA. She was a strong student academically but found her struggle with math began in the intermediate grades. Her use of practical cross-curricular lessons was of particular benefit to the inquiries of the study.

Tara, has been a teacher for 20 years. She currently works in a Toronto school where she teaches grade two. Her teaching experience is vast, teaching kindergarten through to the now defunct grade 13. Tara cites her struggles with mathematics beginning early on in her education, with numerous anxiety producing situations. With a strong arts background Tara was able to shed light on her M-A practise and its benefits to her students.

3.4 Data analysis

Following each of the interviews, I carefully transcribed each audio file, then began the process of Data Analysis. I began the Data Analysis by highlighting each transcript in search of the significant comments, ideas and issues raised by the participants (Coles. A, McGrath, 2010; Lichtman, 2013). These highlights were the system of meaning, through which I initially coded
the data. Next I searched for common micro and macro themes and links between the interviews and literature (Coles. A, McGrath, 2010). I developed categories from the codes, grouping like ideas and concepts, to create lists and sublists (Lichtman, 2013, p.252-254). I went on to further organize these categories into the 3 concepts, or themes, which have become my research findings (Lichtman, 2013). Throughout the process I often went back to the initial interview transcripts intent on distilling the data well and sieving the knowledge to answer the research questions.

3.5 Ethical review procedures

It is crucial in any study involving human participants to carefully weigh the ethical concerns. I adhered to the ethical review process of the Master of Teaching Program, at OISE. In this particular research study, there are few and remote risks to the teacher participants; these include confidentiality concerns and informed consent. To address the issue of informed consent, I provided a Consent Letter (Appendix A) outlining the study, ethical considerations, the expectations of the study, and providing a ‘right to withdraw’ clause. To address the concerns surrounding confidentiality I stored recordings of the interviews on a password protected device, with the commitment to delete the recording in 5 years time, from the study publication date. To protect the participants further I assigned pseudonyms to the participants and removed key identifying information before presenting it.

3.6 Methodological limitations and strengths

Within even the most advanced and exhaustive studies, it can be argued that there exists methodological limitations. This qualitative study, though novel in the subject matter, and therefore an addition to the literature, does have some significant methodological limits. The value of a qualitative study does not necessarily lie in the wide generalizability of the findings,
but in the validating of the individual experience. This research study validated the lived experience of educators, and provided an opportunity for a formalized reflection on their process. Though the study did validate the experience of teachers, it was narrow in scope, interviewing a small number of educators. The inability within the constraints of this study process to hear from Pre-Service Teachers firsthand, was another area that could have added to the richness of the research. However the voice of the experience teachers, who were able to provide their thoughts on their time in teacher education programs and their experience as elementary educators, was invaluable in addressing this study’s questions.

3.7 Overview of chapter 3 and preview of chapter 4

This chapter provided an outline of the methodology used in the formation of this study, including the research approach and procedures, the Participant Sampling Criteria and Biographies, the Method of Data Analysis, the Ethical Review Procedures, as well as the Methodological Limitations and Strengths of the study. In the succeeding chapter, the present study has analyzed the findings garnered.
Chapter 4: Findings

4.0 Introduction

“I love teaching fractions and I hated it as a kid!” (Teacher Participant)

This chapter outlines and discusses the findings garnered from the teacher participants in light of the literature. Throughout I provided thoughts on the significance of the emergent themes found. The teachers were a wealth of knowledge and their lived experiences provided insights into how they transitioned from a history of math anxiety to increased confidence with mathematics. The teachers also shed light on possible reforms to pre-service teacher education programs and the use and perceived benefits of cross-curricular lesson planning. From the semi-structured interviews, there emerged a number of themes, (1) Teacher preparation for math instruction, (2) Pedagogical Approaches, and (3) Benefits of cross-curricular lesson planning. In this chapter I have addressed each of the themes, bringing in the participants own voices and pointing to the convergences and divergences with the research literature, and the significance of the two data sets.

4.1 Teacher preparation

In Hembree’s (1990) involved meta-analysis of math anxiety levels among college majors, pre-service elementary teachers were shown to have the highest instances of math anxiety. The teachers I interviewed had a number of preparation techniques, resources and experiences that helped them move to a place of comfort with math instruction. Among the variety of preparations and instructional strategies there existed some that fell within the realm of the pre-service education program and a great number that took place long after they had left their perspective Faculties of Education.
4.1.0 Within teacher education math courses. The teacher participants I interviewed had a variety of experiences and outlooks on mathematics before, upon, and graduating from their teacher education courses.

During the interviews I enquired about each educators’ experience in their faculty’s math course. Three of the four participants had a mandatory math pedagogical course, the fourth recalled that the program had a significant literacy focus, but math was seldom explicitly taught. When asked to describe the courses, the three educators were able to recall professor’s approach to the subject as well as some specific instructional strategies. Tara and Frank both commented that their instructors were in their words, “…quite passionate about math”, and “…excited to teach it to us.” Tara commented that following a grade school career in which she, “hated” math, she “… actually enjoyed the classes.” This point is not without note, researchers such as Jackson and Leffingwell (1999) and math writers such as Tobias (1987), point to the impact that a teacher’s attitude toward mathematics can bear on a student. It would seem that regardless of age, enthusiasm in an instructor is contagious and beneficial to one’s own perception of mathematics.

In regards to instructional strategies and the pedagogical underpinnings of the classes, all participants spoke about the use of manipulatives, emphasis on group work, and the focus on making math “relatable.” For some, the math methods course was their first introduction to manipulatives, and it was part of their turning point in their sentiments surrounding the subject. Group work was the other key feature of the classes, “…a lot of collaborating, so we would each have different roles in the group, and so we would … bring forth our best talents to work on a given task,” recalled Frank. This aligns with the work of Trujillo & Hadfield (1999) which outlines the positive outcomes of both group work and the use of manipulatives in teacher
education math method courses. One participant, Pamela, spoke about her professor lecturing on math anxiety, over two decades ago and his assertion that math needed to be relatable and practical to life. Only one participant spoke of the instructional inclusion of technologies such as Ipads and computers. All of these instructional strategies correlated to a number of math anxiety reduction research findings (Beilock & Willingham, 2014; Furner & Berman, 2003; Tobias 1993; Tooke & Lindstrom, 2014; Trujillio & Hadfield, 1999). None of the participants mentioned any cognitive behavioural strategies, such as journaling, in their courses to reduce math anxiety, nor specifically practice teaching math lessons, which were other strategies studied in the literature (Park, Beilock, and Gunderson, 2014). Upon graduating these participants felt a range of levels of confidence as they stepped from lecture hall into the classroom.

One sentiment that did carry across all the interviews was, whether limited, perspective altering, or empowering the teacher education math courses were, they were only the start of their math preparation. These courses provided a base, a sample of what they found was required to teach in the classroom and were simply part of their journey towards the alleviation of math anxiety. Pamela stated, “…whatever I did in that pre-service math course it was a foundation, and it was interesting to learn about.” Yet she went on to say, with a smile in light of her experience teaching grade one as a junior/intermediate trained novice teacher, “It’s like anything you are going to learn what you need to and then you are going to be thrown into the fire and you’re going have to figure out what you’re going to need to adapt to.”

4.1.1 Succeeding teacher education math courses. Each participant placed different weight on the role of Teacher Education in their math anxiety alleviation, yet all stressed the role of preparation once in the classroom. Three of the participants specifically spoke about content preparation they did before lesson delivery. Beatrice phrased it beautifully, when she recalled, “I
was re-teaching myself as I went into teach.” Driving this “re-teaching” effort, was a desire to, “understand it better,” remembers Tara. For these educators, “re-teaching” involved interacting with the content before entering the classroom usually in the evening, or altering the way they taught math lessons, trying a variety of instructional strategies and activities with their students. This re-teaching effort aligns with the work of Young-Leveridge (2010), who reported that some pre-service teachers, who themselves had poor experiences with math were committed to learning and teaching the subject in ways their students would enjoy.

Sometimes as was the case for Beatrice, Frank and Pamela the preparation was not as driven by a lack of understanding of the content, but how to deliver it to the students, the pedagogy of math. Being assigned a new or unexpected grade, sometimes caused a reappearance of anxiety in participants. Frank, recalling his move after nine years from kindergarten to Grade 5 said, “I took all the resources I could home, the textbook, the workbook, the curriculum document and … dissected it to look at what I had to do.”

Other methods that the participants used to address anxiety involved taking Professional Development courses, reviewing concepts or pedagogical approaches with a colleague, or reviewing the earlier grade texts to see how concepts were developed.

Though none of these strategies were directly outlined in the literature review, which had as its’ focus pre-service preparatory, the participants outlined an important truth, learning does not end, and in fact math anxiety reduction does not end, simply at the conclusion of the pre-service mathematics course. The conscientious teacher will seek to gain on the base that such courses provides through a number of means. As Beatrice reflected, “As adults you’re doing Grade 4, 5, 6 math but as adults … you’re going to see different things you’re going to remember what you did, and how this is and your lights will go off, you may not say it out loud but in your
head your saying, “Wow this is great!”, and … you know where the confidence comes from.”

This aligns with the plans, for their self-initiated mathematical development that pre-service teachers discussed in Young-Leveridge’s, (2010) mixed method study of New Zealand PSTs.

Overall I found that throughout the decades, math education programs have been implementing many of the research practices that studies have shown to reduce anxiety. Yet the participants themselves greatly reduced their own anxiety through a number of proactive steps. The weight participants placed on this aspect of math anxiety reduction, which fell outside of the key research questions was an intriguing surprise.

4.2 Pedagogical approach

The benefits derived from speaking directly to people who experience a phenomenon such as math anxiety, are immense. As educators, the participants were able to speak to both their feelings and practical instructional methods and approaches they use within the class to reduce anxiety. The participants, having experienced faculty of education math courses, and informed by their own histories as students did have much to say about math pedagogy.

4.2.0 Past experiences. When examining their past as students, participants related both positive and negative math experiences. Tara described her experience the most strongly, commenting, “I hated it … our teacher used to make us write … on the board and he would pick people to come answer it.” Teacher approach was also found in research such as the qualitative work done by Trujillio & Hadfield (1999) to bare heavily in the memories and outcomes of PSTs interviewed. Pamela described a more positive math journey and the support she received from her teachers, as an otherwise high achieving student. Beatrice, recalled her grade eight class in which she was placed beside a strong math student, musing that perhaps the strategy was to create a heterogeneous group. She said that rather than helping her grow and gain confidence the
disparity between the two girls led to a further erosion of her self-efficacy. Upon analyzing the experience of sitting beside a strong math student, she said that it:

increases your awareness of how slow you are at math. It doesn’t make you understand that everyone learns differently. It just pretty much pronounced the fact that I’m slow therefore I must not be getting it or there must be something wrong or it’s just not my thing so then that, of course the confidence goes down and it’s just a downward cycle.

The “downward cycle” described by Beatrice aligns with the concept of self-efficacy crafted by Bandura (1997) which is “concerned with the judgements of personal capability” (p.11). In Beatrice’s experience her self-efficacy was undermined in part due to this teacher decision. The mathematical self-efficacy framework put forward by Warwick (2008), includes “vicarious experience”, comparing oneself to “peers, colleagues, classmates” (p.32); in Beatrice’s experience this comparison led to a lowering of her perceived self-efficacy.

Frank recalled an uneventful math history, until he entered high school, where he began to feel, “overwhelmed.” When examining his primary and intermediate experience, he spoke about receiving parental support, “My father was good with math, so he’d always help me whenever I needed it.” However, one significant hurdle Frank mentioned was his method of approaching math problems, did not match what was taught in class.

I did math in a different way than my teachers taught it ... in my head would just do it a completely different way and still get the same answer, but not able to show how I got my answer…in the way that the teacher wanted.

This methodological difference, also became an issue when receiving help at home, as sometimes, “… [tutor, sibling, parents] couldn’t help me as much as they wanted to because they knew it their way not the way that I was taught.”
Among these math stories are a number of pedagogical points to note. The first involves the role of teacher approach and its effect on students. Teacher, Tara described created an uncomfortable situation, preforming math before an audience. This example typifies the composite definition, crafted in Chapter 2; math anxiety is mental and/or physical unease associated with the performance of mathematics. Such forms of math instruction, writing on the board, timed tests, lack of discussions, have been shown in the literature to increase levels of anxiety (Ashcraft, 2002; Geist, 2010; Jackson & Leffingwell, 1999; Tobias 1993; Zaslavsky, 1995).

The heterogeneous student grouping, and the resulting cyclical lowering of self-efficacy that Beatrice described, aligns with Tobias’ (1993) hardware and debilitating ‘static’ of negative emotions analogy of the process behind math anxiety. Seated beside a strong math student, preoccupied by negative emotions, Beatrice problem-solving capacity was limited making it difficult to do work she already found challenging (p.7). A specific instructional approach may have been behind the student seating arrangements but this rather than reduce anxiety or increase aptitude, acted to increase anxiety.

The emphasis on, a single right way to do math that became an additional hurdle for Frank, should also be noted. In the literature, a lack of debate and a focus on right answers have been shown to contribute to math anxiety (Tobias, 1993). When recalling his teacher education training overseas he noted, “They [professors] basically told me that as long as I am getting the right answer and I am able to explain it, it’s okay if I do it a different way than the teacher taught it.” The pedagogical shift between Frank’s own education and his experience of teacher training, worked to validate his mathematical problem-solving. Beatrice also spoke to this pedagogical
approach, commenting on the way it worked to powerfully to build her understanding and that of her students.

… having them go up show their answers, different ways of doing it … the kids they’re brilliant, brilliant! And so they would be up and someone would say, “I did it different”, and so even that that whole idea of there’s not one way … Just allowing the kids to explore the different answers … It was so interesting to watch as the kids explained to each other and the lights would go off … I learned a lot from them as they were solving as well.

Beatrice created space for students to approach math problems differently; it is also key to note that she created space for classroom discussion. Discussion in math classes can open the door for new understanding for student and in the experience of this educator for teacher as well. In the late 1990s a research based book outlining math best practises pedagogy point to the value of math discussions, questioning and justifying one’s thinking (Zemelman, Daniels, and Hyde, 1998).

The participants each had a variety of pedagogical approaches applied for and to them as young students, shaping their perception of math and these approaches mirrored or diverged from what they experienced in their preservice math course and influenced their pedagogy once in the classroom.

4.2.1 In pre-service programs. The teacher’s experience of instruction of mathematics as students, influenced how they approached the subject. The pedagogical approaches taken in their pre-service training impacted their views of math and their levels of anxiety as well. Pre-service teacher, education afforded the participants new pedagogical approaches to math and
now as experienced teachers that had various views on ways to make programs more effective at math anxiety reduction.

Beatrice clearly stressed the importance of teaching pre-service teachers a deep understanding of math concepts.

…if you [the teacher] are not seeing the patterns in math, you’re not going to bring that across. If you’re just looking at the manual and say yeah okay I am just going to put this example up then that’s great, your level 4s will get it, they don’t need you, the level 4s they can look at the book and do it themselves anyway. It’s your level 1s, 2s, 2 and a halves … is where you need to be. Where you need to show it a different way …. So you know if you don’t have that ability, if you’re not seeing the pattern then you’re not going to get it across to the kids…

This statement was echoed by Tara, who counselled, “…let them [pre-service teachers] practice it, let them see why it is important, what did they discover…” The importance of deep concept knowledge, of providing pre-service teachers room to gain deep mathematical knowledge to take into the classroom, is a pedagogical point to note. This recommendation to build conceptual knowledge in students in Faculties of Education is one mirrored in the research. (Boyd et al., 2006). However key study authors, Beilock and Willingham (2014) and Tooke and Lindstrom (2014) affirm, as Tara did, that this conceptual knowledge must be paired with instruction on how to teach these mathematical concepts. This point becomes all the more striking when placed beside the work of Bulmahn and Young, (1982) who postulate that a math anxious teachers’ approach to math pedagogy, may be due to a desire to limit factors that could lead to a classroom conceptual discussion. Building, perhaps for the first time, a conceptual base for mathematics in pre-service teachers, can be a key factor in combatting math anxiety.
Providing a conceptual base of understanding could then lead to a richer and more research supported type of math instruction, where concept knowledge is the scaffold supporting each lesson.

Tara had much to say in regards to alleviation of math anxiety in pre-service programs, she agreed with Beatrice on the need to build conceptual knowledge, but also suggested it would be “…helpful to give teachers a set of problems that they can use in their classrooms in different areas of math.” Tara went on to add, “…it's not enough just to give it to them [PSTs].” These problems, she asserted, should be questions that pre-service candidates had had an opportunity to work with themselves, not merely a problem bank to bring into the classroom.

4.2.2 Manipulatives. Manipulatives can be thought of as visual tool, physical or (increasingly) digital that can be used to help a learner access the concept of a mathematical principle, giving them the opportunity to manipulate the tool to understand and form connections. Manipulatives were one pedagogical approach that study participants pointed to as a means of relieving their own anxiety or that of their students. For some teacher participants, their pre-service education was the first time they had had the opportunity to use manipulatives. This matches the qualitative research conducted by Trujillio and Hadfield, which found that manipulatives provided an entry point for math anxious PSTs and were tools that participants said they would use with their students to build concept attainment (1990). Frank’s first memory of mathematics was a base-ten manipulative in his kindergarten class. When he became a kindergarten teacher he returned to these visual aids and also added his own manipulatives to the instruction as well.

Because they were so young and so tactile … I could incorporate so many manipulatives that would engage them and that would spur them to want to learn more and to basically
complete the task at hand. So it was good I was able to use stuff that made me learn better, to make them learn but to make them learn period.

Frank’s words, in my view, paint a picture both of a teacher catering to the learning styles of his students and also a teacher who had found a particular pedagogical method successful in his own early understanding of math concepts. Frank went on to give specific examples of using everyday situations, such as a walk to the drinking fountain, as opportunities to have students use their bodies to model patterning. He recalls, “…wherever we were we would look at math.” The use of manipulatives, as a means of anxiety reduction links to work done by a number of researchers (Schneider, 1988 as cited by Tooke & Lindstrom, 2014; Trujillio & Hadfield, 1999).

Tara cited manipulatives as being one of the access points which began her appreciation of mathematics following a history of anxiety. Sloan’s (2010), mixed methods study of the math anxiety levels of PSTs enrolled in math methods course, found that many participants did express anxiety reduction which they linked to the use of manipulatives. Beatrice also, advocated for the use of manipulatives in intermediate grades, “They need to remain in the classroom longer than grade four, it seems like at that age we just take everything and put it away, why? I still see adults using their fingers.” Interestingly, none of the teachers directly mentioned practice teaching math, though Tooke and Lindstrom (2014) do point to this as a means of anxiety reduction among PSTs.

Only one teacher spoke specifically about incorporating technology into their teaching practice. Frank was also the teacher, who had experienced the use of technology in his pre-service math class. He spoke of the usefulness of the Promethean Board for increasing student engagement, especially given that students, “… are accustomed to screens and devices and using their hands.” He also cited the use of technology as a differentiation technique to cater to the
different learners within his class. A meta-analysis conducted by Zemelman, Daniels, and Hyde (1998), lists technology inclusion as a best practice in math instruction.

When queried specifically on what changes they thought should be made to preservice programs the participants presented a wealth of views. Among the changes were the use of manipulatives, a greater emphasis on deep concept knowledge. Their commentary was confirmed by a number of research studies. Their commentary also gave a view of what each teacher was doing to reduce to math anxiety of their students, providing many practical avenues for addressing the challenges of math instruction through a variety of pedagogical strategies.

4.3 Benefits of cross-curricular approach

One pedagogical approach that this study did specifically inquire about in relation to math anxiety reduction was cross-curricular lesson planning. Cross-curricular planning is the authentic merging of more than one subject area curricular strand into the same lesson, task, or performance. Within this theme I will discuss two sub-themes: benefits of cross-curricular lessons to teachers, and benefits of cross-curricular lessons to students.

4.3.0 Benefits to teachers. Cross-curricular lesson planning, first entered my notice as I researched math pedagogy. Yet the intersection of cross-curricular planning, math and art and its possible application in pre-service math education, did not have a deep body of research. One article that did speak about direct cross-curricular math-art practice within a teacher preparation course was published by Uğurel, Tuncer, and Toprak’s (2013). For the purposes of this study I asked more broadly about cross-curricular teaching and the majority of the participants directly discussed a math-art practice.

The most widely mentioned gain teachers cited from interdisciplinary teaching, was in time. Frank reasoned,
So, in teaching there’s so much to cover especially in the junior grades and there’s not a lot of time to do it in 6 hour days, when you consider recesses and lunch breaks and transitions from one subject to the other, we have a [school event] going on now, we had an assembly yesterday you have to be…you have to kill two birds with one stone.

Pamela discussed the ease of integrating math “into many other subject areas because there is so much language involved.” Beatrice also pointed to language as a means of cross-curricular teaching, yet mused that teaching math in this way was more challenging than teaching language using this method. Elaborating on her response she said, “… I think that is probably because the confidence level isn’t there. And so you don’t see it everywhere, you don’t see math everywhere, you see language everywhere…” This ability to view math everywhere, can arguably be linked back to having a deep conceptual knowledge of mathematical concepts. It is worth noting that Beatrice’s teacher education had a significant literacy base and no designated math pedagogy course. The value of conceptual understanding is a point echoed by a number of works in the field (Aslan, 2013; Beilock &Willingham, 2014; Boyd et al., 2006; Bulmahn and Young, 1982; Gresham, 2007; Tooke & Lindstrom, 2014). Gresham (2007), conducted a study of PSTs in pre-service math methods courses, using the Burner mode of learning which emphasizes as a tenant concept driven, “concrete learning of the mathematical content” (p. 186). The study did find a reduction of anxiety amongst the elementary PSTs, interviewed (Gresham, 2007). As Beatrice pointedly stated:

you can repeat the same thing over and over and over again that’s great, you can do 18 examples and you can you know, change the snowman to the snowflakes it’s not going to do anything because you’re not getting to the root, you know, which is the concept behind it.
Without the conceptual base, creating the necessary connections required to teach in an interdisciplinary manner are a considerable challenge and could become an insurmountable deterrent to using this teaching approach.

4.3.1 Benefits to students. It is worth inquiring if cross-curricular teaching is a worthwhile endeavor. Is it of benefit to the students as well as the teachers? Does it afford benefits to those who struggle with math anxiety? The teacher participants all believed that this method of teaching was beneficial not only the educator, but to their students. The teachers said it provided another entry point into mathematics for their students.

Broadly speaking of this method of teaching, Tara said, “It’s always more beneficial to [the students] because then they are making connections and they see a purpose … for math in another context.” This view of seeing math everywhere, of making connections between math and other areas was a benefit also raised by Pamela. Pamela recounted her ongoing integration of real life math problems into the everyday conversations in her class.

I asked, “Can you imagine how much that would be?” … they said, ‘Ms. I know I know!’ “Wow who knew, who knew, that math was so important!” I am very dramatic … So I try to bring in math in that way, to make it fun, little silly things but it gets them thinking and realize ‘Oh, that is math!’ whereas they wouldn’t normally if I just kept on talking, so I try to make it into a teachable moment and its fun for them…

Furner & Berman (2003), citing an earlier study by Furner (1996), wrote that increasing the links between real life and math, has a deescalating effect on math anxiety levels. This finding, echoes an early recollection from Frank who spoke about the, doing a more “technical math” in Grade 10 which he preferred to his Grade 9 experience. “We learned how to do taxes,
and … everyday things…” he recalled. Creating connections between math concepts, other strands of the curriculum, and real life are one of the benefits that teacher participants cite.

The other benefit of cross-curricular teaching that participants pointed out was the way it afforded and entry point to students who may experience math anxiety. As Frank put it benefits the students, “… because they can shine. If they are not super strong in math but you’re doing something art related too it kinda gives them that confidence, ‘you know I able to do this task that somewhat math-ish’.” Pamela relates the story of a student, who often presented classroom management challenges,

And since the first week of school … he said to me, ‘Ms. I am really bad at math’, and so when I’d say take out your math books, he would say, ‘Ms. I am really bad at math’, and then he’d figure something out and I would say, ‘Well you said you are really bad at math, but every time I say something you are always calculating, so you are not I don’t know why you saying that because look at this!’ . And then he would be like, ‘hmmm’!

The participants’ stories align with the research surrounding self-efficacy, which can be thought of as “confidence in his or her competence”, in terms of math anxiety it is the feeling that one can succeed at a mathematical task (Jameson, 2009, p.48). Tobias (1993) points to a decrease in self-confidence, self-efficacy, as interfering with processing ability required to do mathematics. By teaching in a cross-curricular manner, teacher participants were able to provide an entry-point into math that was less daunting for some students, allowing for them to grow in math knowledge while boosting their self-efficacy.

None of the teachers directly spoke on whether they had used a cross-curricular approach to strengthen their own mathematical understanding.
4.4 Overview of chapter 4 and preview of chapter 5

In this chapter, I have drawn on the thoughts of the teacher participants, weaving in the literature to address the key inquires of this study. Throughout I have sought to bring forward the perspectives of four educators and the themes that emerged in our conversations.

Chapter four began with the theme of Teacher Preparation, including the sub-themes Within Teacher Education Courses and Following Teacher Education Courses. There are numerous means of preparation that a pre-service teacher undertakes to prepare themselves for the classroom. The math methods course is one aspect of this preparation. The participants described these courses, in a positive light, indicating that the course had provided them with tools to bring into the classroom, different pedagogical approaches than those they met as students and for some it marked a shift in how they viewed math. The university professors, who taught these courses, in their approach to the subject modelled a positive outlook that the teachers still remembered years later. This aligned with the work of Jackson and Leffingwell (1999) and Tobias (1987), who wrote on the effect of instructor attitude on students. This theme also addressed the preparation that teachers undertook as novice teachers. The participants noted that the courses which they took provided, “a base” but they still required additional preparation in order to confidently instruct mathematics. Their preparation involved ‘re-teaching’, a process by which the teacher taught themselves key concepts before teaching a lesson. Teachers also prepared by taking Professional Development courses, reviewing concepts or pedagogical approaches with a colleague, or reviewing the earlier grade texts to see how concepts were developed. This was a significant finding as it placed onus not simply on what was learned in the pre-service math course but what teachers took proactive steps to learn following such courses.
The Pedagogical Approach theme focused on the instructional strategies that teachers underwent as students, as well as pedagogical approaches they used to reduce their anxiety and that of their students. The theme was divided into a subtheme that examined their past experiences from a pedagogical standpoint. A significant point of note was the way in which, “one right method” pedagogy negatively affected a student, adding an additional burden to overcome. This finding echoed the popular math writings of the prominent writer, Tobias (1993). The next sub theme investigated the pedagogical approach taken in math courses. The teachers emphatically pointed out that concept knowledge should be at the heart of teacher preparation math courses. This assertion, was in-line with that Gresham (2007) who sought to study the role of a concept focused math pedagogy on math anxious elementary PSTs. Gresham found that using concept oriented instruction did reduce anxiety levels among respondents. The use of manipulatives as a pedagogical tool made up the final sub-theme of this section. In it the teachers commented on the ways in which manipulatives reduced their anxiety or that of their students and provided an entry point into understanding mathematical concepts. Their experiential data was confirmed by the literature (Schneider, 1988 as cited by Tooke & Lindstrom, 2014). The use of technology was not discussed widely among participants but was mentioned by one participant, who cited it as a means of engaging their students this aligns well with the work of Zemelman, Daniels, and Hyde (1998), who list its inclusion as a math pedagogy best practice.

The final theme discussed the benefits of a cross-curricular approach to math instruction. There were a number of positive outcomes associated with a multi-disciplinary method of instruction that participants noted. The first sub-theme in this area involved the benefits of cross-curricular lessons to teachers. The prevailing benefit that participants cited was in regards to time and meeting the overall expectations as set out in the curriculum documents. Yet more rich data
that participants discussed, were the benefits of cross-curricular lessons to students. Interdisciplinary teaching, allowed students to “shine”, as one participant phrased it. By teaching in this manner the teachers, created access points for struggling students to meet with success in mathematics, thereby allowing for an opportunity to grow in self-efficacy. This emphasis on self-efficacy is powerful in light of the work of Harper and Daane (1998) who cite poor experiences of mathematics in elementary school, as having a deleterious effect on one’s self-efficacy and leading to an avoidance of math.

Throughout this chapter I have provided the perspectives of four experienced educators and created connections between their lived experiences and the research body on math anxiety as well as possible significance of these connections. In the next chapter I discuss the implications of the findings from this chapter. Chapter five creates links to relevant literature and lists some of the broad implications to the field of education. I will also seek to use the combined wisdom gathered from the teacher participants and the connections to the literature to suggest possible recommendations to the education community.
Chapter 5: Implications

_In a mathematics class for Pre-Service Teachers, an instructor inquired, “Which image would you use as a visual metaphor to represent mathematics?” One student selected the image of the spider, pointing to the intricate web designs of the insect’s craft and commenting on the beauty of their construction, comparing them to the intricacies of math. Another student also selected the spider, presenting a vastly different rationale. “Math is like a spider; it traps its prey, incapacitates it and then feasts on its blood!”_

5.0 Introduction

This study has examined the lived experience of teachers as they journeyed from a history of math anxiety to increased confidence in math. This qualitative case study approach drew on the knowledge garnered to examine what could be done to reduce math anxiety in those posed to enter the teaching profession. In this final chapter, the present study reviews the themes gained from the analysis of the interviews. This chapter also outlines potential implications to the realms of policy and educational practice. To close, this chapter will discuss the limitations of the study, and present avenues for future research.

5.1 Overview of key findings

The conversations with the four participants yielded a great deal of data, which following careful analysis revealed a number of themes. The emergent themes were as follows: (1) Teacher Preparation for Math Instruction, (2) Pedagogical Approaches, and (3) Benefits of Cross-Curricular Lesson Planning. In each of these themes, the participants shed light on their educational journeys as students and then teachers overcoming math anxiety.

5.1.0 Teacher preparation for math instruction. The first theme focused on the preparation for math instruction that the teachers had during their pre-service training and then
the self-initiated preparation that they undertook as practicing teachers. In regards to their training, the teacher participants recalled the use of manipulatives, group work, visuals and practical, relatable math helped lessen their anxiety. These anxiety-reducing practices aligned well with the research of a number of authors (Beilock & Willingham, 2014; Furner & Berman, 2003; Tobias 1993; Tooke & Lindstrom, 2014; Trujillio & Hadfield, 1999). Past initial training, the teachers all spoke of the need to investigate and learn further as they began to teach. This re-teaching effort built up their conceptual knowledge, and with this growth they expressed a growth in their self-efficacy and reduction in their anxiety.

5.1.1 Pedagogical approaches. The succeeding theme explored the pedagogical approaches that the teachers had experienced as students, pre-service teachers and practicing educators. The use of manipulatives emerged as a pedagogical approach that encouraged student and teacher alike to develop courage and confidence when it came to grasping math concepts. Conceptual understanding of mathematics also emerged as a significant method through which the teachers built their self-efficacy. From this conceptual base, teacher participants were able to meet the needs of all of their learners, thereby providing scaffolding and differentiation for struggling students.

5.1.2 Benefits of cross-curricular lesson planning. The final theme emerged while the teachers were asked to speak about cross-curricular planning. The teachers cited timeline considerations as being one of the chief benefits of an interdisciplinary teaching practice. Additionally, by merging mathematics with other curriculum strands, the teachers also felt it gave students who might experience difficulties with math a chance to meet with success. Tobias found that a significant feature of math anxiety was the static of debilitating thoughts about one’s self-efficacy interfering with mathematical processing (1993). There is potential for an increase
in self-efficacy during a cross-curricular lesson as students see the math curriculum connected to strands in which they have a higher degree of self-efficacy.

5.2 Implications

The present study holds a number of implications both for the wider educational community and for myself as a researcher and pre-service teacher.

5.2.0 Implications for the educational community. The collective experiences of the participants and the meaning forming distillation process that has been undertaken presents numerous implications to those concerned with the alleviation of math anxiety, each of which is outlined below:

1. **Cross-curricular math instruction can be put forward as a means to cultivate success in struggling students.** Not all of us have the same strengths, but we all possess capabilities. Teaching in an interdisciplinary manner can furnish students with the tools required to build connections and see math as applicable to the real world. One teacher participant in particular, Tara, commented on the needfulness of ensuring that math, which can be very theoretical was tangible and practical to her students. This research based step, of relatable math ties into the work of numerous researchers (Beilock & Willingham, 2014; Furner & Berman, 2003; Tobias 1993; Tooke & Lindstrom, 2014; Trujillio & Hadfield, 1999). Being able to form connections to real-world multi-facetted problems can then contribute to a growing self-efficacy. Seminal research, such as that conducted by Uğurel, Tuncer and Toprak (2012) on a math-art pedagogy course, may very well become more widely implemented in pre-service programs and researched within academia. Whichever curriculum strands are authentically merged by one’s
pedagogy, the benefits of this form of instruction provide an additional strategy that can be applied to aid the math anxious pre-service teacher and student alike.

2. **Math-anxious teachers can lessen their anxiety by re-teaching themselves and taking professional development courses.** This present study has confirmed the research base that states that for many, formative experiences with mathematics contributed to their anxiety with the subject (Beilock & Willingham, 2014; Bulman & Young, 1982; Tobias, 1993). The findings support research conducted by Martinez (1987) which found that, “gaps in math knowledge or an awareness of imperfectly learned concepts”, contribute to continued levels of anxiety (p.120). Through a process of re-teaching that has been referred to as “overlearning”, PSTs communicated a growing confidence in their competence to teach mathematics (Martinez, 1987, p.120). Beatrice, educator participant, phrases it in this manner, “I was re-teaching myself as I went into teach.” When the platform upon which one is standing is faulty and unstable, one cannot confidently encourage another to climb aboard. Therefore this re-teaching effort affords educators a chance of shoring up faulty or mislaid foundations in their own education.

5.2.1 **Implications for Self** . The study has afforded me an opportunity to examine from an academic point of view a phenomenon I have experienced personally. There is a certain power that one is afforded as a researcher to step back a little distance and survey. However, a reflective researcher must realize they can never be entirely removed from that which they hope to understand. The implication for myself as I enter the classroom is this: math anxiety can be lessened or even alleviated. Research has given me practical tools to ensure that my own negative educational experience with math need not cast a shadow on my students. I will aim to
take my cues from research and implement a cross-curricular math pedagogy to support my learners, paired with a committed self-initiated concept driven re-teaching effort.

5.3 Recommendations

The phenomenon of math anxiety with its potential life-long ripple effects means that any reform efforts must touch many levels of the education field. The present study makes the following recommendations for teachers and teacher educators:

1. Teachers who experienced math anxiety as students need to equip themselves for the classroom by building their facility with math concepts and working to change their perceptions of math. By seeking to grow as informed reflective educators, these teachers can steer clear of the known stressors that personal experience and research have shown lead to math anxiety. In order to facilitate this, boards of education should remove the stigma for teachers who readily own that they need support as math teacher. Specifically, free courses should be offered with incentives for teachers’ participation.

2. Pre-service teachers should be furnished with math pedagogy courses with concept rich learning opportunities including practice teaching math lessons. Through these two pieces, conceptual teaching and practice opportunities, PSTs will gain both the knowledge base and the facility that comes from experience that these findings have shown impact on a teacher’s self-efficacy and instructional approach.

5.4 Areas for further research

The present study has contributed to the growing body of knowledge surrounding the phenomenon of math anxiety. The focus on the benefits of cross-curricular lessons in regards to
math anxiety reduction has worked to address a gap in the literature. However, because the extent to which one study can bring awareness and shed light on a given phenomenon is always limited, further study is needed. In the future, studies could further examine the value of math-art instruction in math anxiety reduction and pursue its possible application in pre-service education. Due to the limitations of this present study, particularly its convenient small-scale sampling methodology, it is necessary to gather more research about the effectiveness of math-art instruction on math anxiety reduction. Another avenue to explore are the potential links between self-efficacy, mindset and anxiety. One teacher spoke often about encouraging her students to “change their mind and try again”, which may work to offset the negative stream of emotions that research has shown factor into math anxiety. Further qualitative research could also examine the role of language-based math on anxiety levels, as multiple teacher participants cited this as a personal or professional extenuating factor in their experience with the subject as students or as classroom teachers.

5.5 Concluding comments

The role of mathematics in everyday life is ever-present, from the grocery store to major life decisions such as career choice; its ripple effects can be felt everywhere and every day. As impactful as math is, so too is this debilitating condition that keeps many from literacy and ease with the subject. The present study has sought to examine the root causes of math anxiety and the practical methods of its reduction within a key population, pre-service teachers. By examining the lived experience of in-service teachers, the present study has found strategies and pursuits that can aid in the reduction of anxiety and the effective instruction of mathematics. The needed shift in the cultural dialogue surrounding mathematics must begin in the classroom. For many, the origin of their anxiety has its roots within the pedagogies, approaches and conversations
within these institutional walls; however the solution exists there as well. Pre-service teachers represent a significant asset to transform dialogues and educate for mathematical self-efficacy and excellence. To equip these potential change-makers, teacher education must itself shift and transform, supporting these to-be teachers towards that end. The present study is valuable in furthering the knowledge and research required to cultivate a mathematically literate society. Through an emphasis on building a solid conceptual base, providing teaching opportunities, encouraging re-teaching and re-engagement with math on deep levels, Faculties of Education can better support math anxious PSTs.

To invoke once more the words of the pre-service teacher quoted at the start of this study, “math is like a spider.” A spider can be beauty and grace as much as it can be terror and menace. Ultimately, it is the role of the teacher to move past their fear and guide students to see mathematics for all it can be; its brevity and beauty, opportunity and creativity, complexity and usefulness.
References


Appendix A: Consent Letter

Date: September 21, 2015

Hello,

My name is Gabriella Kerr and I am a student in the Master of Teaching program at the Ontario Institute for Studies in Education at the University of Toronto (OISE/UT). A component of this degree program involves conducting a small-scale qualitative research study. My research will focus on methods surrounding the alleviation of math anxiety. I am interested in interviewing teachers who have experienced math anxiety personally and have found methods, including cross-curricular approaches to alleviating this condition. I think that your knowledge and experience will provide insights into this topic.

Your participation in this research will involve one 30-45 minute interview, which will be transcribed and audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient for you, outside of school time. The contents of this interview will be used for my research project, which will include a final paper, as well as informal presentations to my classmates and/or potentially at a research conference or publication. You will be assigned a pseudonym to maintain your anonymity and I will not use your name or any other content that might identify you in my written work, oral presentations, or publications. This information will remain confidential. This data will be stored on my password-protected computer and the only people who will have access to the research data will be my course instructor and MTRP Supervisor, Dr. Kenneth McNeilly. You are free to change your mind about your participation at any time, and to withdraw even after you have consented to participate. You may also choose to decline to answer any specific question. I will destroy the audio recording after the paper has been presented and/or published, which may take up to a maximum of five years after the data has been collected. There are no known risks or benefits to participation, and I will share with you a copy of the transcript to ensure accuracy.

Please sign this consent form, if you agree to be interviewed. The second copy is for your records.

I am very grateful for your participation.

Sincerely,

Gabriella Kerr | g.kerr@mail.utoronto.ca

Course Instructor’s Name: Dr. Kenneth McNeilly | kenneth.mcneilly@utoronto.ca
Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw from this research study at any time without penalty.

I have read the letter provided to me by Gabriella Kerr and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: ____________________________________________

Name: (printed) ____________________________________________

Date: ____________________________________________
Appendix B: Interview Protocol

Personal Math Anxiety/Math History

1. Please state your name, school, number of years you have taught and which grades?
2. Can you describe your earliest memory of mathematics?
3. Have you experienced math anxiety? If so, what do you think triggered it? If you have never experienced math anxiety, why do you think that is?

Teacher Education Experience

4. Did you have math classes while in Teacher Training? Did you take these courses voluntarily?
5. Did the Teacher Training program offer remedial math classes? Did you take these courses voluntarily?
6. If you do recall the classes, what stands out for you? (instructor, manipulatives)

Early Teaching Years

7. What were your thoughts/feelings towards teaching mathematics as a new teacher?
8. If you were concerned about teaching mathematics as a PST, can you think of an instance when you began to feel more comfortable with teaching math?
   - If so, what do you feel alleviated your concerns about teaching mathematics?
   - If you did not begin to feel more comfortable, what do you think could have helped you?
9. How do you think PST programs could be made to help reduce MA for beginning teachers?

Current Teaching Practice (Cross Curricular)

10. Do you think any of your students experience math anxiety? How do you know?
11. How do you help students you suspect may be experiencing math anxiety?

12. Have you ever used a Cross-curricular approach to Math, whether it be to help your own understanding or that of a student’s? (Math-Art lesson)

13. Do you think this cross-curricular approach made the lesson more accessible to students?