Correlation Among Math Anxiety, Attitudes Toward Math, and Math Achievement in Grade 9 Students: Relationships Across Gender

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Abstract

This research evaluated (a) the correlation between math anxiety, math attitudes, and achievement in math and (b) comparison among these variables in terms of gender among grade 9 students in a high school located in southern Ontario. Data were compiled from participant responses to the Attitudes Toward Math Inventory (ATMI) and the Math Anxiety Rating Scale for Adolescents (MARS-A), and achievement data were gathered from participants' grade 9 academic math course marks and the EQAO Grade 9 Assessment of Mathematics. Nonparametric tests were conducted to determine whether there were relationships between the variables and to explore whether gender differences in anxiety, attitudes, and achievement existed for this sample. Results indicated that math anxiety was not related to math achievement but was a strong correlate of attitudes toward math. A strong positive relationship was found between math attitudes and achievement in math. Specifically, self-confidence in math, enjoyment of math, value of math, and motivation were all positive correlates of achievement in math. Also, results for gender comparisons were nonsignificant, indicating that gender differences in math anxiety, math attitudes, and math achievement scores were not prevalent in this group of grade 9 students. Therefore, attitudes toward math were considered to be a stronger predictor of performance than math anxiety or gender for this group.

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CHAPTER ONE: INTRODUCTION TO THE STUDY

A major educational focus in the 21st century is on numeracy skills related to mathematics and science. Numeracy skills and achievement in mathematics, in particular, have received much global attention and concern. Major advancements in the technology sector have resulted in the need for an educated workforce in the fields of mathematics and science (Ashcraft & Krause, 2007). As well, the importance and need for basic numeracy skills of the general public are imperative in functioning in everyday life.

Efforts to measure the mathematics achievement, attitudes, and affect of students have produced many national and international large-scale standardized assessments. In Ontario, the Education Quality and Accountability Office (EQAO) develops and administers standardized mathematics tests to evaluate and report on the mathematics achievement of grade 3, 6, and 9 students in the province. Results from the provincial tests show no substantive changes in math achievement among Ontario's elementary school students over the past 5 years and point to significant challenges for grade 9 applied math students (Mullis, Martin, Foy, & Arora, 2012). Furthermore, results from the large-scale assessments are used to report "gender gaps" in mathematics achievement. Studies based on these results indicate small gender differences in performance and participation in mathematics, seen in upper high school and postsecondary education, in favour of males (Fennema & Sherman, 1977, 1978; Hanna, 1989; Hyde, Fennema, & Lamon, 1990; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Lindberg, Hyde, Petersen, & Linn, 2010).

In an attempt to explain the differences in achievement levels among students, extensive research on predictors of math achievement has focused primarily on mathematics anxiety (Hembree, 1990; Richardson & Suinn, 1972; Wigfield & Meece, 1988) and attitudes toward mathematics (Aiken, 1970; Fennema & Sherman, 1977, 1978; Ma, 1997; Ma & Kishor, 1997; Neale, 1969; Tapia & Marsh, 2001, 2004a). One of the goals of this study was to investigate the correlation among math anxiety, attitudes toward mathematics, and mathematics achievement among grade 9 students. Of importance was to identify which predictor, math anxiety or attitudes towards math, is the best indicator of achievement in mathematics. In addition, math anxiety, math attitudes, and math performance in males and females were analyzed to see whether gender differences exist in relation to these variables.

Background of the Problem

Mathematics anxiety involves feelings of apprehension and tension concerning the manipulation of numbers in academic, private, and social environments among students and nonstudents (Richardson & Suinn, 1972). The negative effects of mathematics anxiety include psychological, behavioural, and cognitive consequences. For example, math-anxious individuals may exhibit psychological reactions such as increased pulse rate when exposed to math activities (Faust, 1992; Morris & Liebert, 1970); have negative attitudes toward, and a fear of, mathematics (Neale, 1969); and experience a lower working memory capacity in processing arithmetic and math tasks (Ashcraft & Kirk, 2001). Some global effects of math anxiety have been reported: Mathematics anxiety may prevent individuals from passing fundamental mathematics courses or result in their earning lower grades in math classes, which may hinder them from pursuing advanced mathematics courses or careers in mathematics or the sciences (Hembree, 1990; Richardson & Suinn, 1972). The debilitating effect of math anxiety on math performance has caused an avoidance of the study of mathematics, thereby reducing career options and eroding development in science, technology, engineering, and mathematics (Hembree, 1990).

Much like mathematics anxiety, attitudes toward mathematics influence success in the subject. “Attitudes toward or beliefs about mathematics are thought to be important objectives of instruction . . . [and] positive attitude toward mathematics is thought to play an important role in *causing* students to learn mathematics” (Neale, 1969, p. 631). Previous learning experiences related to mathematics shape students’ attitudes towards math beginning from a very young age (Aiken & Dreger, 1961). These experiences are not limited to experiences in the classroom or teacher attitudes; they also include socioeconomic factors and parental attitudes and beliefs, which also play a crucial role in the value students place on learning mathematics (Eccles & Jacobs, 1986; Geist & King, 2008; Scarpello, 2007). Consequently, once negative attitudes are developed, they may persist into adulthood, encouraging mathematics avoidance behaviour (Ma & Kishor, 1997; Neale, 1969). When students have positive attitudes towards math, they put forth a greater effort and have greater persistence and determination in completing mathematical tasks (Dutton, 1956; Ma, 1997).

Much attention has been given to gender differences in mathematics achievement. Small gender differences in mathematics performance have been reported in various studies, sometimes favouring boys and sometimes favouring girls (Lindberg et al., 2010). Although the differences have diminished substantially, small differences favouring males exist in tasks requiring higher cognitive functioning and advanced mathematics courses in upper high school and postsecondary levels (Hanna, 1989; Hyde, Fennema, & Lamon, 1990; Hyde, Fennema, Ryan et al., 1990; Lindberg et al., 2010). Stereotypes of math as a male domain persist in our society (Eccles, 1987; Fennema & Sherman, 1977; Hyde, Fennema, Ryan et al., 1990). This stereotype may elicit negative attitudes towards mathematics and lessen females' willingness to achieve in mathematics (Hyde, Fennema, Ryan et al., 1990). In general, social stereotypes influence the importance that males and females place on doing well at any particular activity (subjective task value), which may account for gender differences in achievement choices in mathematics (Eccles, Adler, & Meece, 1984).

It is important to provide operational definitions for concepts used in research. The following section will provide definitions for math anxiety, math attitudes, math achievement, and math stream.

Math Anxiety

Anxiety is an ominous construct. Two aspects of anxiety have been distinguished as "trait" and "state" anxiety. Trait anxiety is a tendency to feel anxious across a wide range of situations, whereas state anxiety is feeling tense or nervous in specific personally stressful or fearful situations (Sorg & Whitney, 1992). High state anxiety contributes to poor performance more so than high trait anxiety.

Furthermore, two prominent types of anxiety within school are mathematics anxiety and test anxiety. Many definitions of math anxiety exist. Richardson and Suinn (1972) define mathematics anxiety 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" (p. 551). Generally, math anxiety is an intense emotional feeling of fear and frustration that people have about their ability to understand and do mathematics.

Brush (as cited in Hembree, 1990) described mathematics anxiety as "subject-specific test anxiety" (p. 34), and Richardson and Woolfolk (as cited in Hembree, 1990) stated it was a "general dread of mathematics, and of tests in particular" (p. 34). Thus, test anxiety is anxiety specifically in testing situations regardless of the subject (I. G. Sarason, 1957).

Two components of test anxiety are identified as affective and cognitive. Affective anxiety refers to the emotional component of anxiety, feelings of nervousness, tension, dread, fear, and unpleasant physiological reactions to testing situations. Cognitive anxiety refers to the worry component of anxiety, which is often displayed through negative expectations, preoccupation with and self-deprecatory thoughts about an anxiety-causing situation (Morris & Liebert, 1970; Wigfield & Meece, 1988). The cognitive worry factor of general test anxiety is reported to correlate negatively with test performance (Liebert & Morris, 1967), while for measures of math anxiety, it is the affective factor that correlates negatively with mathematics performance (Wigfield & Meece, 1988).

Math Attitudes

Aiken (1970) defined the term attitude as a "learned disposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (p. 551). Attitudes toward mathematics are defined by Neale (1969) as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (p. 632). Ma (1997) offered a more specific definition of attitudes toward mathematics "as either positive or negative responses, in terms of importance, difficulty, and enjoyment, when learning algebra, geometry, and trigonometry" (p. 222). In general, math attitudes are beliefs and perceptions that people have regarding mathematics, its relevance in their lives, and their ability in the subject area.

Math Achievement

For the purposes of this study, math achievement is defined as one or more of the following math results: EQAO Grade 9 Assessment of Mathematics and grade 9 final term math mark (based on coursework). These achievement results were obtained from the participants' math teachers and the district school board, with permission given by parents to use these results in the research.

Math Stream

Students entering secondary school have the option of taking applied or academic mathematics courses. "Academic courses develop students' knowledge and skills through the study of theory and abstract problems . . . [and] focus on the essential concepts of a subject and explore related concepts" (Ministry of Education, 2005, p. 6), whereas the "applied courses focus on the essential concepts of a subject, and develop students' knowledge and skills through practical applications and concrete examples" (p. 6). The curriculum for both levels is comparable, with three similar strands or general topics and one additional strand for the academic stream. Despite the similar overarching strands, the student expectations within each strand are different. Generally, academic level courses are considered to be more advanced, whereas the applied math course gives students more opportunities to experience hands-on applications of the concepts and theories they study.

Statement of the Problem

Mathematics seems to be a subject that many students dislike and avoid if possible. As a high school mathematics teacher, I have observed many students from grades 9 to 12, both males and females, enter my mathematics classroom with hesitation and fear. Often, they warn me of their lack of interest in the subject matter and the irrelevancy of mathematics to them. Some of the first words uttered to me by some of these students include “Just to let you know, I hate math,” “I am not good at math,” “Math is so hard,” or “Math is my worst subject.” Some attend math class as nonparticipating members, while others avoid coming to math class altogether. Their anxiety and negative attitudes towards math are quite evident and seem to be debilitating their efforts and performance throughout the course. Despite the prevalence of students with negative attitudes, I have also encountered students who have expressed positive attitudes towards math and seemed excited and willing to learn the subject. Students with positive math attitudes do not get as frustrated or give up as easily as students with negative math attitudes and generally put forth a greater effort (Dutton, 1956). These opinions and attitudes toward mathematics may be related to varying levels of math anxiety and appear to impact students’ achievement in math courses.

Students’ attitudes toward mathematics are related to math anxiety, which can hinder their learning and lower math performance (Hembree, 1990; Miller & Bichsel, 2004; Wigfield & Meece, 1988). While students in elementary and secondary school may experience some negativity and anxiety towards mathematics, the highest math worry is experienced by grade 9 students and the lowest by grade 6 students (Wigfield & Meece, 1988). This may be the case due to the transition from elementary school to high school, the various math streams into which students are separated according to math ability (essential, applied, and academic), the emphasis placed on the grade 9 EQAO mathematics assessment (preparation for the standardized test and published results), and possibly previous negative experiences in mathematics. Indeed, it is imperative for mathematics educators to understand that students who appear to be "lazy" or lack motivation may in fact be suffering from high math anxiety. Additionally, a meta-analysis conducted by Ma and Kishor (1997) concluded that "the junior high grades may be the most important period of schooling for students to understand and shape their ATM [attitudes toward mathematics] as it relates to AIM [achievement in mathematics]" (p. 41). If students' math attitudes are related to math anxiety, then this can be used as a predictor of achievement in math classes (Miller & Bichsel, 2004). Furthermore, uncovering students' math anxiety and math attitudes can aid educators in helping students overcome their fearful and negative attitudes and be successful in mathematics.

Purpose of the Study

The purpose of this study is (a) to determine the correlation between math attitudes, math anxiety, and math achievement and (b) compare gender with respect to math attitudes, math anxiety, and math achievement among grade 9 math students in a secondary school within a school board in a large urban centre in southern Ontario. An alarming number of students fear mathematics and are hindered by their anxiety and dislike for the subject. The effects are seen in the classroom through student behaviour, attitudes, motivation, preparedness, and achievement. This practical research can be used in my own classroom and by other educators to identify and treat students' negative attitudes toward math and reduce math anxiety. Ultimately, doing so will promote positive attitudes and improve self-confidence and achievement in mathematics.

Research Questions

Research on mathematics achievement has primarily focused on the effective nature of mathematics anxiety and attitudes toward mathematics on performance. This research is guided by questions regarding the relationships between the variables as well as the effects on math scores. Which variable is a stronger correlate of mathematics achievement: math anxiety or math attitudes? Do gender differences in math performance exist in grade 9 students? If so, which gender experiences higher levels of math anxiety? These key questions are relevant to mathematics educators, principals, and school board officials because while math competence plays a role in mathematics performance, the negative affective nature of mathematics anxiety and attitudes toward math may impair the *learning* of mathematics and ultimately affect success in mathematics. Questions directing this study include:

1. What is the correlation between math anxiety, attitudes toward math, and math achievement?
2. Does gender affect the level of math anxiety, math attitudes, and math achievement?

Theoretical Framework

Gender differences in achievement and attitudes have been explained by various theoretical models. Eccles and Jacobs (1986) suggest that social and attitudinal factors have a greater influence on students' grades and enrollment in mathematics courses than do variations in mathematical aptitude. Further, they propose that gender differences in mathematical achievement and attitudes are largely due to gender differences in math anxiety; that is, the gender-stereotyped beliefs of parents, especially mothers; and the value students attach to mathematics. Eccles and her colleagues created an expectancy-value theory which links educational and occupational choices to ability-related beliefs, expectations of performance on tasks, and perceived importance of the tasks. These choices are influenced by individual differences in the subjective value and appropriateness placed on the choices and their probability for success. In turn, these attitudinal variables are a result of socialization experiences, gender role and self-schemas, their interpretation of past performance, and anticipated demands and cost of the task or role (Eccles, 1987; Meece, Eccles, Kaczala, Goff, & Futterman, 1982). According to the model, individuals' self-concept on mathematical ability and expectations of success or failure in mathematics are shaped by experiences, cultural norms, and behaviours and attitudes of parents, teachers, role models, and peers (Eccles, 1987). Student experiences and values influence performance, effort, and persistence within subject-specific domains (Wigfield & Eccles, 2000). By focusing on choice rather than avoidance, this model takes a more positive perspective to gender differences in achievement behaviour and patterns and can be used to explain why some students are more motivated than others to study and succeed in math.

Importance of the Study

This study is important to teachers and researchers because success or failure in mathematics is greatly affected by personal attitudes and beliefs. Mathematics educators tend to believe that children learn more effectively when they are interested in what they learn, and they achieve better if they like what they learn (Ma & Kishor, 1997).

> Regardless of the teaching method used, students are likely to exert effort according to the effects they anticipate, which is regulated by personal beliefs about their abilities, the importance they attach to mathematics, enjoyment of the subject matter, and the motivation to succeed. (Tapia & Marsh, 2004a, p. 20)

Generally, positive attitudes toward mathematics may increase one's tendency to continue in advanced mathematics courses, once enrollment becomes optional, and elect careers in mathematics and mathematics-related fields. Moreover, gender differences in math performance and problem solving have been shown to emerge at higher age levels (Hyde, Fennema, & Lamon, 1990), which may result from societal factors such as stereotype threat (Beilock, Rydell, & McConnell, 2007; Steele, 1997) and parents' and teachers' beliefs, attitudes, and expectations (Eccles, 1987; Eccles & Jacobs, 1986). Understanding students' attitudes toward mathematics is important for mathematics educators because it affords them the opportunity to address negative attitudes and promote positive attitudes towards the subject. Also, educators can create a classroom environment and employ appropriate instructional strategies that benefit both genders, ensuring that no student is overlooked and/or disadvantaged regardless of gender.

The suggestion that math anxiety threatens both performance and participation in mathematics makes studies like this relevant and worthwhile. Since mathematics anxiety hinders achievement in math, it warrants attention and further research in terms of intervention programs to reduce anxiety and increase performance (Ashcraft & Moore, 2009). "Given society's increasing reliance on standardized testing, knowing how math anxiety affects performance as students actually perform math, or as they are assessed in math, is extremely important" (Ashcraft & Moore, 2009, p. 200). Awareness of students' math anxiety allows educators to incorporate treatment strategies in their classrooms to minimize student anxiety and mitigate its effect on achievement in mathematics.

Scope and Limitations of the Study

For the purposes of this study, a sample of convenience was used to select the sample of participants. Therefore, the sampling method chosen and the small sample size restricted the results from being generalized to a larger group of students.

The research questions and instruments ignore various other influencing factors that may impact math anxiety, attitudes, and achievement. They do not take into account parental and teacher influences, socioeconomic factors, ethnic/racial considerations, and previous experiences with mathematics in elementary school. Ignoring such factors can prove to limit the scope of the results and create gaps in the research.

One of the two math achievement marks used in this study was taken from EQAO standardized tests, which are not high stakes in Ontario. Students were not required to pass the standardized math assessments in order to pass the grade/course; however, the results reflected 5% of their overall mark (teacher's discretion is used to determine which questions of the standardized test are marked). Because students are aware of the low stakes nature of the test, some may not take the time to answer the questions or may not care about the results. Thus, these achievement marks may not have been a true indication of their math achievement and could consequently be invalid.

It was assumed that the students completed the questionnaires honestly and took the time to read and understand the items in the instruments to the best of their ability.

Also, it was assumed that they understood the instructions and language used in the questions. Each student's level of understanding may be different and thus may have influenced how they replied to the questions.

Outline of the Remainder of the Document

This chapter provided background information on predictors of mathematics achievement, namely the effects of mathematics anxiety and attitudes toward mathematics. The theoretical model pertaining to factors that contribute to gender differences in mathematics achievement was outlined. This chapter also discussed the importance of the study and stated research questions guiding this investigation.

Chapter Two provides a synthesis of the relevant research on mathematics anxiety, attitudes toward mathematics, reported gender differences in attitudes and math performance, and factors contributing to the differences.

Chapter Three describes the research methodology, instrumentation, and procedures that were used in collecting and analyzing data for this study. Responses from two questionnaires, the Math Anxiety Rating Scale for Adolescent (MARS-A) and Attitudes Toward Mathematics Inventory (ATMI), were collected from the participants of this study and analyzed. Mathematics achievement results from spring 2011 EQAO Grade 9 Assessment of Mathematics and final grade 9 math course marks were also analyzed. Assumptions, limitations, and ethical considerations relating to this research are presented in this chapter.

Chapter Four presents the results of this research. The variables examined include math anxiety levels, attitudes toward math, achievement in math, and gender comparisons for each variable.

Chapter Five summarizes the results found in this research. An in-depth discussion of the findings and connections with the current literature are presented. Finally, implications for practice, theory, and further research are discussed, with the author's final words concluding this chapter.

CHAPTER TWO: REVIEW OF THE LITERATURE

This chapter provides an extensive literature review of research conducted on various types of anxiety, the prevalence of math anxiety and its negative effects, the importance of attitudes toward mathematics in relation to performance, and trends in gender differences in mathematics achievement and theories explaining the factors contributing to the gender gap.

Math Anxiety

Studies emphasizing the identification of specific types of anxiety have found that different kinds of anxiety, namely general anxiety and test anxiety, lead to different effects on intellectual performance. The study of test anxiety as a subconstruct of anxiety began at Yale University. Based on responses to a Test Anxiety Questionnaire (S. B. Sarason & Mandler, 1952), groups of students were categorized as high or low test anxious. On subsequent intelligence tests, the low-anxious students outperformed their high-anxious peers in both the scores and their variability. Evidence from ensuing studies showed that test anxiety is more consistently related to test performance than general anxiety (I. G. Sarason, 1957; Suinn, 1965).

Research in mathematics anxiety was triggered by observations in clinical sessions of individuals' emotional disturbance in the presence of mathematics. In 1957, Dreger and Aiken conducted a study in which they explored the "emotional reactions to arithmetic and mathematics, tentatively designated 'Number Anxiety'" (p. 344). To investigate the nature and extent of the reactions, three number anxiety items were added to the Taylor Manifest Anxiety Scale, and they renamed it the Numerical Anxiety Scale. Dreger and Aiken hypothesized and confirmed that number anxiety is distinct from general anxiety, although they may overlap; number anxiety is not related to intelligence; and people with high number anxiety will have low scores in mathematics.

Some of the theoretical models of test anxiety address the direction of effects on academic performance. Specifically, proponents of the interference model propose that test anxiety interferes with students' recall of prior learning, thereby lowering performance (Liebert & Morris, 1967; Wine, 1971), whereas proponents of the deficit model propose that poor performance is attributed to poor study habits and/or test-taking skills which lead to high anxiety (Tobias, 1985). Under the inference model, highly test-anxious individuals perform poorly in stressful, evaluative situations due to attentional focuses on self-evaluative worry and self-deprecatory thinking. Since the difficult tasks on which the test-anxious individuals do poorly require full attention for adequate performance, they cannot perform adequately while dividing attention between internal cues and task cues (Wine, 1971). Therefore, highly anxious individuals are overly concerned with the possible consequences of failure and, consequently, this negative emotional state can impede with attentional and learning processes. Furthermore, evidence from a synthesis of test anxiety research indicates that test anxiety was found to be more behavioural than cognitive in nature, thus supporting the interference model (Hembree, 1988).

Math anxiety begins at an early age; the critical stage for the development of attitudes and emotional reactions toward mathematics appears to exist between the ages of 9 and 11 (McLeod, 1993; Newstead, 1998). Research indicates that levels of mathematics anxiety in students "increased through junior high school, peaked near Grades 9–10, and leveled off in upper high school and college" (Hembree, 1990, p. 41).

Similarly, Wigfield and Meece (1988) found that "math worry was highest in 9th-grade students . . . and lowest in 6th-grade students" (p. 213). Very little research has examined students younger than grade 4 (Hembree, 1990; Ma, 1997) to look at the onset of math anxiety and why it grows through the middle years. Although attitudes may deepen or change throughout school, generally, once formed, negative attitudes and anxiety are difficult to change and may persist into adulthood (Newstead, 1998). This is of importance since the implications relate directly to the sample for this study comprised of grade 9 students.

For many decades, researchers have been interested in the effects of math anxiety on student achievement in mathematics. Math anxiety has been found to have a negative relationship with mathematics performance and achievement, indicating that students with higher levels of math anxiety tend to have lower levels of math performance (Hembree, 1990; Richardson & Suinn, 1972; Wigfield & Meece, 1988). Hembree (1990) reported that math anxiety correlates strongly with test anxiety and moderately with general, trait, and state anxiety. Thus, test anxiety is a strong correlate of math anxiety, and math anxiety is separate from, although related to, other anxiety constructs.

Math anxiety is a multidimensional construct in which various types of anxiety related to doing mathematics can emerge in different people (Richardson & Suinn, 1972). Empirical research indicates that "mathematics anxiety seems to be a learned condition more behavioral than cognitive in nature" (Hembree, 1990, p. 45). The cognitive worry factor of general test anxiety is reported to correlate negatively with test performance (Liebert & Morris, 1967), whereas for measures of math anxiety, it is the affective factor that correlates negatively with mathematics performance (Wigfield & Meece, 1988). In a study of students ages 9 to 11, Newstead (1998) found that the majority of these individuals were anxious in all math-related situations or not anxious in any such situations, a small number were anxious only about doing the math (working with numbers), and some individuals were anxious only about the social and public aspects of doing math, such as explaining math problems in the presence of their teachers or peers.

Math anxiety and worry have been reported as having some positive effects on math performance. Wigfield and Meece (1988) claim that the worry that students express about doing well in math may in fact act as motivation for the amount of effort they put forth in math, thus leading to positive results. Interestingly, students from Asian countries, especially Korea, Japan, and Thailand, demonstrated high math anxiety on the Programme for International Student Assessment (PISA) 2003 mathematics assessment (Lee, 2009). Despite their reported high levels of math anxiety, students from East Asian countries were consistently among the top performers on international large-scale assessments (Mullis et al., 2012; Organization for Economic Co-Operation and Development [OECD], 2004, 2010). “The familial and societal pressures placed on Asian students to achieve academically and the importance placed on mathematics achievement may yield high levels of math anxiety” (Ho et al., 2000, p. 365), which may act as a motivational construct to set high goals and achieve a high level of academic performance. Lee (2009) concluded that there was a weak association between math anxiety and math performance in Asian countries compared to a strong association for European countries. This difference suggests that math anxiety and math performance are influenced by societal and educational factors, and, hence, high levels of math anxiety do not necessarily translate to depressed results.

Ashcraft and Moore (2009) suggest that math anxiety functions like a learning disability due to the negative personal, educational, and cognitive consequences. Some of the negative effects of math anxiety include physiological reactions (i.e., sweating or increased pulse rate; Faust, 1992; Morris & Liebert, 1970), cognitive effects—worrisome thoughts (Liebert & Morris, 1967), affective reactions—avoidance of courses and careers with math and science, as well as tension and frustration doing everyday activities that involve math and poor performance in math classes and on math tests (Ashcraft & Moore, 2009; Dreger & Aiken, 1957; Hembree, 1990; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Richardson & Suinn, 1972). Math anxiety has been described as an "important non-intellective factor that contributes to mathematics avoidance behaviours and to disruption of mathematics performance" (Suinn & Edwards, 1982, p. 576). This avoidance of math is an overarching characteristic of math-anxious individuals. Math-anxious individuals avoid taking math courses in high school and postsecondary education and avoid courses of study and careers that involve math. Also, this avoidance behaviour caused by math anxiety may be observed in the classroom through student engagement and participation in class, time spent practicing math, and time spent studying and preparing for math assessments (Ashcraft, 2002; Ashcraft & Moore, 2009). This leads to a cycle whereby this avoidance behaviour causes a delay in learning and, thus, more disappointment and frustration.

Math anxiety was found to be the most important predictor of math performance (Miller & Bichsel, 2004), and higher math anxiety consistently related to lower math performance (Hembree, 1990). The cognitive negative effect of math anxiety generally leads to poor performance in math. Inverse correlations between math anxiety and math achievement exist across grade levels, with -.34 for students in grades 5–12 and -.31 in college students (Hembree, 1990). Ashcraft and Moore (2009) caution that the relationship between math anxiety and achievement is of moderate strength, which suggests that while higher math anxiety consistently related to lower math performance, the dilemma is whether their poor performance was due to low competence or mastery rather than high math anxiety. Individuals with high levels of math anxiety may display lower math competence and achievement because they "are exposed to less math in school and apparently learn less of what they are exposed to; as a result, they show lower achievement as measured by standardized tests" (Ashcraft, 2002, p. 182). This implies that mathematics anxiety has a cumulative effect on the *learning* of mathematics, which limits students' knowledge and results in poor achievement.

To understand the relationship between math anxiety and performance, some researchers have investigated how cognitive processing is affected by math anxiety. Considerable evidence in the literature shows how critically math performance depends on working memory. Working memory is defined as a "short-term system involved in the control, regulation, and active maintenance of a limited amount of information immediately relative to the task at hand" (Beilock, 2008, p. 339). Initial studies by Ashcraft and Faust (1994) and Ashcraft and Kirk (2001) conveyed the belief that math anxiety has minimal effect on performance with simple whole-number addition and multiplication; however, more difficult arithmetic problems with larger numbers showed two math anxiety effects. Compared to individuals with low or no math anxiety, highly math-anxious participants solved problems faster (to minimize their time and involvement in the task) and displayed higher error rates, referred to as "speed-accuracy tradeoffs," when solving more difficult arithmetic and mathematics problems (Ashcraft, 2002). Second, the results showed that the procedural aspect of arithmetic (e.g., carrying, borrowing, long division) was difficult for highly anxious individuals and placed a heavy demand on working memory (Ashcraft, 2002).

Through their research, Ashcraft and Kirk (2001) found that working memory capacity was positively correlated with math performance and negatively associated with math anxiety. They argue that the aspects of math performance that rely heavily on working memory will be the most affected by math anxiety. Part of highly math-anxious individuals' poor performance stems from anxiety-induced depletion of cognitive resources that support complex math tasks. Because math performance did not differ across math-anxiety groups for simple arithmetic problems, it suggests that on-line anxiety reaction, an effect on underlying cognitive processes as the individual performs math, had compromised participants' ability to demonstrate their competence with respect to more difficult math problems (Ashcraft & Faust, 1994; Faust, Ashcraft, & Fleck, 1996). Therefore, "the performance deficits found for high-math-anxiety participants . . . stem from that portion of working memory, presumably the central executive, that applies the various procedures of arithmetic during problem solving" (Ashcraft & Kirk, 2001, p. 225). Consequently, there is a reduction in working memory capacity when anxiety is aroused in highly math-anxious individuals. Moreover, the on-line math anxiety effect has an impact during learning of mathematics as early as middle school, thus reducing the working memory capacity needed for learning and mastery (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007).

Working memory is greatly affected by math anxiety because of a "deficient inhibition mechanism" in which worrisome thoughts, self-doubts, or distracting information inhibit and absorb working memory and attention resources. Therefore, the poorer calculation abilities of individuals with high math anxiety are not a direct consequence of their worrisome thoughts but rather due to an inability to withdraw attention from these thoughts (Ashcraft & Kirk, 2001; Hopko et al., 1998). Simply, the suboptimal mathematics performance arises because of worries that compete for the working memory available for performance. Furthermore, Ashcraft and Moore (2009) found evidence of an affective drop in performance "that can be attributed to math anxiety independent of the individual's competence or achievement in math" (p. 201). They found that relative to college students with low math anxiety, those with higher math anxiety displayed smaller working spans for numerical tasks and exhibited an increase in reaction time and error rates when simultaneously performing mental addition of two-column numbers and letter recall tasks. These highly math-anxious participants had a "three way competition for their limited working memory resources: difficult math, letter retention and recall, and their own math anxiety" (p. 202). Thus, the affective drop in performance was a result of the increased load on working memory.

Since math anxiety depresses math performance, Hembree (1990) experimented with various mathematics anxiety treatments in hopes of diminishing anxiety and improving performance. He found that cognitive-behavioural treatments, which attended to the "worry" factor experienced by highly math-anxious individuals, reduced math anxiety and improved performance approaching the level of individuals with low math anxiety. The improvement in achievement witnessed was a result of a decrease in math anxiety rather than an improvement in math ability. Therefore, this suggests that math achievement scores of individuals with high math anxiety are underestimates of their true math ability.

Attitudes Toward Math

Attitudes toward math play an important role in mathematics education: Attitudes influence success and persistence in math (Ma, 1997). Attitudes toward math are important because “liking arithmetic has a pronounced effect upon the amount of work attempted, the effort expended, and the learning that is acquired” (Dutton, 1956, p. 18). Math anxiety and attitudes toward math can be traced to previous educational experiences (Aiken & Dreger, 1961). For many children, negative attitudes toward mathematics are formed early on in life. Research shows that many children begin schooling with positive attitudes toward mathematics; these attitudes are reshaped in upper elementary grades to junior high grades (Ma & Kishor, 1997). Favourable attitudes toward math tend to decline as children progress in school (Neale, 1969) and frequently become negative in high school (Ma & Kishor, 1997). Little consensus exists in the research concerning the relationship between attitudes toward mathematics and mathematics achievement. Some researchers report a positive relationship between the variables while others do not (Ma & Kishor, 1997). A low but significant positive relation is found when attitude scores are used as predictors of mathematics achievement (Neale, 1969). To assess the magnitude of the relationship, Ma and Kishor (1997) conducted a meta-analysis on 113 primary studies. They found that the overall mean effect size was statistically significant, weaker at the elementary level and stronger at the secondary level. Aiken (1970) attributes the low correlation at the elementary school level to the fact that attitudes are unstable in early years and that young students may not be able to express their attitudes accurately. Hence, because the junior high grades may be the most important period of schooling for students to understand and shape their attitudes toward mathematics, educators have opportunities to treat negative attitudes and promote positive attitudes and high achievement (Ma & Kishor, 1997).

Although some studies indicate a positive relationship between attitudes toward mathematics and achievement in mathematics, a cause-and-effect relationship between the variables has not been established. Some researchers argue that a bilateral relationship needs to be considered in which there is a reciprocal relationship—an interaction between the variables. Ma (1997) developed a causal model to demonstrate the reciprocal relationship between attitudes toward mathematics and achievement in mathematics. He concluded that mathematical achievement did not substantially affect the enjoyment of math, suggesting that students with high achievement do not necessarily enjoy math. Nevertheless, the feeling of mathematics enjoyment directly affects mathematics achievement, and the feeling of difficulty is an important force in *shaping* the feeling of enjoyment. Ma suggests that it is important for educators to ensure that difficult mathematical content is presented in an interesting, attractive, and enjoyable way.

Negative attitudes toward mathematics may impair students' achievement in math classes, limit career choices, and encourage avoidance behavior of any activity that involves mathematics (from simple calculations to problem solving). In their study of college students, Tapia and Marsh (2004b) used four factors to measure attitudes toward math: self confidence, value of mathematics, enjoyment of mathematics, and motivation.

Of these factors, the level of math anxiety experienced had a significant effect on students' self-confidence, motivation, and enjoyment of math. They found that "students who do well in mathematics have more positive attitudes about the subject, thus they are likely to take courses and may perform better" (p. 130). Trends in International Mathematics and Science Study (TIMSS) 2011 results also show a strong positive bidirectional relationship between student attitudes toward mathematics and their mathematics achievement (Mullis et al., 2012).

Positive attitudes toward mathematics related to lower levels of math anxiety (Hembree, 1990). Highly math-anxious people have "negative attitudes toward math, and hold negative self-perceptions about their math abilities" (Ashcraft, 2002, p. 181–182). A strong negative relationship exists between math anxiety and motivation and self-confidence (Ashcraft, 2002), which may affect performance in mathematics. Tapia and Marsh (2004b) reported that students with no math anxiety scored significantly higher in enjoyment, self-confidence, and motivation than students with some or high math anxiety. Also, motivation was found to have an inverse relationship with math anxiety. Students having little or no math anxiety scored significantly higher in motivation than students with some or high math anxiety, and students with some math anxiety scored significantly higher in motivation than students with high math anxiety.

Math attitudes are positively correlated with ability, teacher attitudes, and parental attitudes and encouragement (Aiken & Dreger, 1961). Children's attitudes toward math can be affected by their educational context at school and at home (Scarpello, 2007). "Research consistently shows a strong positive correlation between achievement and indicators of socio-economic status" (Mullis et al., 2012, p. 13). Children from low socioeconomic backgrounds often have parents with less educational background and who also have negative attitudes toward math themselves (Geist & King, 2008). More specifically, a father's education level and a mother's attitude and encouragement toward math are important factors linked to children's positive attitudes toward math and achievement in math (Eccles & Jacobs, 1986; Scarpello, 2007). Gender differences in students' attitudes toward mathematics and plans to continue taking math courses are influenced substantially by parents' perceptions of the difficulty of mathematics for their children and their own attitudes about the value of mathematics (Eccles & Jacobs, 1986). Additionally, parental educational attainment affects the mathematical environment at home. Parents with low educational attainment may possess lesser comfort with math due to limited knowledge of math concepts and negative attitudes toward math, leading to math anxiety. As a result, there is an inability to support and encourage their children in math and, ultimately, promote the importance of mathematics at an early age (Geist, 2008). Overall, higher average mathematics scores are associated with higher levels of parental education and more positive attitudes toward mathematics (Mullis et al., 2012; National Assessment of Educating Progress [NAEP], 2009).

The importance of learning experiences has been linked to the development of attitudes toward mathematics at an early age (Ma & Kishor, 1997). The classroom learning environment is one contributing factor identified to explain variances in student learning, attitudes, anxiety, and achievement. For example, high-stakes testing situations and time requirements on tasks increase anxiety, decrease accuracy, and create negative attitudes toward a subject matter (Ashcraft, 2002; Popham, 2008). Reliance on traditional teaching methods, rote learning, and timed tests can undermine children's natural learning process and lead to negative attitudes toward math (Geist & King, 2008; Popham, 2008). Also, teacher attitudes are significantly related to student attitudes (Tapia & Marsh, 2001). As reported by Hembree (1990), the highest levels of math anxiety occurred for preservice students preparing to teach at the elementary school level. Subsequently, teachers with math anxiety feel uncomfortable teaching mathematics because they do not like mathematics themselves and avoid math-related activities, including developing effective math lessons (Beilock, Gunderson, Ramirez, & Levine, 2010). Further, teachers' negative attitudes toward math make it difficult for them to foster student interest in math, motivate children to learn mathematics, or influence student attitudes toward math positively (Kolstad, Hughes, & Briggs, 1994). This is problematic because attitudes of young students are influenced and shaped throughout their early educational years thereby reinforcing negative attitudes toward mathematics.

Gender-Related Similarities and Differences

Research from the 1970s indicates insignificant gender-related differences in achievement and participation in mathematics in grades 6 to 12 and gender differences in the election of advanced level mathematics courses (Fennema & Sherman, 1977, 1978). More recent studies indicate that the gender gap in mathematics achievement has decreased; however, a small gender difference favouring males in tasks that required functioning at high cognitive levels (complex problem solving) still exists in high school (Hanna, 1989; Hyde, Fennema, & Lamon, 1990; Hyde, Fennema, Ryan et al., 1990; Lindberg et al., 2010). In fact, throughout elementary and middle school, there are virtually no differences between males and females in performance on standardized math tests, yet a trend toward males doing better increases in high school and into adulthood (Hyde, Fennema, & Lamon, 1990).

Large international comparative studies report on gender trends in mathematics achievement. The National Assessment of Educating Progress (NAEP) long-term trends in mathematics from 1973–2008 show that there were no significant differences in average mathematics scores for males and females in the United States during this period of time. For example, scores for 2008 indicate that at age 9, females achieved slightly higher than males, which remained consistent throughout the years of the assessment. The gender gap favouring males, although not significant, seems to be more prevalent between the ages of 13 and 17. According to the 2008–2009 EQAO Grade 3 Assessment of Mathematics results in Ontario, a gender gap in favour of females has existed since 2006, with 72% of females and 69% of males achieving at or above Level 3 (provincial standard). Similarly, since 2005, grade 6 females in Ontario consistently outperformed males on the math assessment, whereas, in 2008–2009 the gender gap for grade 9 students at the academic level was in favour of male students (80% at or above Level 3 compared to 75% for females), a trend that has been consistent since 2004–2005. A similar trend was seen in grade 9 students at the applied level, with males outperforming females (41% at or above Level 3 compared to 34% for females; EQAO, 2009b). TIMSS (2011) reports from 1995 to 2011 showed few differences in average mathematics achievement by gender at the fourth and eighth grades; however, there were substantial gender differences in mathematics achievement for students in the final year of secondary school in favour of males (Mullis et al., 2012). Evidently, while the gender gap in mathematics achievement is relatively small, a disparity does exist at the high school level.

The latest results from TIMSS (2011) show that, while Ontario students are performing well in relation to other countries and provinces, they are not among the top global achievers in mathematics (Mullis et al., 2012). Results from international studies indicate that differences in achievement between countries are much greater than differences between females and males (Hanna, 1989). Else-Quest, Hyde, and Linn (2010) examined cross-national patterns of gender differences in achievement, attitudes, and affect from international data from TIMSS (2003) and PISA (2003) mathematics results. They concluded that "on average, males and females differ very little in mathematics achievement, despite more positive math attitudes and affect among males" (p. 125) and that gender gaps persist in some nations, but not in others. The cross-national data showed that gender gaps in mathematics performance narrow or even reverse in societies with more gender equality (e.g., Sweden and Iceland). Even though the general pattern of gender differences in math attitudes and affect are small, the consistent pattern is for females to hold more negative attitudes towards mathematics than males (Hyde, Fennema, Ryan et al., 1990). This variability "can be explained by important national characteristics reflecting the status and welfare of women . . . [and] differences within education systems, schools, and classrooms are critical influences on student achievement" (p. 125). Girls' poorer math achievement and more negative attitudes toward math may result from societal gender stratification in mathematics. The gender stratification hypothesis proposes that societal opportunity structures faced by female students may hinder the value and importance placed on mathematics in their lives

(Baker & Jones, 1993). Therefore, where there is more societal stratification based on gender, girls will report less positive attitudes and more negative affect and will not perform as well on mathematics achievement tests compared to their male peers. On the contrary, where there is greater gender equity, gender similarities in math will be evident (Else-Quest et al., 2010).

There is a common perception in our society that males are more capable at mathematics than females. The expectation that males are innately better at mathematics and that females achievement in mathematics is related to effort are perpetuated by parental and teacher expectations, differential treatment in the classroom, and socialization of culturally defined gender roles (Eccles, 1987). For example, parents believe that "(a) daughters are better at English than sons, (b) sons are better at math than daughters, and (c) daughters have to work harder to master math than sons and vice versa for English" (Eccles, 1987, p. 156). Furthermore, parents and teachers rate talent as the most important cause for males' math success, whereas effort and hard work are rated as the most important cause for girls' success in math (Geist & King, 2008; Yee & Eccles, 1988). These expectations may inadvertently lead to boys receiving preferential treatment over girls when it comes to mathematics. Consequently, students may internalize these attitudes and shape the experiences they have as they are learning mathematics (Geist & King, 2008).

Theories of stereotype threat suggest that negative stereotypes about a social group in a particular domain (e.g., "girls can't do math") shape academic identities and can reduce the performance outcomes exhibited by group members (Steele, 1997). Moreover, "stereotype threat exerts its impact by co-opting working memory resources—

especially phonological aspects of this system—needed for the successful performance of some types of math problems" (Beilock et al., 2007, p. 272). This impact on performance can spill over onto unrelated tasks that depend on the same processing resource that stereotype threat consumes (Beilock et al., 2007).

Research shows that at an early age, children have clearly defined gender-role stereotypes and appear to monitor their behaviour and aspirations in terms of these stereotypes (Eccles, 1987). "Differences in male and female achievement patterns may result from the fact that males and females have been socialized to have different but equally important goals for their lives" (p. 145). Parents' gender-stereotypical beliefs are critical socializers for gender differences in mathematical achievement and attitudes (Eccles & Jacobs, 1986). According to Eccles (1987), the effect of one's personal experiences and self-interpretation of these events will influence future expectations for performance and success based on perceived ability. Educational and vocational choices are guided by individuals' differing subjective task values, which are influenced by socialization experiences, gender role and self-schemas, their interpretation of past performance, and anticipated demands of the task or role (Eccles, 1987; Meece et al., 1982). Therefore, even though females do as well as males throughout their formative years, their expectations of future success in mathematics will differ from those of males, which will influence their efforts in mathematics and decision to continue in mathematics (Eccles, 1987).

Gender-role stereotypes may lead females into believing that they are less competent than males, resulting in low self-confidence and lower expectations for success at difficult academic tasks. Fennema and Sherman (1977, 1978) examined attitudinal variables and found beliefs about the usefulness of mathematics and confidence in learning mathematics to be critical. Their research found that males exhibited more confidence in learning math than females, and males believed that math is more useful to them than females. Also, the studies indicated that males and females believed that mathematics is more suited for males. Both males and females may hold higher expectations for their performance on specific tasks that are presented or perceived to be more appropriate for their sex; that is, sex-typed (Eccles et al., 1984). As a group, females do not enjoy mathematics and view it as having little importance or usefulness to their lives or futures (Eccles et al., 1984; Fennema & Sherman, 1978).

Evidence from many studies performed on gender differences in mathematics is inconsistent. Before the age of 13, studies show that boys and girls have the same math ability and proficiency on tests (NAEP, 2009; Tapia & Marsh, 2002). Research supports the belief that while females have similar aptitude for mathematics, they are more susceptible to math anxiety due to their aversion to high-stakes testing and social comparison (Miller & Bichsel, 2004). A gender gap exists in levels of mathematics achievement and enrollment in mathematics courses, in which males experience higher levels in both instances in secondary school and college. Despite similar math skills, females around the world have less confidence in their mathematical abilities, which could help explain why young girls are less likely than boys to pursue careers in science, technology, engineering, and mathematics (Else-Quest et al., 2010).

Linn and Hyde (1989) add that girls before the age of 13 have attitudes towards mathematics that are more negative than boys. As indicated by Hembree (1990), female students report higher levels of math anxiety than males; however, females' higher anxiety levels did not seem to translate into more depressed performance or to greater mathematics avoidance. In addition, he found that math anxiety is more predictive of math performance in males than in females. Hembree's (1990) results are supported by Miller and Bichsel's (2004) findings that "math anxiety accounted for more of the variance on basic math performance for males than for females" (p. 605). Therefore, although females seem to experience higher levels of math anxiety, these studies indicate that the anxiety has a greater effect on male students than female students. The gender difference is rather small and may be partly attributable to a greater willingness of females to disclose their anxiety and that females may cope with anxiety better than males (Ashcraft, 2002; Hembree, 1990). In contrast, Aiken (as cited in Ma & Kishor, 1997) stated that attitudes toward math and math anxiety are better predictors of girls' achievement in math than of boys' achievement. Furthermore, Wigfield and Meece (1988) specify that "girls' negative affective reactions to math were stronger than those of boys at each grade level" (p. 213), which may indicate "that as math courses get harder, they will be more likely to stop taking math when they have that option" (p. 215). Clearly, the abovementioned findings indicate that gender differences are connected to and influence math anxiety, attitudes towards mathematics, and achievement in mathematics.

Tapia and Marsh (2004b) found that in a sample of college students, math anxiety and attitudes toward mathematics were not related to gender. They concluded that attitudes toward mathematics among the group studied were likely related to individual personal experiences. Accordingly, it has been reported that gender does not have a significant effect on the relationship between math attitudes and achievement (Ma &

Kishor, 1997) and is not a strong predictor of mathematics performance (Lindberg et al., 2010). The varying results rely heavily on the age group being investigated as well as the instrumentation utilized in each study.

Summary of the Chapter

Chapter Two provided an overview of the literature on mathematics anxiety and attitudes toward mathematics in relation to performance. Also, research and large-scale assessment results on trends in gender differences in mathematics achievement, math attitudes, and math anxiety were discussed. Literature on math anxiety mainly provides evidence on the negative effects of math anxiety; namely, poor math performance and achievement, math avoidance behaviour, physical reactions, and cognitive consequences. Research on math attitudes emphasizes the importance of developing positive dispositions toward math at an early age and relates positive attitudes toward math with better achievement in math. Any gender gaps and/or differences in children's attitudes, anxiety, and achievement may be explained by the expectancy-value theory, which attributes the variability to social and attitudinal factors that influence personal choices within specific subject domains. These factors can influence perceptions and expectations of one's ability and probability of success in math, thus affecting one's perceived value of math, self-confidence, and motivation to succeed in math.

CHAPTER THREE: METHODOLOGY AND PROCEDURES

The purpose of this study was (a) to determine the correlation among math anxiety, math attitudes, and math achievement among grade 9 students and (b) to compare gender in terms of math anxiety, math attitudes, and math achievement. Understanding the correlations among the variables and the implications on student achievement in mathematics can provide insight for math educators on ways to address these factors to improve student learning and achievement. This is important since success or failure in math performance is greatly determined by personal attitudes and beliefs. The constraints to this research included access to participants, time to conduct research, and funding. As a result, a convenience sample of grade 9 math students was selected for this study. Details regarding the research design, site and participant selection, instrumentation, data collection and analysis, methodological assumptions, and ethical considerations are described in this chapter.

Research Design

A quasi-experimental design was used for this study in which quantitative research was conducted. The choice of a quasi-experimental design was based largely on constraints of the researcher (i.e., time, convenience and accessibility of site and participants, and funding to conduct a large experimental design). Quantitative research was conducted to measure the outcomes of the Math Anxiety Rating Scale for Adolescents (MARS-A) questionnaire and the Attitudes Toward Mathematics Inventory (ATMI). This type of research is appropriate for the two instruments because a Likert scale was used to measure participant responses using numerical values (ordinal variables) and to analyze the relationships between the variables. Secondary quantitative data to measure student achievement in mathematics were obtained from participants' grade 9 (June 2011) final math marks and EQAO (June 2011) Grade 9 Assessment of Mathematics results. EQAO results alone were not used because they provide a snapshot of student achievement based on one assessment and may not be indicative of actual student ability and performance.

This research was designed to answer the following research questions:

1. What is the correlation between math anxiety, attitudes toward math, and math achievement?
2. Does gender affect the level of math anxiety, math attitudes, and math achievement?

Site and Participant Selection

Initially, a sample size of 115 grade 9 math students in both the academic and applied streams from a suburban high school within a district school board in southern Ontario was to be included in this study. Restricted by voluntary participation, a sample size of 39 grade 9 math students in academic classes were used in this research. The sample included 13- and 14-year-old participants from four academic classes (*n* = 39); consisting of 21 females and 18 males.

The site selection for this study was determined based on the convenience, accessibility, familiarity, and proximity of the chosen high school to the researcher. Prior to recruitment of participants, clearance (file # 09-232-ENGEMANN) of the proposed research was obtained from the Brock University Research Ethics Board. Before commencing the study, the school principal and mathematics department were informed about the proposed study by the researcher and permission was granted to conduct the research in their classrooms. Also, permission from the district school board was obtained in order to conduct the research at the chosen school.

Convenience sampling was employed to select participants for this study. All students in a grade 9 applied or academic math course during second semester were invited to participate in this study. Students in the selected classes were informed about the research by the researcher, who visited classrooms to explain the purpose and process of the research. Participants were notified that they were not obligated in any way to participate in this study and that participation was strictly voluntary. They were also informed that their decision would not impact their relationship with the researcher and/or classroom teacher, nor would it have any influence on their overall course mark. In addition, students were told that should they decide to participate, they have the option to withdraw from the study at any time without consequences and that all data collected pertaining to them would be destroyed and not used in the results.

Interested students were given a letter of invitation detailing the purpose and the process of the study, along with an informed consent form to be signed by themselves and their parent(s)/guardian(s) because the participants were under 18 years old. Participants were also given a participation assent form which further emphasized the purpose of the study, the rights and responsibilities of the student, and the instruments used to collect data on the sample. Interested students were given 2 weeks to return the signed informed consent and participation assent forms to the researcher or the classroom teacher. The researcher visited classes regularly to collect signed forms and again reminded students that their participation was strictly voluntary, and only those interested to participate returned the forms within the given 2-week timeframe.

Instrumentation

Within this study, two instruments were used to collect data on math anxiety and attitudes toward math, and one instrument, along with final math course marks, was used to collect data on math achievement scores. The following section describes the instruments used in this research.

Attitudes Toward Mathematics

The first instrument used in this study was the Attitudes Toward Mathematics Inventory (ATMI) developed by Martha Tapia (1996). The inventory consisted of 40 statements regarding students' perceptions about their own math ability and confidence, usefulness and application of math in their everyday lives, and attitude towards math in general. The ATMI has been tested and retested for content and construct validity and reliability (see Tapia 1996; Tapia & Marsh, 2004a, 2005). The ATMI is a four-factor model measuring self-confidence, value, enjoyment, and motivation. The Cronbach’s alpha coefficient reported for the factor scores are 0.95, 0.89, 0.89, and 0.88 respectively (Tapia, 1996; Tapia & Marsh, 2004a). The reported alpha reliability coefficient for the instrument is 0.97, indicating good reliability and good internal consistency (Tapia, 1996).

Content validity was achieved by getting feedback from math teachers on the instrument, and construct validity was established by showing item homogeneity with an item-to-total correlation higher than 0.49 and by conducting a factor analysis (Tapia, 1996). Also, content validity was established by relating the items to the variables; self-confidence is measured by 15 items, value of mathematics is measured by 10 items, enjoyment is measured by 10 items, and motivation is measured by five items (Tapia & Marsh, 2004a, 2005). Eleven items of this instrument are reversed to ensure reliability.

Some examples of the statements include: "Studying mathematics makes me feel nervous," "Mathematics is important in everyday life," "Mathematics is dull and boring," and "I am willing to take more than the required amount of mathematics." Participants were asked to read each statement, think about how they feel about each item, and then select a response that best describes their feelings. Responses were measured using a 5-point Likert scale with anchors of 1 to 5: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, and 5 = *strongly agree*. For the purposes of this study, a revision was made, with permission granted from Martha Tapia, to the format of the questionnaire in which students circled their responses from *strongly disagree*, *disagree*, *neutral*, *agree*, and s*trongly agree* instead of selecting A, B, C, D, or E as originally provided in the instrument. The total score was calculated by taking the sum of the ratings for the 60 items of the inventory. The scores for the four subscales were tallied by taking the sum of the responses to the indicated items pertaining to each factor (self-confidence measured by 15 items, value of math measured by 10 items, enjoyment of math measured by 10 items, and motivation measured by five items).

Math Anxiety

The second data collection instrument was the Math Anxiety Rating Scale for Adolescents (MARS-A). The MARS-A was revised by Suinn and Edwards (1982) from the original Math Anxiety Rating Scale (MARS) created by Richardson and Suinn (1972), which is the most frequently used measure of math anxiety. The Spearman-Brown split-half reliability coefficient for the MARS-A was found to be 0.90. "As an index of internal consistency, a coefficient alpha also was computed and found to be .96" (p. 579). A factor analysis was conducted to show construct validity; the primary factor that accounts for the variance in all test items was found to be numerical anxiety, and the second factor is test anxiety.

The instrument consists of 98 items in which two factors are measured: numerical anxiety (89 questions) and mathematics test anxiety (9 questions). The items reflect both everyday life and school-related situations that involve math or dealing with numbers. Examples of some of the items include: "Collecting money to buy tickets," "Playing cards where numbers are involved," "Tallying up the results of a vote," and "Deciding how much of a tip to leave" (Suinn & Edwards, 1982, p. 557). For each situation, students indicated how anxious or tense they felt by selecting from the following responses: *not at all*, *a little*, *a fair amount*, *much*, and *very much*. The level of math anxiety was calculated by taking the sum of each response measured on a 5-point Likert scale from 1 to 5. The lowest possible total score would be 98, indicating low anxiety, while the highest score possible would be 490, indicating extreme anxiety (Suinn & Edwards, 1982).

Mathematics Achievement

Participants' overall math mark for grade 9 (based on second semester term work and final exam for 2011) and the EQAO mathematics assessment results for the grade 9 participants were used as measures of math achievement. The researcher obtained participants' grade 9 math course achievement results and EQAO mathematics assessment achievement results from the participants' classroom teachers at the end of the semester and the school board respectively.

The standardized tests are curriculum-based provincial assessments designed and administered by the Education Quality and Accountability Office (an arm's-length agency of the Ontario government) and are systematically reviewed, revised, and pilot-tested to ensure reliability and validity (EQAO, 2004).

> EQAO follows rigorous scoring procedures to ensure that its assessment results are valid and reliable. All responses to open-response field-test and operational reading and mathematics items, as well as writing prompts, are scored by trained scorers . . . . In order to maintain consistency across items and years, item-specific rubrics for open-response items are based on generic rubrics . . . . The anchors are chosen and validated by expert educators from across the province during the range-finding process. Scorers are trained to constantly refer to the anchors to ensure consistent scoring. (EQAO, 2009a, p. 12)

Items for each assessment are developed by 10 to 20 educators and are field-tested, scorers are trained, and procedures are put into place to ensure scorer reliability and validity. For the primary and junior assessments, the "Cronbach's alpha estimates range from . . . 0.87 to 0.89 for mathematics" (EQAO, 2009a, p. 62). The Cronbach's alpha estimates of test score reliability for the grade 9 assessment "ranged from 0.81 to 0.85 for applied mathematics and from 0.82 to 0.84 for academic mathematics" (p. 79), indicating good reliability.

The EQAO results reported to students and schools are based on an achievement summary which identifies the students' Ontario Curriculum achievement levels: below Level 1, Level 1, Level 2, Level 3 (provincial standard), and Level 4 (above provincial standard). For the purposes of this study, participants' EQAO raw scores were used which indicate where their score fell within the achievement level. For example, raw scores from 1 to 1.9 are reported as a Level 1, raw scores from 2 to 2.9 are reported as a Level 2, and so forth.

Methods of Data Collection

Data collection for this study occurred over one school semester and was administered on site by the researcher and the classroom teachers (whenever a conflict existed for the researcher). Before the questionnaires were administered, teachers in the Mathematics Department were asked for their participation in this study. As the researcher, I visited each of the participating classes to introduce myself and discuss the details of the research in which the students might be involved. All the students in the selected grade 9 math classes were asked to participate in the study, and each received a letter of invitation, a consent form, and a participation assent form to be signed by themselves and by a parent/guardian in order for their children to partake in the study. Students were informed that participation in this study was voluntary and that they had the option to withdraw from the study at any time without consequences. Also, they were assured that participation or nonparticipation in this study would not affect their achievement in the course or relationship with the researcher or classroom teacher in any way. Moreover, student anonymity was maintained by allocating identification codes to each participant and would remain confidential because their names would not be disclosed to anyone or published. The researcher was the only person who had access to this information.

Open and frequent communication between the researcher and the participating teachers occurred throughout the length of this study. During the semester, the researcher visited the classes regularly to address any questions or concerns the students or teachers had. Each instrument was administered separately on a different day set out by the researcher and classroom teachers so as to not disrupt classroom instruction and learning. The researcher met with the math teachers before the data collection commenced to review their class schedules in order to select dates that were best suited for them to administer the instruments. This was important, as some of these courses were scheduled at the same time of day, thus making it impossible for the researcher to be in more than one class at a time on a given day. Next, the researcher reviewed the instruments with the teachers and provided them with a script on how to deliver and explain the instructions to the participating students in a consistent fashion. The script defined language used in the instruments as clarification for participants, such as “anxiety,” “apprehension”, and “tension,” and provided instruction for reading over examples identified by the researcher so that the students understood what was asked of them and to ensure validity and reliability of their responses.

To minimize disruption, teachers were instructed to administer the questionnaires to the students during the second half of the period, after the lesson was taught. Each period was 75 minutes in length, thereby giving the teacher enough time to complete the lesson, assign work, and distribute the instruments to those participating in the study. Teachers from each participating grade 9 math class received a set of copies of the ATMI and MARS-A for administering. Copies of the instruments provided to the teachers contained only student identifier codes, not names, to ensure participant confidentiality and anonymity. Therefore, the teachers were instructed which students were to receive the specific instrument via a temporary removable identifier (i.e. post-it note). While the teacher was aware of which students were participating, their responses were anonymous since only the identifier code remained when questionnaires were collected and sealed in an envelope.

Before beginning each questionnaire, the participants were once again reminded that their participation in the research study was voluntary and that confidentiality and anonymity would be maintained through the use of research identification codes. Participants were also reminded that they could drop out of the study at any point without repercussions and any completed research data would be shredded and not used in the data analysis. Also, the teachers and/or researcher read and explained the instructions, reviewed examples with the participants, and reminded them that they were expected to answer all the questions carefully and honestly.

The ATMI was the first instrument administered on the agreed upon date. This instrument had 40 items, and students were given 10 to 15 minutes to complete it. The second instrument administered was the MARS-A, which consisted of 98 items. Participants were given 15 to 20 minutes to complete this questionnaire. Once the questionnaires were completed, the teacher collected them, placed them into an envelope provided by the researcher, and sealed the envelope, waiting for pick-up. All completed instruments were collected in sealed envelopes by the researcher on the date they were administered.

Finally, math achievement data were collected from two sources: results from the grade 9 EQAO standardized mathematics assessment and final grade 9 math marks. As mentioned previously, data for participants' achievement marks for Grade 9 math courses were available from teachers at the end of the school term, and the EQAO math assessment marks were available from the district school board once the results were published. Therefore, the researcher could not access or analyze the data that were received. Furthermore, this information was accessed and used for this study with parental permission (as stated on the informed consent and participant assent forms).

Types of Data Analysis

Various methods of statistical analysis were utilized to examine quantitative data from the two questionnaires. The data were found to be nonparametric, and thus nonparametric tests were conducted for relationships between the variables. Spearman's rho correlation tests were performed to investigate the correlation between the variables: math anxiety (ordinal variable), attitudes toward math (ordinal variable), and math achievement. Also, Mann-Whitney *U* tests were conducted to make gender comparisons in terms of math anxiety, math attitudes, and math achievement.

Reliability and Validity/Establishing Credibility

In order to ensure reliability and validity, the same two questionnaires were given to all participants, who received exactly the same instructions from a script prepared by the researcher, and participants were given the same amount of time to complete the instruments. Providing classroom teachers with scripts was imperative in ensuring consistency and validity in participant responses because students' level of understanding varied greatly. By defining key terminology that may have been unfamiliar to the participants and by reviewing instructions and expectations, the participants were better able to comprehend the instruments and, therefore, make more accurate responses to the items.

All of the instruments that were used for this study have been tested and retested for reliability and validity. Although a revision to the format of the ATMI was made, it did not compromise the reliability or validity of the instrument because representative letters for the responses were changed and not the content or wording of the items themselves.

Methodological Assumptions

Several assumptions were made during the course of this research. First, because a sample of convenience was used, it is assumed that the participants did not feel pressured or intimidated by the researcher to participate in the study. Every precaution was taken by the researcher to ensure that participants were aware that their participation was optional and that withdrawal from the study could have occurred at any time without any negative repercussions. Therefore, it is presumed that participants willfully partook in this study.

Second, the researcher provided pretest training to the grade 9 teachers on how to explain and administer the instruments. It is assumed that the teachers followed the script/instructions, as per direction, and took the time to clarify terminology and/or instructions for the participants. This training was a means of increasing the likelihood that the participants would understand the instructions, the items, and what was being asked of them. Similarly, it is assumed that the participants took the time and care to read the items carefully and answer truthfully.

Another assumption is that all the teachers involved in teaching grade 9 mathematics at the chosen high school covered the expectations outlined in the Ontario curriculum documents and were not teaching to the EQAO test. In addition, it is assumed that the math teachers evaluated students based on the same or comparable assessments throughout the term and graded the assessments in a similar fashion, thereby keeping consistency and equity among the math classes.

Last, the assumption is that the teachers who administered the EQAO math assessments followed the EQAO script and did not deviate from it. Further, it is assumed that they did not help or guide students during the assessments, thereby not influencing math achievement results.

Scope and Limitations of the Study

For the purposes of this study, a sample of convenience was used to select the sample of participants. Due to this, the findings of this research may not be as statistically valid as they would be if a random sampling method had been used. Therefore, the sampling method chosen restricts the results from being generalized to a larger group of students.

The research questions and instruments ignore various other influencing factors that may impact math anxiety, attitudes, and achievement. They do not take into account parental and teacher influences, socioeconomic factors, ethnic/racial considerations, and previous math-related experiences. Ignoring such factors can prove to limit the scope of the results and create gaps in the research.

One of the math achievement marks used in this study was taken from EQAO grade 9 standardized math assessments, which are not high stakes in Ontario. Students were not required to pass the standardized math assessments in order to pass the grade/course, and the results were reflected in their overall mark but account for only 5% of that mark. Seeing as students were aware of this, some may not have taken the time to answer the questions or did not care about the results. Thus, this EQAO math score may not be a true indication of their math achievement.

It is assumed that the students completed the questionnaires honestly and took the time to read and understand the items in the instruments to the best of their ability. Also, it is assumed that they understood the instructions and language used in the questions. Each student's level of understanding may have been different and may have influenced how he or she replied to the questions.

Ethical Considerations

This study involved human participants and, therefore, great attention was placed on protecting their rights. Before the research began, clearance was obtained from the Brock University Research Ethics Board and the district school board in which the research was conducted. Participants were informed by the researcher in writing and through personal communication that participation in the study was optional and that no connection would be made from this research and their final grade in the course. Initially, prospective participants received a letter of invitation outlining the purpose and the process of the study and the rights of the participants to decide whether to participate or not and their right to withdraw at any time without consequences. Those interested in participating in this study received a letter of consent and a participant assent form to be signed by each participant and his/her parent(s)/guardian(s), granting permission for their son/daughter to partake in the research. Throughout the study, participants were reminded that their participation was not a factor in their overall grade and that they were free to withdraw from the study at any given time without ramification.

Several steps were taken to protect the privacy and rights of the participants. The names of participants, secondary school, and district school board or other distinctive characters were not used or disclosed to anyone. Confidentiality and anonymity were maintained by creating an identifier code for each participant, and only this code appeared on each instrument. A master list with each participant's name and identifier code was kept by the researcher in a locked secure place. All collected data from the three questionnaires were stored and locked away by the researcher. A soft copy of the raw data collected and the master list were kept in electronic files on the researcher's password-protected personal computer and was accessible only by the researcher.

Summary of the Chapter

This chapter systematically outlined the methods and procedures that were used to analyze the data from the MARS-A and ATMI questionnaires as well as math achievement data from grade 9 EQAO scores and final math marks. The research design, instrumentation, and data analysis used in this study were explained. Also, any assumptions, limitations, and ethical considerations were addressed and included in this chapter. Chapters Four and Five present the findings of this research as well as a detailed analysis of the results and any implications of this study.

CHAPTER FOUR: PRESENTATION OF THE RESULTS

The purpose of this investigation was (a) to determine the correlation between math anxiety, math attitudes, and math achievement among grade 9 students and (b) to determine whether there was an effect of gender on math anxiety, math attitudes, and math achievement among grade 9 students. The participants of this study included a convenience sample of 39 grade 9 students enrolled in academic math during one semester. Two instruments, the MARS-A and ATMI, were employed to collect information regarding levels of math anxiety and attitudes toward math respectively. Results from grade 9 EQAO standardized mathematics assessments and final grade 9 math marks were used to measure achievement in math. Spearman's rho correlation tests were performed to investigate the relationships between the research variables. The Mann-Whitney *U* test was conducted to make gender comparisons for each of the study variables. The following section provides detailed information regarding the findings from each of these tests.

Findings

The findings are based on an analysis for determination of (a) possible correlations between math anxiety and math achievement, math anxiety and attitudes towards math, and attitudes towards math and math achievement and (b) gender comparisons of math anxiety, attitudes toward math, and math achievement among the grade 9 participants. Each of these analyses is presented under separate headings below.

Math Anxiety and Math Achievement

A spearman's rho correlation (r_s) of -.26 was calculated between math anxiety and final math marks and was found to be nonsignificant since $p = .12$. A similar result occurred for the relationship between math anxiety and EQAO raw scores in which no statistical significance was found for the correlation between the variables (r_s = -.22, p = .19).

Math Anxiety and Attitudes Toward Math

A moderate to strong negative correlation was found between math anxiety and attitudes toward math (r_s = -.55). The correlation is statistically significant at $p < .01$. A further analysis of the relationship between math anxiety and value, self confidence, enjoyment, and motivation was conducted. Math anxiety was found to be a moderate correlate of value of math, with a statistical significance reported (r_s = -.42, p = .01). A strong negative relationship was found between math anxiety and self confidence (r_s = -.60), with statistical significance at the $p < .01$ level. There was a moderate negative relationship reported between math anxiety and enjoyment (r_s = -.45) as well as between math anxiety and motivation (r_s = -.41); both were reported with statistical significance ($p < .01$ and $p < .05$ respectively).

Attitudes Toward Math and Math Achievement

A strong positive correlation between attitudes toward math and final math marks among the participants was reported (r_s = .71). Also, a strong positive relationship between attitudes toward math and EQAO raw scores was found (r_s = .61). Both results are statistically significant, with $p < .01$ reported for each correlation.

A Spearman's rho correlation analysis of the ATMI subscale variables (value, self-confidence, enjoyment, and motivation) and math achievement was also conducted. Strong positive correlations between value and final math marks and EQAO raw scores were reported (r_s = .68 and r_s = .65 respectively). Moderate positive relationships were found between self-confidence and final math marks and EQAO raw scores (r_s = .55 and r_s = .44 respectively). A strong positive correlation of r_s = .68 was found for the relationship between enjoyment and final math marks, and a moderate positive correlation of r_s = .58 was reported for enjoyment and EQAO raw scores. Last, strong positive correlations were found for motivation and final math marks (r_s = .75) and motivation and EQAO raw scores (r_s = .64). All of these results are statistically significant at $p < .01$.

Comparisons by Gender

The Mann-Whitney *U* test was used to compare gender in terms of achievement scores, attitudes toward math, and math anxiety levels reported.

Math anxiety. There was no statistically significant difference on MARS-A scores between males (M = 21.27) and females (M = 17.06; U = 137, $p < .25$).

Attitudes toward math. No statistically significant difference was reported for ATMI scores between males (M = 22.21) and females (M = 18.30) in this sample (U = 149.50, $p < .29$). Also, there was no statistically significant difference reported for value of math between males (M = 22.24) and females (M = 18.27; U = 149, $p < .29$). Differences in self confidence between males (M = 22.91) and females (M = 17.75) were reported as nonsignificant (U = 137.5, p = .16). There was no statistically significant difference reported for enjoyment between males (M = 20.38) and females (M = 19.70; U = 180.5, $p < .85$). Similarly, no statistically significant difference was reported for motivation between males (M = 22.15) and females (M = 18.34; U = 150.5, $p < .30$).

Math achievement. The analysis results of grade 9 final math marks indicated that no statistically significant difference was found for achievement scores between males (*M* = 20.82) and females (*M* = 19.36; *U* = 173, *p* < .70). Also, no statistically significant difference for EQAO raw scale scores was found between males (*M* = 21.38) and females (*M* = 17.98) for this sample (*U* = 146.5, *p* = .34).

Summary of the Chapter

Chapter Four presented the results of this study using math achievement data collected from EQAO (2011) and grade 9 math marks and math anxiety and attitude scores using the MARS-A and ATMI respectively. Generally, the findings indicated that there are strong correlations between math anxiety and attitudes toward math and strong correlations between attitudes toward math, value, self-confidence, enjoyment, and motivation and math achievement among the research participants. Also, any gender differences reported for each of the variables were found to be statistically nonsignificant. Chapter Five will discuss the findings in greater detail and provide implications for practice, theory, and further research.

CHAPTER FIVE: SUMMARY, DISCUSSION, AND IMPLICATIONS

Chapter Five begins with a summary of the purpose of the study, the methodology that was used, and an overview of the findings. A discussion of the research findings follows that draws connections to current literature. The chapter continues with implications for theory, practice, and further research, and it concludes with the author's final word.

Summary of the Study

The intention of this study was to determine the correlation between math anxiety, math attitudes, and math achievement among grade 9 students enrolled in academic math classes. Two instruments, the MARS-A and ATMI, were administered to collect data on the participants' levels of math anxiety and attitudes toward math respectively. Math achievement data were collected from grade 9 EQAO standardized mathematics assessment results and final grade 9 math marks. Nonparametric tests were performed to investigate the relationships between the research variables and to make gender comparisons for math anxiety, attitudes towards math, and math performance. The findings indicated strong correlations between math anxiety and attitudes toward math and strong correlations between attitudes toward math and math achievement among the research participants. Also, no gender differences were found for each of the research variables.

Discussion

A discussion of the findings for the relationships between math anxiety, attitudes toward math, and math achievement as well as the effect of gender on these variables is presented in the following section.

Math Anxiety and Math Achievement

Much of the research on math anxiety indicates that math anxiety negatively affects performance in math; specifically, it hinders performance/achievement and elicits avoidance behaviour (Hembree, 1990; Richardson & Suinn, 1972; Suinn & Edwards, 1982; Wigfield & Meece, 1988). Previous studies indicate that significant negative correlations exist between anxiety level and math performance, whereby higher levels of math anxiety relate to lower math achievement (Hembree, 1990; Richardson & Suinn, 1972). Findings from this study contradict this notion and show that there is no relationship between math anxiety and math achievement scores. Some literature suggests that higher levels of math anxiety do not necessarily translate into lower marks; in fact, some math worry/anxiety can act as a motivational force having positive effects on success in math (Ho et al., 2000; Lee, 2009; Wigfield & Meece, 1988). Students who place importance and value on math may experience higher levels of math anxiety due to their desire to do well in math, which in turn gives students more determination to study and do well. Therefore, although students in this sample disclosed varying degrees of math anxiety, from low (120) to high (328) anxiety scores, their performance in math did not suffer as a result.

Differences in conclusions from this study in comparison to other studies conducted on math anxiety may also be attributed to the sample sizes used for each study, the age of participants, and the tests used to analyze the data to determine correlations between the variables studied. Sample sizes used in past research vary from 30 to over 700 participants, ranging from 5th to 12th grades to postsecondary school level. Since the sample used for this research consisted of a small sample of grade 9 students in academic math classes, it is plausible that not enough data were collected to show any significant correlation between math anxiety and achievement. Further, research reporting relationships between the variables was primarily based on parametric tests, whereas nonparametric tests were used in this study, which may account for the varying results. Nonetheless, in this sample, levels of math anxiety did not have a noteworthy effect on math achievement scores overall.

Math Anxiety and Attitudes Toward Math

Results from this investigation concur with research reporting that positive attitudes toward math are strongly related to lower levels of math anxiety (Hembree, 1990). Specifically, a strong negative correlation was reported between math anxiety and attitudes toward math, indicating that higher levels of math anxiety are associated with more negative attitudes toward math.

The four subscales of the ATMI used to measure the distinct aspects of attitudes toward math were all found to have a considerable effect on math anxiety and vice versa. Hembree (1990) and Tapia and Marsh (2002, 2004b) also showed that levels of math anxiety had a significant effect on students' self-confidence, motivation, and enjoyment of math. Highly math-anxious students exemplify math avoidance behaviours whereby they take fewer elective math courses beyond the required high school math courses (Hembree, 1990). This avoidance behaviour is indicative of a lowered sense of math self-concept, a dislike of the subject, and beliefs of its irrelevance in their lives, resulting in a reduced desire to continue with math.

In this study, a moderate negative relationship was found between math anxiety and value of math, implying that students experiencing higher levels of anxiety believe that math is not as relevant and useful in their lives and futures when compared to those with lower math anxiety levels. Results showed a strong negative relationship between math anxiety and self-confidence, indicating that the higher the level of math anxiety experienced by the students, the less confident they feel about their ability to do and perform well in math. The moderate negative correlation reported between math anxiety and enjoyment of math suggests that students with lower math anxiety have a higher enjoyment of math and math classes. A moderate negative correlation was also reported between math anxiety and motivation. Thus, for these grade 9 students, the lower the level of math anxiety experienced, the more interested they are in the subject, the more motivated they are to well in math, and the more likely they are to pursue studies in math in the future (high school and postsecondary).

Attitudes Toward Math and Achievement

The relationship between attitudes toward math and achievement in math has been reported to be weak but positive (Ma & Kishor, 1997). Surprisingly, the results for the sample studied in this investigation showed a strong positive correlation between attitudes toward math and achievement, indicating that students with higher ATMI scores, or more positive attitudes toward math, performed better on the EQAO math assessment and in their grade 9 academic math course. Students who do well in mathematics generally have more positive attitudes toward math (Tapia & Marsh, 2004b) in which a strong positive bidirectional relationship between the two variables has been reported (Mullis et al., 2012). Thus, for this group of grade 9 students, positive attitudes toward math translated to better performance in math.

Significant positive relationships were also found for the relationship between the four subscales of the ATMI and math achievement. Value of math was found to be a strong positive correlate of math achievement; the higher the importance students place on math, the higher their achievement marks in math. Enjoyment of math was found to be a strong positive correlate of final math marks and a moderate positive correlate of EQAO scores. Again, the higher the level of enjoyment of math indicated by the students, the higher their achievement scores were. A strong positive correlation was found between motivation and math achievement in this sample. This shows that students with greater motivation to continue in and succeed in math generally experience higher achievement in math. Last, a moderate positive relationship between self-confidence and achievement was found, indicating that the more confident students feel about math and their ability in the subject, the better they perform in math.

Gender Comparisons

Contrary to many published results (i.e., Else-Quest et al., 2010; Hembree, 1990; Hyde, Fennema, Ryan et al., 1990; Miller & Bichsel, 2004), the grade 9 female and male participants in this research had similar reported levels of math anxiety, math attitudes, and math performance. No significant gender differences were shown for math anxiety levels between males and females. There were no notable differences found for attitudes toward math, value of math, enjoyment of math, self-confidence, and motivation between females and males. Finally, no significant disparities were found in math achievement marks, specifically for EQAO raw scores and final math marks, between genders. Hence, according to these results, a supposed "gender gap" does not exist for this group of grade 9 students.

Why are there no significant differences in all of the variables tested? Similar research results have been discussed in the literature comparing gender in terms of anxiety, attitudes, and achievement in math. The finding that gender does not have an effect on the relationship between attitudes toward math and achievement is supported by a meta-analysis conducted by Ma and Kishor (1997) in which similar relationships between the variables where found for both genders. According to Lindberg et al. (2010), gender is not considered a predictor of math performance and achievement.

The fact that, in this study, no gender differences in math attitudes were shown is supported by the idea that individual and educational experiences in relation to math affect math attitudes, *not* gender (Aiken & Dreger, 1961; Tapia & Marsh, 2002). It is plausible that, in this study, the participants, both males and females, may have had mostly positive personal and educational experiences with math, thereby positively influencing their attitudes toward math. These experiences may be rooted in parental and teachers' perceptions, expectations, education levels, attitudes, encouragement, and support, which have been recognized as important forces in shaping attitudes, fostering anxiety among students (Eccles & Jacobs, 1986; Geist & King, 2008; Mullis et al., 2012; Scarpello, 2007) and ultimately affecting success in math. Socioeconomic factors were not assessed in this research but have been reported in the literature as having critical influence on all the variables of this study (Geist, 2008; Geist & King, 2008; Scarpello, 2007). It is reasonable to speculate that participants from this sample belonged to a similar socioeconomic group whereby they were encouraged to study and do well in math and the importance and value of math were emphasized at an early age. This may account for the invariability among the results for gender comparisons; namely, females did not report higher levels of anxiety or more negative math attitudes than their male counterparts.

The age group and grade level assessed in this study may be another reason why differences were not found. Most of the research that shows any gender disparity in achievement, even the slightest, is evident in senior grade levels (Lindberg et al., 2010; Mullis et al., 2012). Perhaps the “gap” in this sample is not evident yet because of their grade level. Also, the size of the sample is considered to be small; therefore results cannot be generalized to grade 9 students as a whole. It is reasonable to suggest that the attitudes, anxiety levels, and math achievement were similar for each gender in this sample and are not representative of other grade 9 students in general. A larger sample may have rendered different conclusions.

Implications

Although no relationship was found between math anxiety and achievement for this sample, strong relationships were reported between math anxiety and attitudes toward math and attitudes toward math and achievement in math. Also, regardless of the fact that no significant gender differences in anxiety, attitudes, and achievement were uncovered, students from this sample have varying levels of math anxiety and differing attitudes toward math as seen from their scores on the MARS-A and ATMI. Therefore, implications from this research will be guided by strategies to prevent and reduce math anxiety and promote positive attitudes toward math in order to improve success in the subject.

Implications for Practice

The following section presents implications for practice that this research may have for teachers and parents.

Teachers. Math educators have an opportunity every day in their classrooms to uncover students' dispositions towards math and employ various strategies to influence their students in a positive and meaningful way. Being aware of students' negative attitudes and math anxiety along with the effects on performance is the first step in assisting students to overcome their negative feelings. This awareness is important not only for teachers but also for affected students and their parents so that the proper support may be received (Scarpello, 2007). Considering that strong relationships were found in this study between math anxiety and math attitudes as well as between attitudes and performance in math, teachers should assess students' attitudes toward math through a survey such as the "Mathitude" Survey for example (see Appendix A; Furner & Duffy, 2002, p. 70), at the beginning of the school year. Also, incorporating writing in the curriculum, such as math journals in which students can confidentially express their understanding of math concepts and/or express their feelings about math, is a great way for teachers to uncover any gaps in student learning and any feelings of anxiety (Furner & Duffy, 2002). Math journal questions can include both questions about the curriculum and their personal experiences with and feelings about math (see Appendix B for a sample of "Math Journal/Discussion Questions for Students"; Furner & Duffy, 2002, p. 71).

Once students' math dispositions are revealed, various strategies can be used to address anxiety and negative attitudes. Teachers can help lessen math anxiety in their classrooms by employing effective teaching methodologies that address different learning styles and focus on concept development, process, critical thinking, and problem solving rather than rote learning, computation, and correct answers (Furner & Berman, 2003; Geist, 2008). Shifting the focus from getting the right or wrong answers to emphasizing process and concept development will help deepen student understanding of the math curriculum. Other strategies include utilizing alternative forms of assessment that give students many opportunities to demonstrate their math comprehension and help students gain confidence (Furner & Duffy, 2002). Using different assessment techniques like journal writing, observation, interviews, and performance tasks may reduce the pressure to perform well on traditional pencil-and-paper tests and allow students to show their understanding and ability in a nonthreatening testing environment.

Helping students overcome anxiety also means that teachers must take on a counselor-like role. Regular discussions of feelings, attitudes, and appreciation for math with students will encourage communication to help them recognize and face their fears (Furner & Duffy, 2002). Students need to be aware of their own attitudes and anxiety in order to begin to deal with them and learn how to cope. Understanding when and how these dispositions toward math began and recognizing the first signs of anxiety, such as nervousness, panic, and sweaty palms, is important so that students can use strategies to control and eliminate these negative feelings. Some coping strategies include desensitization and relaxation techniques (Hembree, 1990), using positive self-talk and "I" messages, and talking through word problems (Tobias, 1987). By using coping skills, students will be able to manage their negative debilitating thoughts and resulting physical reactions while maintaining focus on the math task at hand. The goal is to improve self-confidence in math, eventually leading to more successful experiences in math.

Preventing math anxiety altogether should be a goal for educators and parents. Teachers can elicit positive learning experiences in math by following current best practices for teaching math. For example, Zemelman, Daniels, and Hyde (as cited in Furner & Berman, 2003) compiled the best teaching practices for math: Use manipulatives to make math learning concrete, make math relevant, use a problem-solving approach to instruction, accommodate for different learning styles, use cooperative group work at all grade levels, include critical thinking skills, use technology in the classroom, and encourage journal writing. Teachers should also encourage students to be self-learners and take responsibility for their learning in order to build their self-confidence through practice of math problems. The saying "Math is not a spectator's sport" signifies that one must *do* and practice math rather than just *watch* on the sidelines. Studying and practicing various math problems, from simple to complex, and working through them can help students become better problem solvers and more knowledgeable about and improve competency with the math concepts being studied. Thus, students can learn to negotiate their anxiety and build their self-confidence through regular review and successful applications of mathematical concepts. Essentially, the more students are exposed to and practice math, the more familiar they will be with the math concepts, and therefore, the more confident they will be in their math skills and ability.

It is also imperative for teachers to deal with their own negative attitudes and math anxiety and have a strong knowledge base for teaching math (Furner & Berman, 2003). This is especially important since the literature suggests that students' dispositions toward math are shaped and influenced by teachers (Tapia & Marsh, 2001) and math-related experiences beginning at a young age (Ma & Kishor, 1997). Teachers' feelings of inadequacy in their own math ability and understanding can translate into negative consequences for students' learning of math and affect their attitudes toward math and achievement in math, which may lead to math anxiety. A positive learning environment will encourage students to participate, take chances with their problem-solving strategies, and be persistent when faced with challenging math problems.

Parents. Research suggests that parents have even more influence on student success in math than teachers. The math experiences in the home environment are critical in developing or hindering positive dispositions toward math (Furner & Duffy, 2002). Parental involvement at an early age is essential in shaping children's positive math attitudes and numeracy skills. Results from TIMSS (2011) showed that math achievement was higher for students whose parents reported that:

- They often engaged in early numeracy activities with their children;
- Their children had attended preprimary education; and
- Their children started school able to do early numeracy tasks (e.g., simple addition and subtraction). (Mullis et al., 2012, p. 11)

Engaging children at a young age through activities fosters fun, positive learning experiences where they can begin to enjoy math and be excited about it while developing basic numeracy skills. Parental involvement should continue throughout their child's academic career through communication with the math teacher, keeping up with the schedule of math concepts being taught, and following their child's progress by examining their math books, tests, and homework (Furner & Berman, 2003). Also, to prevent or minimize anxiety and to ensure success in math, parents should place their child in an appropriate math level in high school based on the student's mathematical understanding and abilities. Students in the wrong math levels may experience feelings of intimidation, frustration, and being overwhelmed, which may enhance feelings of inadequacy and anxiety. The goal should be to build self-confidence, enjoyment, and motivation in math through positive successful experiences, not by setting them up for failure.

Parental attitudes toward and beliefs about math can have grave effects on their children's success in math; therefore, they are an important piece of the puzzle in preventing math anxiety. Understanding the effects of math anxiety and how their own dispositions can affect their child's success in math is crucial for parents to be aware of in order for them to offer the necessary support to lessen or eliminate their child's negative feelings. Parents need to play a supportive role to promote positive attitudes toward math and emphasize the value and importance of math in their lives. Students' beliefs about their own ability to be successful in math courses and related careers may be improved through strong parental support of the student's career choice (Scarpello, 2007). They should also encourage their children to be active learners and take responsibility for their learning, concentrate, and put forth an effort in math class and when working through math problems. When difficulties arise, students should be encouraged to communicate with their parents and teachers so that they may get the clarification and assistance needed to avoid gaps in their learning and understanding of math concepts. The key, however, is that in order for students to benefit from any extra help provided (free or otherwise paid for), students must be active participants in the process—they must *do* rather than just watch.

Implications for Theory

The expectancy-value theory attributes differences in student achievement and career choices due to their ability beliefs, expectancy of success, and value of the subject-specific task at hand. These factors are related to past experiences, both home and educational, and influence performance, motivation, persistence, and effort (Eccles, 1987; Eccles & Jacobs, 1986; Meece et al., 1982; Wigfield & Eccles, 2000). Results from this research did not show any gender differences in achievement, self-confidence, motivation, value of math, enjoyment of math, or math anxiety. While no gender differences were found, this research does support the relationship between students' perceived ability in math (self-confidence), subjective task value (value of math), motivation to continue in math, and performance in math, as posited by the expectancy-value theory. These math attitudes were found to have positive relationships with achievement in math. Therefore, students' perceptions of their math ability and probability of success will determine the value they place on math tasks, in terms of their math courses, and value of math in their lives and careers, in terms of occupational choices. These perceptions and expectations will also influence their effort and persistence in the subject, ultimately affecting their success in mathematics. According to the expectancy-value theory, these attitudinal variables are shaped by factors such as past performance and experiences, social factors, and influences of parents and teachers, which were not assessed in this research. Thus, it is difficult to make conjectures about how or why this group of students displayed similar results.

Implications for Further Research

The main goals of this research were (a) to uncover the relationships between math anxiety, attitudes toward math, and achievement in math among grade 9 students and (b) to compare math anxiety, attitudes toward math, and achievement in math in terms of gender. This research can be extended to include a more in-depth investigation into identifying participants with high anxiety and poor attitudes toward math and uncovering the reasons *why* they have negative dispositions toward math. This could be conducted through both quantitative and qualitative methods whereby a case study could be performed on the highly anxious students specifically. It would be interesting and worthwhile to discover the antecedents of when these feelings started to manifest and the external factors that affect dispositions and achievement in math. For example, gathering information on socioeconomic status, past experiences and performance in math, and parental level of education, attitudes, and beliefs regarding math would prove beneficial. An analysis of this information could reveal links with the child's attitudes, anxiety, and achievement in math.

The findings of this research may have been limited due to the small sample of grade 9 students used in the study. In future research, a larger sample of students from various schools across the province, including math students from different math streams—applied and academic levels—should be considered to broaden the scope and depth of data collected. More interesting comparisons and discoveries between students in various math levels could be made to discover whether students in the applied level experience greater math anxiety and more negative attitudes toward math than those in the academic level and the effect of these differences, if they exist, on math achievement.

Also, a larger sample could reveal different results and would allow for more concrete conclusions and generalizations for a greater population.

Finally, more research is needed to explore math anxiety and attitudes toward math among younger students in elementary and junior high school (grades 7 to 9). It will be useful to determine when these can be identified in students so that preventative measures and interventions to create positive attitudes toward math and reduce anxiety can take place in the classroom. Early experiences in math are critical in formulating attitudes as well as perceptions and expectations of ability and performance in math (Ma, 1997; Ma & Kishor, 1997; Neale, 1969). Attitudes toward math are already developed by junior high school, and this is when negative attitudes toward math become more noticeable (Ma & Kishor, 1997). Therefore, it is crucial to understand how students' math dispositions and their relationship to achievement are influenced and shaped early on in the classroom environment. Furthermore, because teachers are essential in facilitating positive math experiences in the classroom, assessing their beliefs, attitudes, and anxiety levels is important. Interestingly, the highest levels of math anxiety were experienced by students in the preservice education program preparing to teach at the elementary level (Hembree, 1990). Helping teachers overcome their own negative attitudes and anxiety should produce less math-anxious students and cultivate more positive dispositions toward math.

Final Word

Imagine a math classroom where students have a positive outlook on their expectations for success in math, express their like of the subject, are excited and motivated to learn mathematics, and perform well in math. Educators, parents, and administrators must work together to help all our students succeed in math. The negative implications of math anxiety and poor math attitudes are well known and far reaching. Applicable preventative measures and interventions can be used to mitigate the negative impact of math-related stress or anxiety. The goal should be to identify students with math anxiety and negative attitudes toward math and help them overcome them. Math teachers must keep abreast of best practices for teaching math and utilize various teaching strategies to encourage excitement and enjoyment of math among their students, beginning at the elementary level. Parents need to take active, supportive roles in their child's learning and be aware of the implications of how their own feelings, beliefs, expectations, and anxieties toward math can impact the child's performance and success in math. Additionally, students must be aware of their negative dispositions toward math and realize the source of their fear. With the help of teachers and parents, students can learn coping strategies to deal with and overcome negative feelings and anxiety so that they can become more successful in math. The important message here is that student attitudes and anxieties *can* be changed and, by doing so, they will be more capable of *learning* math and *will* experience success in math.

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Appendix A

Mathitude Survey

1. When I hear the word *math*, I _______.
2. My favourite thing in math is _______.
3. My least favourite thing in math is __________.
4. If I could ask for one thing in math, it would be ______.
5. My favourite teacher for math is _______ because _________.
6. If math were a color, it would be ______.
7. If math were an animal, it would be ______.
8. My favourite subject is _____ because ______.
9. Math stresses me out: **True** or **False.** Explain if you can.
10. I am a good math problem solver: **True** or **False**. Explain if you can.

(Furner & Duffy, 2002, p. 70)

Appendix B

Math Journal/Discussion Questions for Students

1. When you solve your math problems for homework or in class, draw a line down the middle of your paper. As you solve the problem on one side of the line (column), in the other column describe how you are feeling at each step until you have solved the problem.
2. Imagine yourself doing or using math either in or out of school. What does it feel like? Describe.
3. For me, math is most like _____. Why?
4. Are you the type that does well in math class? Why or why not?
5. Describe how you feel in math class?
6. Pretend that you have to describe mathematics to someone. List all the words or phrases you could use.
7. In your own words, write the general rule for adding two 2-digit numbers together, adding fractions with like denominators, dividing with decimals, and so forth. (The students could do this for almost any math concept in the curriculum.)

(Furner & Duffy, 2002, p. 71)