

School Based Practices to Address High Rates of

Math Anxiety

By

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Abstract

High levels of anxiety towards mathematics are prevalent in learners from an early age into college, and in many areas of the world. The most common result of mathematics anxiety is avoidance of math courses. With today's dependence on technology, educational systems must find a way to combat this problem. This paper will review and critically assess literature on mathematics anxiety with an aim of identifying school based factors that lead to or increase math anxiety. A teacher training program will be developed to address the school based factors that are identified with math anxiety. Tactics will be suggested for the classroom and society as a whole that can control, reduce, and alleviate the problem. With lower levels of math anxiety, it is hoped that our educational system can increase its production of students with strong skills and confidence in mathematics.

Keywords: math anxiety, working memory, math competence, math achievement

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CHAPTER 1 INTRODUCTION

In an increasingly technological society, knowledge of mathematics is critical to the pursuit of many existing and emerging occupational fields (Carnegie Commission on Higher Education, 1973, Betz, 1978). Although this is as true, if not more so, now as it was in 1973 when the Carnegie Commission completed its report on higher education in the United States, we see Canada's world ranking in secondary math achievement falling (Proudfoot, 2010) and enrolment in higher level secondary and post-secondary math courses decreasing ("Trends in higher," 2011). Basic "mathematical skills have been shown to be crucial predictors of an individual's life success—"it is so critical that a deficit in basic mathematical abilities has been found to have a greater negative effect on employment opportunities than reading difficulties" (Maloney, Risko, Ansari, & Fugelsang, 2010, p. 293). Despite the relevance of a sound understanding of mathematics for today's world, many capable students avoid taking the math courses that will allow them to participate in technology, business, economics, and science based fields. Not only are many students not taking math courses, but many are also performing poorly in the courses they do take, a likely factor in not taking more advanced mathematics later on.

As a child I was lucky, mathematically speaking, to be raised in a home with a teacher father and mother who worked at a bank. Neither of them displayed any discomfort around math (although years later my mother returned to school and had to take grade 11 and 12 math and revealed to me her horrible experience in school with math learning and her feeling of not understanding or not being good at math). I played games that involved numbers from an early age and always enjoyed and experienced success in mathematical

endeavours. My parents instilled a love of learning in me and I wanted to succeed in all academic areas.

As an educator I have witnessed a dislike and lack of confidence in math in children as early as grade one. Research shows that a “negative attitude towards mathematics is a growing barrier for many children” (Geist, 2010, p. 24) Even with my own children who are, according to their teachers, meeting or exceeding expectations for their grade levels and enjoy mathematical games and puzzles I heard “I don’t like math” and “I’m not good at it” in the early grades. As a teacher who enjoys and is confident in math, I find this attitude alarming, as it is sure to hinder a student’s ability and desire to continue in math. When teaching Grade 4 math I would always plan for students to experience success. I want to foster student’s self-confidence: for them to experience that they can complete mathematical tasks with confidence and explain their answers when questioned. To this end I began to read about and introduce student centered mathematics teaching into my practice. This fits with my philosophy of learning through doing, working in groups, and reflecting on learning through discussion and journaling. A hands-on approach allows students to conceptualize ideas before moving on to learning matrices and formulaic ways to solve problems. Reflection on learning appears to increase my students’ feeling of success and confidence as measured by grades and also in the attitude displayed towards math instruction and task completion. I make math a fun, hands-on, game filled time of learning. It seemed that these techniques countered the often negative attitude many students came into my classroom with. I became an advocate in the schools I worked at for student centered instruction and playing games that linked to the curriculum being covered. Indeed, research has found that children often “associate mathematics with boring work that . . . does not relate to everyday life” (Geist, 2010, p. 25) and that some teachers believe

that if the students are having fun then it is not learning (Geist, 2010). The Masters of Education program gave me time and opportunity to research mathematics instruction and learning and to explore and understand why some students have such a negative view of this curriculum area.

One factor that has a direct link to performance and enrolment numbers in mathematics education is math anxiety. Math anxiety can be defined as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972, p. 23). As with anxiety of any kind, the uncomfortable feelings one has subjectively are future focused and out of proportion to the perceived threat. Through its international study of education levels the Organization for Economic Cooperation and Development (OECD) found that:

countries and economies where students tended to report higher levels of anxiety are also those where students tend to perform less well in mathematics. For example, among the lowest-performing countries in mathematics (those that score below 400 points on the PISA test), Argentina, Brazil, Jordan and Tunisia reported the highest levels of student anxiety towards mathematics. Conversely, countries that perform above the OECD average (494 score points), notably Austria, Denmark, Finland, Germany, Liechtenstein, the Netherlands and Switzerland, tended to show the lowest levels of anxiety" (Organization for Economic Cooperation and Development, 2015, p. 1).

In a study which asked college aged subjects to solve grade four number problems, Ashcraft (2002) found evidence of "trembling hands, nervous laughter" (p. 181), evidence of the emotional, anxiety ridden behaviour of his participants. They expressed concerns

about their performance and what it says about their general intelligence. These reactions were not brought about by intentionally stressful procedures. This suggests that even at the college level, students can feel anxiety and intimidation when asked to complete relatively simple mathematics questions.

Current educational practices do little to alleviate mathematics anxiety and are in fact a contributing factor to the prevalence of this condition. Hooker (2013) cites Stodolsky, Furner and Duffy, Miller and Mitchell, and Geist as all agreeing “that a major contributor to math anxiety is mathematics teachers” (p. 5).

It is not only the negative behaviours of teachers of mathematics that affect the anxiety levels of their students but also their own attitude towards math itself. When Hembree (1990) tested college students and grouped his findings according to college major, he found that students in elementary education had the highest levels of math anxiety. This could be evidence that numeracy and mathematical confidence are not thought to be important by those people entering the teaching profession.

Besides the behaviour and attitude of math teachers, other school based factors that increase math anxiety are communication and language barriers, quality of instruction, evaluation methods and difficulty of material, the school system itself, and anxiety around test taking (Furner & Duffy, 2002). The most significant negative correlation with high levels of math anxiety was found to be the enjoyment level students in Grades 5 to 12 and their own perceived self-confidence in Grades 6 to 11 (Hembree, 1990). Surely it is these factors that need to be addressed in any proposed educational reform.

Furner and Duffy (2002) go on to discuss factors outside of school that also contribute to increased math anxiety. These include gender, socioeconomic status, of students, and mathematical educational level of parents. Because parental attitude towards

math, level of education, and previous success in math greatly affects children (Geist, 2010), it follows that a decrease in anxiety in one generation will positively affect the next. Geist (2010) also lists previous mathematical education as a factor affecting math anxiety levels. This is not limited to high school and college math courses. In addition, children's "numerical competence in kindergarten is highly predictive of their acquisition of mathematics in Grade 1 and Grade 2, suggesting that experiences at home before schooling are important in understanding how numeracy develops" (LeFevre et al., 2009, p. 55). Early math experiences may therefore shape one's attitude and aptitude, which in turn can affect levels of math anxiety.

The question posed here is, what school based practices can be used to reduce or prevent math anxiety? This paper will examine current and historical research in the area of mathematics anxiety with the aim of proposing a direction for continued research on reducing, alleviating, and preventing this condition through school based practices. What can schools do to assist students suffering with this condition? How do we as an educational system alleviate and reduce mathematics anxiety and how do we change to prevent it from occurring in the first place?

We must find a way to increase our students' passion for and feeling of success with mathematics if we are to produce educated adults who can contribute to this advanced society.

Researchers such as Ashcraft (2002) and Furner and Duffy (2002) have observed that the disconnection between an increasingly diverse student population and our current "one-size-fits-all" curriculum will not produce the desired academic achievement gains expected in the 21st century. We know that one of the negative side effects of this educational model is an increase in mathematics anxiety (Friesen, 2006). Through re-

examining the past research into math anxiety I will suggest tactics for the classroom and society as a whole that can control, reduce, and alleviate the problem. With lower levels of math anxiety, it is hoped that our educational system can increase its production of students with not only strong skills and confidence in mathematics, but passion and creativity as well: Students who are ready to address the technological problems of, and meet the demands of our 21st century world.

In order to find studies on the topic of mathematics anxiety, databases of scholarly journals were searched. These include Academic Search Premier, Education Research Complete, and the Professional Development Collection through the library at City University of Seattle. Information on achievement levels of students was found from databases such as the National Center for Educational Statistics and from the Organization for Economic Cooperation and Development. Relevant studies were also found from citations within journal articles. Newspaper articles, government reports, and lectures on video were also used as reference material.

The research discussed in this paper is broad in scope. Many factors that are linked to math anxiety are examined: Gender and age of students; previous levels of math education; socio-economic status of the families the students are members of; teaching styles and methods of evaluation students are exposed to; as well as student levels of self-confidence and math enjoyment.

An area of limitation in this research is that almost all the research I was able to access and use was done in western English speaking countries. As well, anxiety in students with special academic needs was not reviewed.

In the next chapter I will review relevant literature on the study of math anxiety, its prevalence, distribution, and causes. I will go on to highlight school based practices to

reduce and prevent mathematics anxiety. In Chapter 3 I will offer a mixed methods approach to study the effects of improved teacher training in the area of mathematics education. Chapter 4 will summarize the entire paper and offer recommendations for the implementation of my findings.

CHAPTER 2 LITERATURE REVIEW

In this chapter, I examine the literature with a focus on what has been learned about mathematical anxiety in order to suggest areas for further study on school based strategies to address this important issue. Math anxiety is defined as “a feeling of tension, apprehension, or fear that interferes with math performance” (Ashcraft, 2002 p. 181). An important feature of our modern world frames this topic: We live in a time of increasing dependence on technology and therefore mathematics. At the same time, studies show that educational systems in the west are slipping lower and lower in world rankings and many students are not mastering even the basics of numeracy. According to the Organization for Economic Co-operation and Development (OECD), Canada’s ranking in mathematics is down from seventh in 2006 to 10th in 2009 while the US sits in 37th place (Proudford, 2010).

In this review of literature I examine academic journals, government and professional organizations databases, dissertations and manuscripts, and books, newspapers and magazines, tracing the history of research on math anxiety, and findings on its prevalence and connections. I also explore strategies that can prevent and alleviate mathematics anxiety.

The study of test anxiety predates that of math anxiety. As early as 1952, students at Yale University were given the Test Anxiety Questionnaire to determine their level of test anxiety (Mandler & Sarason, 1952). Test anxiety will be examined as a starting point for the exploration of math anxiety. From this starting point of test anxiety the focus will turn to math anxiety. Is it a subspecies of test anxiety or a distinct form of anxiety? Once the conceptualizations of the problem have been discussed, I will explore questions such as: How is math anxiety measured; what is its prevalence and what are effects; what factors

cause and maintain it both within and outside the educational system; what are treatments; and, how can we incorporate such treatment modalities into the school system in order to relive math anxiety?

From Test Anxiety to Math Anxiety

One specific area of research into anxiety that has been studied at length is test anxiety. Beginning in the 1950s researchers examining results of intelligence tests began to look at the factors that led to students becoming anxious, what the effects of this anxiety were, and what mechanisms were behind the anxiety. They claimed that “little attention has been paid in the literature to the influence of various drive states on the performance of typical intelligence test items” (Mandler & Sarason, 1952, p. 166). Up to this point “hunger, restlessness, desire to please . . . timidity and a hundred other motives” (Mandler & Sarason, 1952, p. 166) were discussed in relation to problems with test taking. They cite earlier research that found clinical anxiety affected scores on the Kohs Block Design Test and conclude that the “possible influence of anxiety . . . in psychological examinations must be considered more seriously” (p. 166).

Initially, behavioural constructs were put forward to explain the difference between high and low anxious students. Learned anxiety drives led to behaviours such as efforts to “finish the test and thereby reduce the anxiety” and “heightened heartbeat, anticipation of punishment and loss of status or self-esteem, and strong desires to escape the test situation” (Hembree, 1990, p. 33).

Later researchers identified both cognitive and behavioural factors in test anxiety. Liebert and Morris (n.d.) label two aspects of anxiety; “Worry (W) was conceptually identified as a cognitive expression of concern about one’s own performance” (p. 975),

while emotionality referred to behavioural reactions. Other researchers constructed a purely cognitive framework, claiming that people suffering with test anxiety “divide their attention between task-relevant efforts and preoccupations with worry, self-criticism, and somatic concerns” (Hembree, 1990, p. 34). In this model of the construct, one’s attention is deflected from the test taking and focused on these non-test taking, cognitive tasks. For the highly math anxious person these thoughts “probably involve preoccupation with one’s dislike or fear of math, one’s low self-confidence, and the like” (Ashcraft, 2002, p. 183).

After robust research on test anxiety, some researchers began to look specifically at mathematics anxiety. Betz (1978) was one of the first researchers to examine the relationship between math anxiety and both general and test specific anxiety. Betz found in her 1978 research that there was a strong correlation between math anxiety and test anxiety and suggested that “basic anxiety management techniques, treatment of test anxiety, and training in test-taking skills may be useful” (p. 447) treatment options for those students suffering from math anxiety. Later research has shown a weaker link between high math anxiety scores and high test anxiety.

In the 1970s journals began to publish the results of math anxiety studies “using the methods, procedures, and treatments already applied to test anxiety” (Hembree, 1990, p. 34). Much of the research shows that these two ideas—test and math specific anxiety—are similar. Many of the journal articles and books on mathematics anxiety have a section dealing with the correlation between math anxiety and the more general test anxiety (see for example Furner and Duffy, 2002).

Math Anxiety as a Separate Construct

Math anxiety is now seen as a separate construct from that of test anxiety (Maloney et al. 2010). Persons who are highly math anxious score as such across differing tests with a correlation of .50 to .70 whereas when that group tests for test anxiety the correlation drops down to as low as .30 (Ashcraft, 2002). This suggests that high math anxiety is related to a type of generalized anxiety indicative of higher trait anxiety. Research has shown that increasingly difficult math tasks cause highly math anxious subjects to sweat or have an increase in heart rate whereas the same group did not experience these physiological changes when given increasingly difficult verbal tasks (Faust, 1992). The anxiety the subjects experience is directly related to mathematics and not to being presented with increasingly difficult questions.

In to the new millennium, researchers such as Ashcraft (2002) were still unsure as to the makeup of math anxiety. In his 2002 paper, *Math Anxiety: Personal, Educational and Cognitive Consequences* he states that research is still needed on “the origins of math anxiety and on its “signature” in the brain activity, to examine both its emotional and its cognitive components” (p. 181). Later still, in 2010 we find Geist claiming that, “there is little empirical research about the causes of mathematics anxiety” (p. 26).

People suffering with math anxiety do demonstrate correlative behaviours. Math anxiety is correlated with a strong desire to complete assignments quickly and get through the task in a speedy fashion so as to lessen the time spent in the anxiety inducing activity (Hembree, 1990).

Hembree and Faust were the first to measure the cognitive effects of mathematics anxiety in their 1994 and 1996 research (as cited in Ashcraft, 2002). They found little significant effect with single digit addition and multiplication. They did find that math

anxiety interfered with people's ability to make decisions involving number sense even with single digit problems. When making "true/false judgments, highly math-anxious individuals made more errors as the problems became increasingly implausible (e.g., $9 + 7 = 39$), whereas low-anxiety participants made fewer errors on such problems." (p. 183). During the same research they also discovered that high math anxious individuals would answer two digit addition questions speedily as would the low anxious subjects. This is akin to avoidance as they opt to spend less time on the anxiety inducing task (REF). This move to avoid the task comes at a cost of a considerable decrease in accuracy.

Another cognitive area that is affected by math anxiety is the system for conscious, effortful mental processing: working memory. Aside from accuracy, Ashcraft (2002) found that addition problems that involved carrying took three times longer than those that did not involve carrying. His interpretation was that "any procedural aspect of arithmetic, might place a heavy demand on working memory" (2002, p. 183). In an ingenious experiment to test this, participants were asked to remember two to six letters, to perform addition with carrying, and then recall the letters. The highly math anxious subjects had twice as many errors in recall as the subjects with low anxiety (Ashcraft, 2002). This supports the idea that math anxiety is related to cognition.

Studies with Grades 2 and 3 students also produced data that could be explained by a link between working memory and math anxiety. Scores for math anxiety were more negatively correlated with lower levels of mathematical reasoning as compared to numerical operational skill (Wu, Barth, Amin, Malcarne, & Menon, 2012). During the numerical operations subtest children were given unlimited time, whereas during the mathematical reasoning section subjects were read questions and required to remember details. As the mathematical reasoning subtest involved more complex problems, and

called for more effort from working memory, perhaps subjects' working memory is being hindered by mathematical anxiety, resulting in lower scores.

Research has found that not all areas of mathematics induce the same levels of anxiety in subjects with high math anxiety. Ashcraft, Kirk and Hopko gave standardized tests to subjects in which the questions increased in difficulty as the test progressed. They found that when these tests were given to low, medium and highly math anxious subjects the scores were inversely related to levels of math anxiety. This is exactly what one would expect. They then examined the tests line by line and found no math anxiety effects on the first half of the test (Ashcraft, 2002). As the questions became more and more difficult the anxiety effects increased.

History of Research

Research into mathematics anxiety began by looking at college students. Counselling psychologists were "increasingly involved in the treatment of math anxiety . . . [but little was known] about its prevalence, nature or effects" (Betz, 1978, p. 441). Researchers found that although mathematics was becoming increasingly important across many fields many students who were capable were not taking mathematics courses in high school or college or those who did take higher level math courses were not performing to their full potential. Because of this they were restricting their career options to ones that did not have a need for mathematical knowledge (Betz, 1978). Popular magazines were exploring this issue by the late 1970s. Both *Ms. Magazine* and *Change* ran articles linking math avoidance and poor performance in mathematics courses to math anxiety (Tobias, 1976; Stent, 1977).

To begin to understand the size of the problem, Ohio State University conducted the first large-scale research into mathematics anxiety. Betz conducted one part of the research dealing with the prevalence and nature of the construct. She looked specifically at three areas: the prevalence and intensity of math anxiety in post-secondary students; the correlation of sex, age and prior math education to math anxiety and; the correlation between general anxiety and test anxiety to math anxiety (1978). She used a 10 question Math Anxiety Scale similar to the Mathematics Anxiety Rating Scale (MARS; Richardson & Suinn, 1972).

It was found that overall “moderately large percentages of students within all three groups responded in ways suggesting the presence of math anxiety” (Betz, 1978, p. 444). There was a consistent disagreement with the statement “I almost never get uptight during math tests” and agreement with statements “Mathematics makes me feel uneasy and confused” and “Mathematics makes me feel uncomfortable and nervous” (see Appendix A).

The Programme for International Student Assessment (PISA) test run by the Organization for Economic Co-operation and Development is an internationally standardized assessment for 15 year olds in North America and Europe. Exhaustive testing with scales such as the PISA has found that on average one of three students feels anxious about performing mathematics (Organization, 2015). On their shortened version of MARS, 59% of students reported that they often worry that math class will be difficult and 61% report that they worry that their grades will be unsatisfactory (p. 2).

Gender Differences

In most studies females were found to have significantly higher levels of math anxiety than males (for example Betz, 1978, Organization, 2015). This is true in both college and high school students according to both Betz (1978) and Fennema and Sherman (1977) who found that boys in high school generally had more positive attitudes towards math than high school girls did. Geist found that both sexes share an aptitude for math but that females “are more susceptible to math anxiety due to their aversion to high stakes testing and social comparison” (2010, p. 24). Interestingly Ashcraft and Faust found that more women than men scored for high levels of math anxiety but the opposite was true for low levels of math anxiety (1994).

Betz found that math anxiety was related to age in females but not in males. Older females showed increased math anxiety (1978, p. 445). She explains this by stating that younger women would have recently attended high school math courses whereas older women, with more time spent away from the math class, would naturally be more anxious about taking math courses. Some researchers have explained the gender difference in part to females’ willingness (as possibly opposed to their male counterparts) to share their personal attitudes (Ashcraft, 2002, p. 182). Others have found that females are often overlooked in math classes or socialized to dislike math (Geist, 2010).

Geist (as cited in Jussim & Eccles, 1992) found that teachers often attribute success in math to males and females for different reasons. Many teachers attribute boys’ success to an innate talent for mathematics, as if one is born with some special ability in math (artistic ability is another area of study where this refrain is often heard). These same teachers will often attribute girls’ mathematical success to hard work and determination. These differing attitudes can undermine female confidence in mathematics; the girls begin

to believe what they are being told. This can be seen when levels of enjoyment in mathematics is tested. As they get older and move through elementary and high school, “girls assessment of their enjoyment of mathematics falls much more drastically than boy’s assessment” (Geist, 2010, p. 26). The PISA supports these findings—a higher percentage of girls reported anxiety on all of the questions. Also, “almost all countries and economies that participated in PISA 2012, girls reported greater mathematics anxiety than boys” (Organization, 2015, p. 3).

Math Anxiety and Intelligence

Later studies have found that math anxiety is only weakly correlated to general intelligence. Ashcraft (2002) found a correlation of only $-.17$ and sees this correlation as inflated due to the fact that intelligence tests include “quantitative items, on which individuals with math anxiety perform more poorly than those without math anxiety” (2002, p. 182).

Betz (1978) found that the number of years of high school math courses taken in the past positively correlated to level of math anxiety and were statistically significant across different subject groups. This makes intuitive sense—individuals who suffer from math anxiety are not likely to take more math courses. Unfortunately, this only weakens their mathematic skill.

It is easy to see that a hungry child will have less focus and energy for learning. The National Assessment of Educational Progress (NAEP) found that students who receive a subsidized lunch consistently fall behind those students who do not in national US mathematics assessments and that even though average scores have risen over the last two decades, the gap between the classes remains constant (Geist, 2010). Geist theorizes that

children from low socioeconomic backgrounds “often have parents with less educational background and who often have negative attitudes towards mathematics themselves” (p. 24).

The NAEP is a country wide standardized test conducted by the US Department of Education. They test students from Grades 4, 8, and 12 across many curriculum areas and also test for educational experience. NAEP conducts nationwide and state testing and also long term trend testing in math and reading that has been going since 1970. This study illuminates many trends in mathematics education and supports the research mentioned above. It finds that “when parent educational level is examined, there is a positive correlational decline in NEAP scores on the mathematics portion of the test” (The National Center for Educational Statistics, as cited in Geist, 2010, p. 66).

Similar results were found when using PISA data. As the parents’ level of mathematics education increases so does their children’s scores on the mathematics section of the PISA. These tests also show that both the father and mother contribute to the attitude a child develops towards mathematics. The father’s level of math education had more effect than the mother’s on the child’s attitude and achievement. However, the mother’s level of support and encouragement around math learning has a measurable effect towards her child’s attitude and achievement levels on the NEAP (Scarpello, 2007).

Other research supports the findings of the PISA and Neap in relation to children’s perception of their parents’ attitudes. Hembree (2014) tested 575 students in Grades 9 to 12 and studied how their perceptions of others’ attitudes towards math correlated to their own math anxiety. He found a high correlation between parents’ attitude and levels of anxiety: $-.39$ for fathers and $-.37$ for mothers. This reveals the significant relationship between parental education level, parental attitude towards math and children’s attitude

and ability in mathematics. Scarpello and Turner et al. found “a link between parental attitudes towards mathematics, educational level and their child’s level of math anxiety” (as cited in Geist, 2010, p. 26). Attitudinally, parental disinterest or fear of math; and educationally, a low level of parental mathematics education; leads to increased levels of mathematics anxiety in those parents’ children.

We can see that unfortunately attitudes towards math are shaped well before college and that by the time one becomes an adult a negative attitude may already be set. As the study of mathematics anxiety progressed many researchers looked to younger and younger subjects looking for antecedent conditions of the construct.

Measures of Math Anxiety

With this aim in mind researchers in the departments of neuroscience, psychiatry and behavioural science at the University of Colorado and Stanford teamed up “to develop standardized measures of math anxiety in young children and to then examine the relationship between anxiety and achievement in 7 to 9 year old children at one of the earliest stages of formal math learning” (Wu et al., 2012, p. 889). They first assessed the achievement and aptitude of their subjects using standardized measurement tools—the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The focus was on only second and third grade students resulting in data that was more narrowly focused and would support their research goals; the study of math anxiety and its effects on young learners. One major improvement over earlier studies was that this group “assessed and controlled for trait anxiety in order to remove the effect of general anxiety, an important issue that previous studies in children have overlooked” (Wu et al., 2012, p. 901).

Wu et al. (2012) also created a new measurement tool specifically for the age group they were targeting. They based their tool – the Scale for Assessing Early Mathematics Anxiety; SEMA – on the MARS and MARS-E an elementary school version of the MARS. Other studies have also adapted the MARS to measure younger participants but Wu and colleagues found none that were appropriate for measuring second and third grade students at their level of learning; namely “addition, subtraction, number patterns, and spatial reasoning in a problem solving context appropriate for second and third graders, based on the curriculum recommended by the National Council of Teachers of Mathematics. They went on to develop SEMA to be grade appropriate in order to analyze the effect of math anxiety on this young population of learners.

Wu et al. (2012) tested 162 children from the San Francisco area; 86 in second grade and 76 in third grade, 90 boys and 72 girls. One must keep in mind that earlier studies did find that standardized tests such as the WIAT-II and WASI have been shown to raise anxiety and therefore decrease test scores of participants with math anxiety. This study however controlled for both trait anxiety and full scale IQ by using hierarchical regression analysis. After controlling for these factors, the researchers still found that math anxiety was still significantly and negatively correlated with achievement levels. They also found that trait anxiety had little effect on math achievement (Wu et al., 2012).

The SEMA was designed to measure mathematical anxiety’s effect on both mathematical reasoning and on numeric operation, and it was found that “math anxiety has a significantly stronger effect on Mathematical Reasoning” (Wu et al., 2012, p. 6) than on numerical operation. This indicates that the students with math anxiety were less impacted when performing simple operations but felt more anxiety and were affected by it more extremely when asked to apply their mathematical skills to more abstract or real world

problems. I have seen this in my own classroom. Students become agitated or avoidant when asked to perform problems that require reasoning over simple addition or subtraction questions, even if the underlying operational skill is the same. This has been reported by others in research on math anxiety as well; the

effects of math anxiety become more pronounced as problems become more difficult. That is, individuals with high levels of anxiety performed significantly worse than the lower-anxiety groups on the more difficult problems, and performed similarly to the other groups on the easier problems. (Ashcraft, M. H. and Krause, J. A., 2007, p. 245)

This “may explain why Thomas and Dowker (2000) and Krinzinger et al. (2009) did not find a relationship between math anxiety and basic calculation ability” (Wu et al., 2012, p. 7). These findings follow from the theory that math anxiety affects working memory (Ashcraft, 2002). As problems become more abstract working memory is more taxed.

It is worth mentioning here that it is not only performance on standardized tests that is affected by math anxiety (Faust et al. 1996). Faust et al. found that participants with math anxiety performed more slowly and made more mistakes than participants without math anxiety on complex two-digit addition questions under test conditions, but when given pencil and paper and unlimited time their performance increased. .

Today’s Dominant Theory

Through this review of literature on mathematics anxiety it has become evident that there is a dominant theory about the construct and that two themes prevail. First, Ashcraft et al. (2002; 2007) found that participants with math anxiety show little difficulty with simple mathematical operations, and that math anxiety significantly affects those who

suffer with it only when the questions become complex. Second, researchers theorize that math anxiety impedes performance by negatively impacting working memory (Wu et al., 2012). The dominant theory of mathematics anxiety “claims that math anxious individuals have difficulty with complex mathematical problem solving because math anxiety induced ruminations occupy their working memory” (Maloney et al., 2010, p. 293).

Maloney et al (2010) have questioned this theoretical position. Individuals with mathematical disabilities such as developmental dyscalculia¹ have been shown to have difficulty with not only mathematical processing but also basic number tasks such as comparing amounts, subitizing, and enumeration. This suggests the possibility that problems seen in higher level math skills may be due to lower level mathematical processing skills. Maloney et al. set out to determine if skill deficits in persons with math anxiety were correlated to basic numeric processing skills. Undergraduate participants were asked to name the number of objects shown on a screen as quickly as they could. For a range of 1–4 items responses are fast and accurate. This skill of instantly understanding the total amount in a small group is called subitizing. For five or more items response times typically increase and accuracy decreases as the number of items increases. This is called counting. A “deficit in either the subitizing or counting range among individuals with math anxiety would provide evidence that highly math anxious individuals not only have a difficulty with high level mathematical processing but also a difficulty with basic numerical processing” (Maloney et al., 2010, p. 294). Maloney et al. go on to explain that these two subtests of enumeration are thought to use working memory differently. Counting uses

¹ Typically understood to be a developmental disorder, people with dyscalculia experience difficulty in learning or understanding numbers, learning how to manipulate numbers, and learning math facts (Wikipedia, 2015).

more working memory than subitizing, which allows this research to test the working memory component of the dominant theory.

Besides being tested for enumeration speed and accuracy, participants were tested for their working memory by recalling sequences of letters and numbers in reverse order. They were then given the Abbreviated Math Anxiety Scale (AMAS; REF) to determine their levels of math anxiety. This study found that highly math anxious subjects performed significantly worse in the counting range but not on the subitizing range of the enumeration task. This finding is contradictory to the current dominant theory that math anxious individuals only have difficulty with more challenging math questions. “Individuals with math anxiety do, in fact, have a basic numerical processing deficit . . . [and] contrary to existing hypotheses, the effects of math anxiety extend to numerical processing tasks that are more basic than single digit arithmetic” (Maloney et al., 2010, p. 296).

This experiment supported the second main idea of the dominant theory; that there is a decrease in working memory capacity when math anxious individuals are performing math tasks. If working memory capacity available to perform mathematical tasks is limited by ruminations induced by math anxiety, then one would expect to see a deficit in performance in counting but not subitizing (Maloney, et al. 2010). This is exactly what was shown in this research.

The School System

Studies of math anxiety found that it indeed begins early on. Both my experiences as a teacher, and reviewed research, support the idea that many children develop negative attitudes towards math very early in life, before entering school (Geist, 2010). As preschoolers, children begin to construct meaning through experience. Mathematical

concepts such as correspondence, order and sequence, classification and addition begin when young children interact with the environment and the adults around them. Research “strongly suggests that children’s experiences at home or preschool form the foundation for mathematical learning in school” (LeFevre et al., 2009, p. 55).

Upon entering school there is a shift away from an exploratory, child centred learning style to a focus on teacher led lessons and the use of textbooks. Rote learning and a focus on quick recall of memorized facts can “undermine the child’s natural thinking process and lead to a negative attitude towards mathematics” (Geist, 2010, p. 24). The move to high stakes methods of learning and testing for knowledge increase levels of anxiety.

As evidenced from the reviewed literature it seems that there is a kind of feedback loop at work in individuals suffering from mathematics anxiety (Wu, Barth, Amin, Malcarne, & Menon, 2012). Their performance decreases as time pressure and difficulty of the questions increases. This leads them to perform poorly on standardized tests, which almost always have time pressure and arrange questions according to increasing difficulty. Poor scores affect their self-perception around math ability and lead to an avoidance of math courses in the future. This leads to an increase in math anxiety and more avoidant behaviours. Further, these individuals affect the next generation as parents and teachers of mathematics whose own anxiety is projected onto young learners in the home and classroom.

Of equal importance are findings that students’ perceptions of math teachers’ attitudes have a greater negative effect than their own parents’ attitudes (Geist, 2010). Knowing this and that elementary math teachers have the highest levels of math anxiety among college majors it would seem we have identified another major area of concern in

our education system. Public school teachers need to be confident in their math skills and need to project this confidence in their teaching.

Stodolsky (1985) made a case for how the instructional style typically linked to a subject area influences students in later life in terms of their belief about the dissemination of knowledge. She uses the example of graduate students and faculty in the psychology department at the university in which she works who often ask for advice with the use of statistics. The questions are often framed in the format of “tell me what to do” whereas a student “does not enter the psychology professor’s office and say, ‘Tell me Piaget’” (1985, p.125). When seeking advice in mathematics the seekers assume that:

(a) they don’t have the needed knowledge; (b) the way to obtain it is from and expert or knowledgeable person; (c) they are not expected to have tried to figure it out on their own, (as for example, by reading a book); and (d) the conversation will be one way: Knowledge will flow from the expert to the novice; little two-way or co-equal dialogue can be expected.

In contrast, the students in the psychologist’s office assume that: (a) they have enough knowledge to engage in conversation; (b) there are multiple ways of knowing, including reading, research, reflection, and seeking knowledge and help from others; (c) they can try to solve the problem or resolve the confusion before the meeting (e.g., by reading in a variety of sources); and (d) the conversation will be two way; the expert will know more and take the lead but the student will be able to contribute. (Stodolsky, 1985, p. 125)

Here we see how the typically top down teaching style associated with elementary school math instruction (Friesen, 2006) disables adults in their ability to gain mathematical knowledge later in life.

Beginning in the early years, math is taught through memorization of facts and high stakes testing. “It is often taught as if all the students are not just similar, but identical in terms of ability, preferred learning style, and pace of working” (Boaler, 2002, p. 7). Although there is little empirical research “on the effects and efficacy of times testing as an instructional approach . . . we do know that adding time requirements to tasks does increase anxiety, decrease accuracy and create a negative attitude toward the subject matter” (Geist, 2010, p. 26).

Research has also found that certain teaching styles resulted in avoidance, a precursor to math anxiety. Ashcraft (2002) found that when interviewing his participants, they reported that “public embarrassment in math class contributed to their math anxiety” (p. 184). Turner et al. (2002) show this fear of embarrassment is directly linked to teachers who demand excellence but offer little support through instruction; become annoyed when students give incorrect answers; and hold the students responsible for their incomplete understanding. So it would seem that math anxiety does not arise from the subject itself but from the way it is introduced to students in high pressure, pedagogically unsound ways.

Consequences of Math Anxiety

In our increasingly technological world we must understand the consequences of mathematics anxiety in order to successfully lobby for change to combat it. Many researchers including Hembree (1990) and Ashcraft (2002) cite the extensive research on the consequences of math anxiety on students and society. They both agree that the most common consequence is that those who are highly math anxious avoid mathematics. These people take fewer math courses. Because of this avoidance, those with math anxiety end up with lower levels of math competence. “They are exposed to less math in school and

apparently learn less of what they are exposed to” (Ashcraft, 2002, p. 182). This creates a testing problem. Lower scores on standardized tests for those who are highly math anxious could be a result of their low competence rather than anxiety around math testing. In order to discover whether or not it is competence or anxiety at play Faust, Ashcraft, and Fleck (1996) tested subjects on untimed math questions and then again on-line and timed with the same questions. The time pressure increased anxiety and lowered scores whereas the untimed pencil and paper version did not solicit physiological symptoms of stress and the participants scored higher.

Highly math anxious individuals also have a strong negative attitude towards math and see themselves as poor in the subject regardless of evidence to the contrary (Geist, 2010). For those with math anxiety, motivation for and self-confidence in math have a strong negative correlation of between $-.47$ and $-.82$ (Ashcraft, 2002).

It cannot be overstated that today's world relies heavily on mathematics, math anxiety and the avoidance of math that it causes must be remedied.

Treatment Methods

Research has found a high level of mathematics anxiety in university students (Hembree, 2014) and that two thirds of American adults report fearing math (Furner and Duffy, 2002). Other research has found that on average one in three younger students feels anxiety around mathematics (Organization, 2015). Parents, instructors and students need to be made aware of this both to normalize feelings for students and to move increase the use of instructional methods and parental supports to assist these students.

With initial research linking avoidance and poor performance in mathematics courses to mathematics anxiety, which was seen as a psychological problem, counselling

psychologists were “increasingly called upon to assist in designing and implementing plans for its treatment” (Betz, 1978, p. 441).

Ashcraft (2002) showed that math anxiety caused interference with working memory. One form of Cognitive Behaviour Therapy (CBT; REF) to help with this aspect of the construct would be to teach those with high math anxiety to inhibit their attention to those internal distractions. More practically, students can be given manipulatives and use technology to reduce the amount of working memory required during more complex mathematical work.

Students appear to be moved through to higher level math courses when they have not mastered the level they are on (Ashcraft, 2002). It seems obvious that moving students forward when they do not have a firm grasp of previous material will lead to poor performance and a dislike for subject matter due to frustration. Anxiety is shown to have little effect on whole number arithmetic, an area of math learned in the lower pressure environment of primary school. On the other hand questions involving mixed fractions, percentages, equations with unknowns, and factoring show increasing levels of anxiety effect (Ashcraft, 2002). If these areas of the curriculum were taught in the same low pressure environment, or if students were allowed to master each area before being moved on in a skill-arbitrary grade grouping, perhaps they would show little anxiety effect as well. One possible solution would be to group students by ability rather than age.

Changes in the Classroom

Teachers of math must have a comfort level with the material in order to teach it without experiencing anxiety themselves. Turner et al. (2002) linked certain teacher behaviour to high levels of math avoidance and anxiety in students. Teachers who

demanded excellence but did not assist students who were struggling with explanations or new ways of looking at the information; became upset with students who gave incorrect answers or; blamed students for their failure to understand caused their students to avoid mathematics. As Ashcraft (2002) suggests, such behaviours place students at risk for math anxiety. These teachers appear to need the most basic assistance with controlling their own emotions and displaying caring and empathy in the classroom.

While elementary school teachers were found to have high levels of anxiety towards math, Grade 9 to 12 math teachers' attitudes towards math also has large influence on levels of math anxiety among their students (Hembree, 2010). Teachers may be able to reduce their own math anxiety by taking more rigorous math education. Even if they are anxious they should be trained to not pass this anxiety on to their students. Statements that increase misunderstanding, fear, and anxiety such as "I was never good at this," "you are either good at math or you aren't," and "I'm not sure what this has to do with anything in the real world" must be eliminated from classroom dialogue.

Hooker (2013) found that math teachers' own anxiety with math is related to high anxiety in students (Hooker, 2013). It would seem one important path towards reducing the overall problem of high math anxiety in students is to train teachers to teach math more effectively, which would include alleviating their own anxiety around it and possibly increase their competency. There are many strategies teachers can use to prevent and reduce mathematics anxiety in themselves and thus in their students. Modern, effective pedagogy can change the attitudes of students and make learning math more relevant and enjoyable. More time in university should be spent on basic math and how to teach it. It is the common view in mathematics pedagogy that "mathematical proficiency is developed through five interwoven and interdependent strands: conceptual understanding, procedural

fluency, strategic competence, adaptive reasoning and productive disposition” (Friesen, 2006, p. 2). Teachers must be well versed in this understanding of math learning and base their practice on addressing each strand—not just procedural fluency. Friesen calls the American teaching script model of demonstration, repetition, and individual practice a misunderstanding of mathematics (2006). I have often felt this way myself both as a teacher and learner of math.

As stated earlier, when researchers removed the time pressure from highly math anxious subjects they performed better than on timed versions of the same test (Faust, Ashcraft, & Fleck, 1996) and showed lower physiological symptoms of anxiety. This would lead one to believe that the removal of time restrictions on tests in the school setting could alleviate the anxiety of students and allow them to experience success. This could have the secondary benefit of then having students become more willing to move on into higher level math courses.

A variety of modern assessment techniques can be implemented within the classroom to reduce pressure and anxiety. High stakes testing has been shown to increase anxiety and lower accuracy (Wu et al., 2012). “Journal writing, self-reflections, portfolios, and interviews/ observations are just a few alternatives that can take the pressure off the student to always perform well on a right or wrong paper-and-pencil test” (Furner and Duffy, 2002, p. 69).

The PISA 2012 asked students about formative assessment in their classrooms. How often does the teacher give feedback on their strengths and weaknesses? Does the teacher go on to suggest ways for individuals to improve? Students who “reported that their teacher practices these teaching methods extensively reported less anxiety towards mathematics” (Organization, 2015, p. 4). Formative assessment must be intentionally built

into the instructional design of student learning from the beginning by teachers who have been trained to plan and teach this way. It “provides learning scaffolds and feedback to the student and to the teacher. Multiple means of expression and assessment enable both teachers and students to assess what they currently know and to identify and plan the required next steps” (Friesen, 2006, p. 5) for further learning.

Researchers’ Kamana and Wong (1993) taught students to use positive internal dialogue to increase their positive feelings about their math ability. Students were trained to replace defeating internal dialogue; statements like “I can’t do this” with positive statements like “I am doing my best”. They also used internal dialogue to remind themselves to go slowly and to plan for success.

Finish Case Study

Perhaps a look at Finland’s education reform can highlight successful changes that have been made at a systemic level. Finland was referred to in the OECD’s PISA 2012 report as a country in the top performers and lowest math anxiety. In 1971, in order to move their economy to a high tech base as they had little in natural resources, Finland began an educational reform that has moved them from the middle of the pack, where the US currently sits, to a world leader in science, math and reading among western countries according to PISA results (Abrahms, 2011). They have made teaching a desirable profession. Reduced class size, high pay for teachers and a mandatory master’s degree for teachers were introduced. Teachers earn 102% of the average master’s degree holder and only one in 10 applicants is selected to proceed with teacher education. Working conditions and pay have attracted the best math minds to become teachers. A decrease in math anxiety and corresponding increase in math proficiency is what one would expect from these

measures. The research reviewed here has shown that those who pursue math at a high level have little math anxiety (Hembree, 2014) and that math anxiety is passed from highly math anxious teachers to their students.

Finland has also given up anxiety inducing systems within the schools; systems that affect students and teachers. National standardized tests were abandoned in the 90s as was the school inspection program (Abrams, 2011). Much to the chagrin of conservative politicians' teachers and students' performance increased according to 2000 PISA results. Anxiety is reduced in the schools through play. The average Finish elementary school student has 75 minutes of play time and:

students in grades one through nine spend from four to eleven periods each week taking classes in art, music, cooking, carpentry, metalwork, and textiles. These classes provide natural venues for learning math and science, nurture critical cooperative skills, and implicitly cultivate respect for people who make their living working with their hands. (Abrams, 2011, p. 41)

Time to unwind, co-operative learning, and a chance to conceptualize math in real world settings with no time constraints: all strategies suggested in the research that has been reviewed here.

Summary of Chapter 2

Basic math skills are a predictor of one's life success; even more critical to employment opportunities than reading ability (Maloney et al., 2010). Even though this is true we see more and more students opting out of higher level mathematics courses ("Trends in higher," 2011) that will increase their career prospects. Indeed, "many

academically capable students prematurely restrict their educational and career options by discontinuing their mathematical training early in high school” (Meece et al., 1990).

One factor for this avoidance is mathematics anxiety (Maloney & Beilock, 2012); defined as “uneasiness or apprehension regarding mathematics” (Chavez & Widmer, 1982, p. 272). The earliest research on math anxiety found that a large percentage of college students suffered with the condition (Betz, 1978). Modern international testing has found that on average one in three students feels anxious about mathematics (Organization, 2015). Other research has found that two thirds of American adults report fearing math (Furner & Duffy, 2002). So, math anxiety is common and has serious consequences in our math dependent, technological world.

The review of current literature has shown that many factors affect the development of math anxiety. Gender is one factor linked to math anxiety. In most studies, across the entire span of research, females were found to have significantly higher levels of anxiety towards mathematics than their male counterparts (Betz, 1978, Organization 2015). Both Betz (1978) and Fennema and Sherman (1977) found this to be true from high school through university, with boys demonstrating a more positive attitude towards math than girls. This gender difference has mediating factors. Often females are treated differently by teachers. Jussim and Eccles (1992) found that many teachers attribute an innate talent for math to boys while attributing girls’ mathematical success to hard work and determination; and that these differing attitudes undermine confidence in mathematical ability and increase avoidance. Geist (2010) also found that girls were often overlooked in math classes. Regardless of these mediating factors the PISA 2012 found that girls experienced higher levels of anxiety in all countries that participated (Organization, 2015).

Family also affects levels of math anxiety. Low socio-economic status of a student is correlated to higher math anxiety. The NEAP found that students who received a subsidized lunch scored lower on mathematics assessments (Geist, 2010). Hembree (2014) also found that negative parental attitudes towards math increased the anxiety of children. A lower level of math education among adults in a household also correlates to lower NEAP math scores for students in that household (National Center for Educational Statistics, 2007). Research has found that when children grow up with parents who have a low level of math education or have negative attitudes towards math they do not receive the same pre-schooling, math based experiences in the home, and that it is precisely these early mathematical experiences that “form the foundation for mathematical learning in school” (LeFevre et al., 2009, p. 55).

The factors and predictors discussed above happen outside of the realm of schooling. However, many elements correlated to high levels of mathematics anxiety occur within the school system. Miller and Mitchell (1994) list mathematics teachers as one major contributor to math anxiety. Poor teaching skills; teachers who offer little support or become angry with students who do not understand what is being covered and then hold the students responsible for their lack of understanding builds anxiety around the subject matter in students (Turner et al., 2002). Ashcraft (2002) found that fear of embarrassment in math class contributed to anxiety in the subjects he interviewed. The reviewed literature has also shown that elementary teachers scored highest among college faculties for math anxiety on the MARS (Hembree, 1990). Poor teaching skills and high levels of math anxiety do not lead to a positive view of one’s math teacher. While a students’ parents’ attitude to math was found to be a strong positive predictor for math anxiety, a students’

perception of their teachers' attitude and ability was even more strongly correlated to high levels of math anxiety (Geist, 2010).

Besides the math teachers themselves, the school system and pedagogy of teachers also creates and maintains high levels of math anxiety. When one enters the school system there is a move away from exploration of math concepts to teacher led lessons and rote learning of procedures and memorized facts; a top down teaching style (Friesen, 2006). This pedagogical model leads to a negative attitude towards math (Geist, 2010). The OECD (2015) also found a strong correlation between evaluation methods and student levels of math anxiety and performance. Teachers who used formative assessment, providing feedback as part of assessment for learning; and did not publicly rank students on performance created students with lower levels of math anxiety (Organization, 2015). The removal of time constraints also reduced levels of math anxiety and increased accuracy (Geist, 2010).

According to Hembree (1990), the most telling indication in regards to high levels of math anxiety is the lack of enjoyment levels and low self confidence in middle and high school. Ashcraft (2002) and Geist (2010) also found that highly math anxious students have a negative attitude towards math and perceive themselves as weak in math, regardless of actual performance. Unfortunately, students' levels of enjoyment decrease steadily through elementary school (Geist, 2010).

Recommendations for the school system can be made that follow from the reviewed literature on mathematics anxiety. As research into the five strands of mathematics learning show, teachers must emphasize the importance of original, quality thinking over rote manipulation of formulas (Furner & Duffy, 2006) and accommodate for different learning styles (Maloney, 2012).

A variety of testing environments that remove social pressure and time restraints, and incorporate ongoing feedback and assessment for learning, will address some of the issues detailed above. As negative attitudes towards math are so highly correlated with high levels of math anxiety, educators must create positive experiences for students in their math classes. Social pressures must be reduced or removed from classroom practice as fear of embarrassment in math class contributes to anxiety (Ashcraft, 2002). As PISA 2012 found, ranking students increases anxiety. Classrooms where students perceive themselves to be at a lower level than their peers had higher levels of mathematics anxiety (Organization, 2015). Math must be made to be relevant (Abrams, 2011).

Furner and Duffy differentiate between strategies that reduce math anxiety and those that prevent it. They list suggestions from the National Council of Teachers of Mathematics from their Principles and Standards for School Mathematics for the prevention of math anxiety:

- accommodate for different learning styles
- create a variety of testing environments
- design positive experiences in math classes
- remove the importance of ego from classroom practice
- emphasize that everyone makes mistakes in mathematics
- make math relevant
- let students have some input into their own evaluations
- allow for different social approaches to learning mathematics
- emphasize the importance of original, quality thinking rather than rote manipulation of formulas
- characterize math as a human endeavor ("Principles and standards," 2000)

When it comes to the reduction of math anxiety they see it as a counselling role. They list strategies such as systematic desensitization, relaxation training, positive self-talk and “visualizations of successful math performance” (Furner & Duffy, 2002, p.70).

Researchers agree (see for example Maloney & Beilock 2012, Turner et al, 2002, Hembree, 1990) that the most common consequence of math anxiety is the avoidance of mathematics. This avoidance compounds math anxiety as the person then gains less experience and knowledge in math and scores lower on evaluations (Ashcraft, 2002). This avoidance of math limits one’s ability to partake in the current technological economy of the west (Maloney et al., 2010) and so has serious consequences for students’ futures. With rates as high as 33% of students feeling anxiety towards math (Organization, 2015) this is a serious problem that affects many people, and that therefore must be addressed by our educational system. As Furner and Duffy (2002) argue, educators “must prepare all students to compete globally in a world that relies heavily on using mathematics confidently” (p. 87).

CHAPTER 3

As this review of literature on mathematics anxiety has shown, there are many factors that contribute to mathematics anxiety: the “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” (Richardson & Suinn, 1972, p. 223).

As is evidenced by the review of literature, mathematics anxiety is a prevalent and important issue for today’s learners. The purpose of Training to Reduce Anxiety in Math (TRAM) is to make changes to the learning environment and teaching methodology to reduce mathematics anxiety of students. This is a replicable model that can be used by a wide range of educators.

In-service training has been shown to be an effective method of improving teaching standards. Swan and Swain (2010, p. 116) outlined the following features of successful training programs that TRAM incorporates.

- it is sustained over time (Cohen and Hill 1998)
- it is related to the local context in which the teachers operate (Cobb et al., 2003)
- it involves teachers in active and collective participation (Garet et al., 1999)
- it focuses on developing teachers’ knowledge of the content, the pedagogy and the underlying principles (Hammerness et al., 2005)
- it offers continuing support for teachers in translating new ideas into everyday practice (Lee & William, 2005)

The BCTF defines professional development as “a process of personal growth through programs, services and activities designed . . . to enhance professional practice” (British Columbia Teachers Federation, 2015). Teachers in BC will have six professional development days during the 2015/2016 school year. TRAM is a proposed professional development program for teachers in British Columbia that can take place during these six days. It will initially be offered in the lower mainland for ease of organizing training and mentors for participant teachers.

The proposed TRAM is designed for elementary generalists for three reasons that Hembree (1990) brings to light. First, because “high-anxious students took fewer high school mathematics courses and showed less intention in high school and college to take more mathematics” (p. 38) it is important to lower the anxiety of students before they enter high school and have the option of not taking further math courses. Secondly, when measuring math anxiety of K to 12 students, anxiety steadily increased to grade 10, then levelled off. It is therefore valuable to intervene early on this path of increasing anxiety. Lastly, elementary teachers of math were shown to have the highest levels of math anxiety among college faculties. By reinforcing best practice in teaching, and learning anxiety management tools, elementary teachers can lower their own anxiety and pass along less of it to their young students.

Research Design

This experimental project will analyze the correlation between teacher training and math anxiety levels. The levels of math anxiety of school populations not involved with the program will be the independent variable used to measure the level of effect the TRAM program has. The year before TRAM is implemented participant schools will have students complete the math anxiety survey to create a baseline for comparison. It is the purpose of this study to see if there is a significant difference in anxiety scores for those who have the TRAM and those who do not. Secondly it would be interesting to see if these anxiety rates reduce further over time. As school districts will be involved in this study, whole school populations will be recruited (but actual participation will be based on those receiving positive parental consent). These will be compared to individual classrooms within those schools. A consent form will be sent home to all students

explaining the research project, that data collection will be anonymous, and that participation is voluntary.

The Program

The review of literature has identified 6 factors linked to math anxiety that can be addressed through the school system. These will be the focus of the six workshops put on by TRAM. They are:

- Creating a supportive environment - “Focusing on what students can do, encouraging multiple outcomes, and being sensitive to past histories of frustration and failure” (Furner & Duffy, 2002, p.71) will allow a wider range of students to learn and enjoy mathematics.
- Assisting teachers in identifying and controlling their own mathematics anxiety.
- Removing the American Teaching Script from the classroom and moving to 5 strands – conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, productive disposition. (Furner & Duffy, 2002, p.71)
- Increased use of varied assessment, and the limiting of times testing.
- Use of counselling techniques in the class to reduce math anxiety that exists in learners.
- Involving caregivers in the learning of math.

Teachers will participate in workshops throughout the year designed to address these factors. The workshops will be collaborative in nature and be led by an expert in the area addressed that day. Each cohort will develop their own ideas on how to address issues affecting mathematics anxiety, through a guided inquiry led by that workshops leader. Below is an example of the types of interventions that could be devised during the workshop on removing the American Teaching Script from math lessons:

Table 1 Examples of Tasks to be Devised by Teachers

Classifying mathematical objects	Learners devise their own classifications for mathematical objects (e.g. shapes, numbers, symbols), and/or apply classifications devised by others. In doing this, they learn to discriminate carefully and recognize the properties of objects. They also develop mathematical language and definitions.
Interpreting multiple representations	Learners work together matching cards that show alternative representations of the same mathematical idea (e.g. words, pictures, symbols). They draw links between representations and develop new mental images for concepts.
Evaluating mathematical statements	Learners are given statements and are asked to decide upon their validity. (E.g. "Max gets a 10% pay rise, Mary gets a 5% pay rise, so Max gets the bigger pay rise".) When are they true? When are they false? Learners suggest their own examples and counterexamples.
Creating and solving problems	Learners are asked to devise their own problems for other learners to solve, using given constraints. When the 'solver' becomes stuck, the problem 'creators' take on the role of teacher and explainer. These activities exemplify the 'doing' and 'undoing' processes of mathematics.
Analyzing reasoning and solutions	Learners compare different methods for doing a problem, organize solutions and/or diagnose the causes of errors in solutions. They begin to recognize that there are alternative pathways through a problem, and develop their own chains of reasoning.

Small groups of participant teachers will be linked to a mentor. This teacher of mathematics will be available to guide inquiry and implementation during the time in between professional days. In this way the TRAM program will "offer continuing support for teachers in translating new ideas into everyday practice", one of the benefits of on-going professional development (Lee & William, 2005, p. 117).

Data Collection

A year before TRAM begins a call for volunteer teachers to participate will go out in September to public schools in the lower mainland (see appendix). Included in the application package is a math anxiety rating tool. This will be used at the end of the program to evaluate the correlation between the level of math anxiety in teachers and the level of math anxiety in their students.

A year before TRAM is implemented in the classroom, in schools with TRAM participant teachers will be given math anxiety questionnaires two times to create a baseline for the next year's study. The questionnaires will be identified only by classroom and not by individual.

By implementing changes to the six areas found to affect levels of math anxiety it is hoped that research will show TRAM results in a decrease in mathematics anxiety in participant classrooms. As the program continues, member teachers will add to an ongoing database of interventions developed during the workshops and tested in the classroom. Access to the database will be given to participants of TRAM once they complete the course.

Summary of Chapter 3

The review of literature revealed many factors that correlate with high levels of math anxiety. This chapter has presented an outline for a teacher training module to address math anxiety through classroom and school wide pedagogical approaches. A professional development model is to be used as it has been found to be highly effective (Swan & Swain, 2010). Teachers are actively involved throughout the year in improving their math teaching abilities within their local context. Mentors are assigned to participants in order to offer on-going support in increasing their knowledge of underlying principles of math education.

CHAPTER 4 CONCLUSION AND RECOMMENDATIONS

This review of literature on research into math anxiety revealed that this problem is prevalent and far reaching, affecting over one third of college, high school, and elementary school students. American adults have been shown to fear math and to have negative views of their mathematics education.

The most common result of high math anxiety is avoidance of math; by either avoiding future math courses in school or avoiding situations that involve mathematical thinking in life—yet 21st century learners must be able to face problems involving mathematics without fear or anxiety.

This paper started by posing the question, what school based practices can be used to reduce or prevent math anxiety? Math anxiety was found to be related to some elements from outside of the school system. Age, gender, and socio-economic are beyond the control of public education, but may be addressed tangentially by schools. Is the treatment of girls and boys so different in schools that they are in fact the cause of the gender differences in the experience of math anxiety?

Factors responsible for high math anxiety that involve the school system directly such as the attitudes of teachers, teaching methodology, and assessment techniques can be challenged and changed. Training such as the proposed TRAM course to be run over a year's professional development days can be initiated and tested in order to make these important and relevant changes to our educational system.

Recognizing of math anxiety's effects on the school system and economy brings into focus the problem's importance. The effects of innumeracy and a fear of math permeate through society on many levels—from employers and university research, to pre-school children and their parents. Teacher training must address it. TRAM is one suggested

small step in helping teachers already in the classroom. Another course of action could be to have specialist teachers of math employed earlier within schools. Administrators at district and school levels can turn some of their focus on math anxiety through professional development and strategic planning. Removing the American teaching script of rote learning must be high on the agenda of the education system as it is in direct conflict with best practices in math education.

With increased awareness about math anxiety, teachers can create learning environments where more students are successful with mathematics—research shows that a teaching style that presents math as boring and irrelevant is a major cause of mathematics anxiety. Creating classrooms where math is relevant, fun, and hands on will engage learners and allow them to flourish. High stakes testing can be replaced with more varied assessment techniques; assessment that involves a partnership between teacher and student, assessment that shows a student where they are and what they need to do to improve.

“By using modern, research based pedagogy and training teachers in sound, research based methodology for math instruction, schools can reduce the anxiety many students feel towards mathematics, the first step to what must be a multi-generational approach to tackling this problem. One hopes that this approach could lead to a future where knowing “that $15 - 8 = 7$ is as basic as knowing how to spell cat” (Ashcraft, 2002, p. 181).

Today, counsellors who understand the high level of math anxiety in students can use this knowledge to assist their clients. Students suffering from math anxiety may need extra support in reaching their academic goals. These students may also be limiting their career

options because of a fear of mathematics but with proper treatment and support, be able to succeed and expand those options.

A move away from textbooks, to a child centered approach, where the classroom teacher designs the math lessons has a positive effect on both the teacher and learner. “Focusing on what students can do, encouraging multiple outcomes, and being sensitive to past histories of frustration and failure” (Furner and Duffy, 2002, p. 71) will allow a wider range of students to learn and enjoy mathematics.

Teaching for mathematical proficiency requires that the teachers design a learning environment that provides a solid foundation of detailed knowledge and clarity about the core concepts around which that knowledge is organized to support effective learning. The type of practice required to promote mathematical proficiency stands in sharp contrast both to transmission-type pedagogies and to discovery-type pedagogies. Rather, the type of practice that builds mathematical proficiency requires that students be brought into a place of deep understanding through a collaborative relationship between different information and facts students are learning, between the procedures they are learning and the underlying concepts, through robust, rich problems and investigations that reach deep into fundamental mathematical ideas. (Friesen, 2006, p. 9)

In order to design lessons that meet the above criteria, a teacher must have a deep understanding of the material. A move away from textbooks to teacher designed math units and lessons will necessitate teacher understanding.

Students will then have more opportunity to make sense of the subject as each of the five strands is addressed, especially when taking time to gain a conceptual

understanding through experimentation and personal matrices before moving on to procedures.

Group-work on complex problems where members are free to experiment with and share their strategies, allows for learning strategic thinking. Defending their ideas and journaling about them allow reflection and challenge to their thoughts in a constructive way. Friesen explains that she is not claiming “practice and skill building is not necessary when learning mathematics—they are. Rather when students lose sight of how and what they are practicing relates to the bigger math idea then reasoning and understanding is forfeited.” (2006, p. 5).

Counselling techniques can be adopted by teachers to reduce math anxiety. Hackworth (1992) suggests discussing and writing about feelings around math. As with any form of anxiety, one must be able to recognize its onset before it becomes unbearable. “In order to reduce math anxiety, learners must first recognize when the panic starts... realize when they are anxious about the math they are doing” (Furner and Duffy, 2002, p. 70). They must learn to read the queues of anxiety, which may range from sweaty palms and racing heart to mounting negative internal dialogue.

Students need to be assisted in developing ways of calming themselves. These could include breathing and mindfulness, visualization or relaxation breaks. These life skills have the added benefit of being transferrable to other anxiety inducing situations. Teachers can allow students to remove themselves from frustrating situations and teach them how to recognize the onset of frustration before it takes over.

Counsellors and teachers must also involve parents in tackling math anxiety. Homework in the form of games and involvement in math based activities in the home and community such as shopping and cooking, building, and banking relate mathematics to real

life and make it practical. Parent education on the importance of math based activities in the home can be disseminated from pre-school through to high school. Parents need to be made aware of the seriousness and pervasiveness of mathematics anxiety among children and youth, and the ramifications this has for future success.

Teachers and pedagogy clearly affect students' levels of math anxiety (Miller and Mitchell, 1994). There are many ways to improve the classroom for math learners. A nurturing atmosphere must be present in classes to prevent anxiety. Teachers have been identified as suffering from above average math anxiety (Hembree, 2014) and this must be addressed within the teacher training system. The current model of demonstrate, repetition and practice does not address the five strands of mathematics learning adequately and a new model that incorporates conceptualization, strategic thinking and mathematical reasoning as well as the commonly focused on procedural aspects of math must be adopted in the main. Removing time pressure from assessments reduces anxiety and increases accuracy. PISA 2012 found that formative assessment practices in the classroom greatly reduced math anxiety in the 39 countries they looked at (Organization, 2015). Clearly assessment for learning must also become common practice in math classrooms. Counselling techniques can be used to prevent the formation of math anxiety and reduce math anxiety that is already present in many learners. Finally, the school can involve parents in making math relevant and introducing it to children at an early age.

As the research shows, parents' attitudes towards math have a strong influence on their children's attitudes towards math and to their levels of math anxiety, and in the end, to how well they do and how far they go with mathematics. Pre-school and extra-curricular parent education on math anxiety and the importance of early math experiences to one's understanding of concepts can be addressed in a manner similar to literacy. Literacy has

been promoted in and out of school and linked to future success. Parents and society as a whole can be made aware of the importance of numeracy in the same way.

The long term effect of decreasing math anxiety will be to decrease its most damaging effect: the avoidance of mathematics in school and in life.

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APPENDIX A

Table 1
Response Percentages for Items in the Math Anxiety Scale (reproduced from Betz, 1978)

Categories	Item	Response		
		SA or A	U	D or SD
1	It wouldn't bother me at all to take more math courses.	39	26	35
		37	19	44
		49	22	29
2	I have usually been at ease during math tests.	41	19	40
		33	12	55
		49	14	46
3	I have usually been at ease in math courses.	56	17	27
		48	14	38
		63	14	23
4	I usually don't worry about my ability to solve math problems.	48	17	35
		24	15	61
		45	15	40
5	I almost never get uptight when taking math tests.	35	19	46
		25	7	68
		29	12	59
6	I get really uptight during math tests.	46	13	41
		63	8	29
		53	14	33
7	I get a sinking feeling when I think of trying to solve hard math problems.	35	23	42
		58	20	22
		35	21	44
8	My mind goes blank and I am unable to think clearly when working mathematics.	20	19	61
		31	15	54
		20	14	66
9	Mathematics makes me feel uncomfortable and nervous.	27	19	54
		51	12	37
		22	15	63
10	Mathematics makes me feel uneasy and confused.	28	16	56
		45	18	37
		23	16	61

Note. Under each response category, the top, middle and bottom percentages were obtained in the Psychology 1 (n = 182), Math 1 (n = 122), and Math 2 (n = 348) subject groups, respectively. Response categories are as follows: SA or A = strongly agree or agree; U = undecided; D or SD = disagree or strongly disagree.

From Betz, 1978

APPENDIX B

Math anxiety testing tool to be given to teachers prior to beginning the TRAM and to students in TRAM participant teachers in October and May of the year before TRAM and the year of TRAM.

Betz Math Anxiety Scale

Item		Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
1	It wouldn't bother me at all to take more math courses.					
2	I have usually been at ease during math tests.					
3	I have usually been at ease in math courses.					
4	I usually don't worry about my ability to solve math problems.					
5	I almost never get uptight when taking math tests.					
6	I get really uptight during math tests.					
7	I get a sinking feeling when I think of trying to solve hard math problems.					
8	My mind goes blank and I am unable to think clearly when working mathematics.					
9	Mathematics makes me feel uncomfortable and nervous.					
10	Mathematics makes me feel uneasy and confused.					

From Betz, 1978

APPENDIX C

Copy of the consent form to be sent home to students participating in the data gathering component of TRAM

Consent Form for Participation in a Research Study

Training to Reduce Anxiety in Math (TRAM) A Teacher Training Program to Reduce Mathematics Anxiety

Description of the research and your participation

Your child is invited to participate in a research study conducted by the Ministry of Education. The purpose of this research is to study changes to the learning environment and teaching methodology that propose to reduce mathematics anxiety of students.

Your child's participation will involve completing four questionnaires over the period of this year and next. Your child's classroom teacher will be participating in mathematics teaching professional development and measuring the success of the training to reduce math anxiety among students in the class.

Risks and discomforts

There are no known risks associated with this research.

Potential benefits

Your child will benefit from their teacher's increased proficiency in math teaching. This research may help us to understand how to reduce math anxiety in the classroom.

Protection of confidentiality

Questionnaires will not be attached to the name of the participant. Your child's identity will not be revealed in any publication resulting from this study.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Cameron Robertson at City University at 217.223.5432, ext. 2222. If you have any questions or concerns about your rights as a research participant, please contact the City University Institutional Review Board at 217.228.5432, ext. 3106.

Consent

**I have read this consent form and have been given the opportunity to ask questions.
I give my consent for my child to participate in this study.**

Participating Child's name _____ Date: _____

Signature of Legal Guardian _____

A copy of this consent form should be given to you.