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The phenomenon of math anxiety

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Abstract
Math anxiety has cognitive, physical, and affective components. The physical component is recognizable by sweaty palms, nausea, rapid heart rhythm, and shortness of breath – all of which are the body's response to anxious feelings. The affective component is displayed through lack of confidence in one's ability to accomplish the required mathematics computations, avoidance of studying mathematics, limitations of career choices, and an over-all sense of helplessness when confronted with mathematical situations. The cognitive component occurs when the anxiety reaches a level that reduces the efficiency of the working memory in the brain while learning new mathematical concepts. Tobias, a respected authority on math anxiety, believes that everyone will experience some level of math anxiety sometime during his/her lifetime.

The Phenomenon of Math Anxiety

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Chapter I

Introduction: The Phenomenon of Math Anxiety

Imagine a student in a typical school classroom on a typical school day. The sun shines brightly outside, but inside the classroom seems dull and depressing. This is a typical math classroom and the student is experiencing math anxiety. For a number of years now I have wondered why some students who are considered to be intelligent and do well in other subjects, struggle in math. There is no doubt that math anxiety exists. Math anxiety is a common phenomenon among students. According to Perry (2004), Department of Mathematics and Physics at Springfield College, many students suffer from the problem in some form or other; in most cases, math anxiety is not extreme or overwhelming.

At the beginning of the school year for the last four of the seventeen years that I have been teaching math, I have asked my students several questions.

1. Do you like math?
2. What is the one area in math that you feel is your strongest?
3. What is the one area of math that you feel is your weakest?
4. Identify at least one thing a teacher has done in a math class that has made the studying of math easier for you.

The middle two questions are used as an informal diagnostic to aid my decision of what review material to use at the beginning of the school year. The first question gives me an idea of the level from which I will need to begin building my classroom environment for the year. The last question gives me an idea of the type of teaching strategies that have been successful in the past for these students.

It has interested me that I have rarely received a yes/no response from the first question like I had expected. Most students answer similar to the responses below:

Yes, when I like the teacher.
Yes, when I understand it…but that doesn't happen very often.
Yes, but a lot of it is confusing.
No, the teacher doesn't explain it well.
No, it's not my specialty.
No, I do it because I have to.

One student was very definite about his feeling towards math when he said, "It makes my stomach hurt."

Math anxiety usually begins at an early age and continues to haunt most students throughout their mathematical career; for some it continues into their professional careers. I have a friend who is a principal of a middle school in a large eastern Iowa school district. My friend is a respected professional. She readily admitted to me that she is terrified of anything related to math. She jokingly said one day, "There is a reason why I studied language arts and literature." For many people, math anxiety affects the classes they take in school and the careers they choose to pursue professionally.

I have come to the conclusion that I personally cannot prevent math anxiety. I am presently teaching high school math at a school where students are tracked via previous math performances. Students, with the assistance of the educational system, have already developed ideas as to their ability to be successful in math by the time they arrive in my class. Much of their perception of success or failure is based on the presence or level of math anxiety.

Students in my Basic Geometry classes either have Individual Education Plans (IEP) and have moved up to my class from the special education math class, or the students have been unsuccessful in the average level track so have been moved down to my class. My classes have become the bridge between the special education department and the math department. My students have a wide range of ability both in mathematics and reading which requires my teaching style to be different from many of the other high school teachers in the building. My fifteen years of middle school teaching prior to moving to the high school have helped me fill this requirement.

Chapter II

Statement of the Problem:

Math anxiety impedes a student's ability to learn math. So my ultimate concern is what teaching strategies can be implemented to reduce student math anxiety levels and thus improve a student's ability to learn mathematics?

Defining Math Anxiety

Researchers have defined math anxiety using different words, but ultimately stating the fact that math anxiety produces for individuals a negative feeling towards mathematics and their ability to be successful in the study of mathematics. Townsend of the University of Auckland, New Zealand, states, "Mathematics anxiety refers to a person's feeling of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary and academic situations" (1998, 42).

"Mathematics anxiety has been described as a multidimensional construct with cognitive as well as affective roots" according to Sloan of Athens State University (2002, 85). "Buckley and Ribordy (1982) defined math anxiety as an inconceivable dread of mathematics that can interfere with manipulating numbers and solving mathematical problems within a variety of everyday life and academic situations" (2002, 85). In 1989 the National Council of Teachers of Mathematics recognized math anxiety as a problem and made specific recommendations "that teachers assess their students' mathematical dispositions."

"Math anxiety is an inability by an otherwise intelligent person to cope with quantification, and more generally, mathematics. Frequently the outward symptoms of math anxiety are physiological rather than psychological. When confronted with a math problem, the sufferer has sweaty palms, is nauseous, has heart palpitations, and experiences paralysis of thought" according to Krantz, as quoted by Sherman (1999). Most people do not suffer this level of difficulty; however, many do suffer from math anxiety in some form or another. The level of suffering differs per individual and per mathematical level being studied.

Math anxiety has been related to personality type, negative attitude toward mathematics, math avoidance, math background, instructor behaviors, level of math achievement, lack of confidence, and negative school experiences (Sloan, 2002). Based on the research, I have grouped these factors into four classifications:

1. Self-concepts
2. Gender and cultural variances
3. Trait and state anxiety
4. Learning disabilities

Self-concept:

Self-concept has been defined as "attitudes, feelings, and knowledge that individuals have about their skills, abilities, appearance, and social acceptability" (Sherman, 1999). The student's self-concept concerning mathematics begins at an early age and develops over the years of mathematics study. This level of math anxiety appears as test anxiety, fear of failure, and feeling of inadequacy. Over a period of time the student transfers such fears and feelings into a dislike for the study of mathematics eventually developing an avoidance of the subject, or learned helplessness when faced with studying it. In her book, *Motivation for Achievement,* Alderman (1999) defines learned helplessness as the expectation that the student's "actions will be futile in affecting future outcomes." She continues, "Helplessness exists in achievement situations when students do not see a connection between their actions and their performance and grades" (38). In research studies students felt they could not control events and gave up trying to solve problems after a minimum of effort. With this level of effort, a student's math anxiety continues to develop at an alarming rate.

Fear of failure develops when teachers place more emphasis on the correct answer than on the process for generating that answer. This often occurs when a teacher places a major emphasis on memorized algorithms. One student described the situation in this manner, "A lot of teachers show you how to do something, but leave out the why. Sometimes if you know the why, it is easier to come up with the how" (Perry, 2004, 324).

Research conducted by Jackson and Leffingwell in 1999 found that 93% of Americans have had negative math experiences. Perry and others suggest negative math experiences occur because of generally poor instruction by elementary teachers who are not sufficiently capable of teaching mathematics due to little interest or appreciation of the subject and insufficient training in how to teach the subject.

Individuals who choose to be elementary teachers tend to have math anxiety; more so than in any other profession. Many elementary teachers begin their collegiate studies with a sense of anxiety toward mathematics. They are not confident about their math abilities and often view the study of mathematics as an arbitrary collection of facts and memorized algorithms. A weak understanding of mathematics, compounded by negative attitudes and math anxiety, causes some elementary teachers to spend less time in the classroom on the study of mathematics than any other subject as quantified by Stevenson and Stigler in their book, *The Learning Gap* (1992). They discovered in the research for their book that some elementary teachers in this country spent as little as 20 minutes per day in the teaching of mathematics. NCTM states in its standards, "Elementary school students need at least an hour of mathematics instruction each day" (2000, 373).

Teachers are not the only source of anxiety transference. Wieschenberg offers this explanation, "At home, when a mother remarks casually that she can't balance her checkbook, her children may assume that one can become a perfect adult—as mothers often are in the eyes of young children—without liking or knowing mathematics. It is interesting to note that explanatory styles of both sons and daughters are in most cases similar to their mother's, not father's. When children at an early, impressionable age hear these casual remarks they too assume that it is all right not to like or excel in math; they then develop a lack of motivation together with a sense of fear" (1994,).

Gender and Cultural Variance:

Examining the relationship between math anxiety and social desirability, Zettle (1998) reported that females tend to report higher levels of math anxiety than males. The research team admitted that at the time of the study the reason for this was yet unclear. They suggested that females may be "socialized to focus greater attention on their internal states and sense of psychological well-being", or it may be "more socially acceptable for females than it is for males to admit to experiencing math anxiety" (82).

Some researchers have thought math anxiety was associated with feelings of perfectionism and inferiority and concerns about gender roles and identity. Ho (2000) and his research team published the results of a cross-national gender study they conducted using students from the Republic of China, Japan, the United States, and the People's Republic of China (Taiwan) in 2002. "In our cross-national comparison of gender differences in math anxiety levels, the two Asian samples did not respond similarly; that is, whereas Taiwanese females' ratings for both affective and cognitive math anxiety were higher than ratings of their male counterparts, the ratings did not differ between boys and girls in the Chinese sample for either factor" (376). The ratings for the Japanese and American samples were comparable to those of the Taiwanese. The researchers continue to add, "Although speculative, our hypothesis is that the lack of gender differences found in the student sample from the People's Republic of China may reflect social implications of the one-child policy. This policy allows each family to have only one child and may cause parents to have high academic and career expectations for their one child, irrespective of gender. In addition, new marriage laws appear to have contributed to the improved economic status of women: both men and women are expected to work outside the home, and they receive both equal pay and pensions when they retire" (376).

Research conducted by Zettle (1998) on the relationship of trait and test anxiety with mathematics anxiety showed "the relationship between math anxiety and test anxiety was found to vary as a function of gender. Significantly higher levels of both math and test anxiety were noted for women as well as a significantly stronger relationship between math and test anxiety than between math and trait anxiety" (251). Research conducted by Miller and Bichsel (2004) reported a similar conclusion.

Test Anxiety, Trait Anxiety, and Math Anxiety:

Perry (2004) stated that test anxiety is the mildest and most frequent form of math anxiety. Students understand the material well during ordinary class work and while doing assignments, but become anxious, and sometimes even panic, when faced with an exam. This is probably due to the realization that the score obtained on an exam affects their future more than class work or assignments.

There are numerous types of anxiety; two types of anxiety are associated with math anxiety, trait and state. Trait anxiety is characterized by a tendency to feel anxious across all types of situations; whereas, state anxiety tends to be specific to personally stressful or fearful situations. In a 2004 study conducted by Miller and Bichsel, results suggest "math anxiety is not purely a consequence of anxiety over being tested;" math anxiety is related to both trait and state anxiety as well as test anxiety.

Anxiety affects the working memory of the brain. "Individuals with high trait anxiety suffered from working memory deficits and poorer performance when placed under the additional stress of a high state anxiety condition" (593) as is present with math anxiety. The research found that anxiety interferes more with verbal than with visual task performance. Furthermore, the working memory is related to math performance requiring both verbal and visual tasks.

Learning Disabilities:

Dyslexia is a learning disability that causes the individual to transpose numbers, letters, or both depending on the severity of the disability. Dysgraphia is a recently discovered learning disability where the individual has difficulty reproducing shapes; writing is usually the first visibly identifying area. Dyscalculia is a learning disability that is characterized by a poor understanding of the number concept and the number system. This last disability causes the sufferer to have difficulties counting, making change, telling time, sequencing events either past or future, and learning abstract concepts. Such learning disabilities often cause math anxiety to increase. Students with learning disabilities need to have concepts taught with the instructor mindful of their learning needs as well as the awareness of possible math anxiety caused by the disability.

Chapter III

THE LITERATURE:

Individuals with math anxiety have been identified at every level of education—elementary school, middle school, high school, college, and into adulthood. Researchers and educators have stated repeatedly that math anxiety is a major contributor to what courses students choose to study and ultimately what careers are pursued. Tobias argues that math anxiety "is not a failure of intellect, but a failure of nerve" (Perry, 2004, 9).

Various aspects contributing to math anxiety have been measured, including whether math is liked or disliked; is math easy or hard to understand; is math easy or hard to accomplish; is math important or unimportant; is ability or effort more pivotal in the mastery of mathematics; and does the individual believe he/she is actually good at math. Gender and race have been hypothesized as contributors to math anxiety; however, recent studies have not reached the same conclusion as earlier studies. Areas of research dealing with math anxiety include the relationship between math anxiety and other anxieties such as state, trait, and test anxiety; the relationship between math anxiety and math performance; and the relationship between math anxiety and the working memory of the brain.

Elementary:

Math anxiety has been identified in all cultures beginning as early as elementary school. Stevenson and Stigler conducted a 10-year study of elementary students that compared the United States educational practices and student performance levels to those of Japan, Taiwan, and China. Their book, *The Learning* Gap (1992), begins,

> It is no secret by now that American education is in crisis. Teachers work long hours for little reward. Our children's academic achievement is in decline. We pour more money into our schools, but we don't see a corresponding improvement in quality. Especially in mathematics and science, American children trail their counterparts in Europe and Asia, and they are losing ground. (13)

Academic achievement, school organization, teacher training, classroom practices, as well as societal norms and expectations were examined.

Some of their observations were:

- American students experience a striking discontinuity between home and school.
- Americans accept the need for practice and drill to achieve excellence in sports, music, or dance, but few parent—and even fewer children—favor spending more time at home on academic activities.
- A national curriculum exists in Asian countries; the inconsistent curriculum in the United States makes American teachers isolated within their classrooms.
- The smaller amounts of mathematics class time and the time wasted in transitions and irrelevant behavior are important factors that lower U.S. student performance levels.
- Tracking does not exist in Asian elementary schools.
- Asian teachers tend to use short, frequent periods of seatwork, alternating between discussing problems and allowing children to work problems on their own.
- American teachers tend to relegate seatwork to one long period at the end of the class, where it becomes little more than a time for repetitious practice.
- Asian teachers focus "initially on interpreting and defining a problem and then on discussing the ways the problem can be represented through mathematical notation".
- American elementary school teachers "are more prone to use language to define terms and state rules than are Asian teachers, who in their efforts to make mathematics meaningful, use language as a means of clarification and elaboration".
- American elementary school teachers like to teach reading; Asian elementary school teachers like to teach mathematics. (Stevenson & Stigler, 1992, 184)

The authors do not indicate that American teachers should teach in the same manner as their Asian counterparts. They do say that the American education system needs to make changes. Among the many conclusions recommended by the authors is "the likelihood that all children will profit from each day's lesson can be maximized if teachers vary their approaches to teaching, particularly in presenting new material. Class discussion, manipulation of concrete materials, group solution of problems and other techniques that all teachers use at times would increase children's understanding and add to the liveliness of the class if they were introduced more frequently" (211).

Among the many items discussed in the book is the emphasis in the United States on students' innate abilities to study and understand mathematics. This belief has generated a decline in student efforts when studying mathematics. "Children who believe that their high ability is sufficient to ensure success find little reason to work hard; children who perceive themselves as having low ability and doubt that they can master their lessons through continued effort also have little reason to work hard" (95). In contrast, "Chinese and Japanese societies allow no excuses for lack of progress in school; regardless of one's current level of performance, opportunities for advancement are always believed to be available through more effort" (95).

American students see their lack of mathematical comprehension as a lack of ability. They do not see how studying the subject of mathematics will change this innate ability. Therefore, they avoid mathematics as much as possible decreasing their success in the subject—a fact that researchers view as a contributor to math anxiety.

Stodolsky (1985), a member of the Department of Education at the University of Chicago, summarized math anxiety research for a project sponsored by the Amoco Foundation through the University of Chicago School Mathematics Project (1985). She comments:

> Math anxiety is usually assessed through self-report instruments that include questions about situations involving the use of numbers, formal study of arithmetic or mathematics, and taking math tests. Through various scoring procedures, respondents are deemed more or less anxious

> about math and the use of numbers depending on how many mathematical situations evoke discomfort in them and the strength of their unease in settings that involve mathematics (126).

Stodolsky (1985) conducted an observational study of demographically diverse fifth-grade math and social studies classes in the Chicago area. She discovered "teachers instructing the same children in the same physical setting systematically altered their instructional practices depending on whether they were teaching math or social studies" (127). Math instruction was more homogeneous. The typical math class had high reliance on teacher presentation of new concepts and procedures; high reliance on recitation and seatwork pattern of instruction; textbook-centered instruction with lack of instruction for development of math concepts; lack of manipulatives; and lack of social-support or small group work.

The way math is taught in the United States may be the reason why this country has such a high level of math anxiety (Stodolsky, 1985). Americans hold a view that math ability is a crucial element in the learning of mathematics. The lack of manipulative usage and in-depth material development only adds credibility to this view.

- The dependence between the math teacher and math learner created by the heavy emphasis on teacher-based instruction over many years may contribute to math anxiety.
- The heavy emphasis of text-book generated curriculum restricts the development of the math concepts necessary for comprehension. "It may be more possible for a student to use a high school or college text independently, but by high school many students have given up on math and do not expect the textbook to be helpful" (131).

Stodolsky (1985) concluded that the existence of negative attitudes toward mathematics has generated shortages in qualified employees in certain career areas. Course enrollment figures indicate smaller percentages of students pursuing math courses from high school through college. However, "research evidence that provides a demographic or incidence rate for math anxiety is sparse" (126). The author noted that a study by J. I. Goodlad involving 17,000 elementary students indicated that children in lower elementary grades had a positive attitude toward mathematics. The 1980 National Assessment of Education Progress (NAEP) study found that, "9-year-olds ranked math as their best-liked subject, 13-year-olds ranked it second best, but 17-year-olds placed it as the least-liked subject" (126). Recent information has shown similar data results.

Additional studies show that "a substantial portion of the adult population seems nervous or reluctant to pursue mathematical activity, often feeling that they will simply not be able to do it; . . .anxiety, helplessness, fear and even guilt among adults of all education backgrounds exists" (127).

> The nature of instruction itself seems a powerful force in shaping later attitudes, expectations, and conceptions of learning. Math instruction dominantly assumes only one way to learn: teacher presentation followed by practice. If a learner has a poor teacher, or needs additional channels for learning, or additional time for learning, the typical math learning situation cannot respond. Even if math learning is adequate in the elementary grades, an implicit set of expectations about what it means to learn math are consistently communicated starting in the early school years. (Stodolsky, 1985, 133)

Research conducted by professors from The University of California, the National Chang-Hwa University of Education in Taiwan, Beijing Institute of Education in China, and Seisen Women's Junior College in Japan (Ho, 2000) showed that students with higher levels of math anxiety tend to correspond with lower levels of mathematics performance. Math anxiety may have a number of important indirect consequences:

- Math anxious individuals avoid mathematics classes.

- Math anxious elementary school teachers spend less time teaching mathematics than their less anxious colleagues.
- Math anxiety manifests itself in test anxiety.
- High anxiety is attributed to poor study habits.
- Math anxiety has an emotional component as well as a cognitive element in the development of the individual's perception of his/her mathematical ability.

The cross-national mathematics achievement study using data collected from sixth-grade students, their parents and teachers was conducted (Ho, 2000). The subjects included 211 students from China (92 girls and 119 boys), 214 students from Taiwan (106 girls and 108 boys) and 246 students from the United States (111 girls and 135 boys). In an attempt to obtain a representational sample, schools were taken from both rural and urban settings with considerations for parental educational, economic, institutional, and residential characteristics in all three countries.

The findings of this study indicated that "the affective factor of math anxiety is consistently related to mathematics achievement for all three national samples whereas the cognitive factor yields inconsistent results across the samples" (375). Asian students have typically scored higher than their U. S. counterparts on mathematics achievement tests; however, the affective and cognitive dimensions of math anxiety were found in all three countries.

In the 1990's, some educators hypothesized that math anxiety would be eliminated if teaching instruction was of a universally high standard. *The Principles and Standards for School Mathematics* (2000), a book produced by the National Council of Teachers of Mathematics (NCTM), presents recommendations for good instruction in math classrooms. It has been the guideline used for curriculum reform in the two school districts where I have taught. The principles of school mathematics as identified by NCTM are:

- Equity
- Curriculum
- Teaching
- Learning assessment
- Technology

For the purpose of my research, I will concentrate on the principles of equity, curriculum, and teaching.

The Equity Principle requires high expectations and strong support for all students "regardless of their personal characteristics, backgrounds, or physical challenges" (NCTM, 2000, 12). However, "equity does not mean that every student should receive identical instruction; instead, it demands that reasonable and appropriate accommodations be made as needed to promote access and attainment for all students" (12). The principle continues, "well-documented examples demonstrate that all children, including those who have been traditionally underserved, can learn mathematics when they have assess to high-quality instructional programs that support their learning" (14).

The Curriculum Principle states that mathematics curriculum should be coherent, focused, and articulated across the grades. It should model and predict real-world phenomena, and support the quantitative literacy of students. Mathematical ideas should be "linked to and build on one another so that students' understanding and knowledge deepens and their ability to apply mathematics expands" (14).

As in teaching any subject, teaching mathematics well is a complex endeavor. "Effective teaching requires knowing and understanding mathematics, students as learners, and pedagogical strategies. Teachers need several different kinds of mathematical knowledge—knowledge about the whole domain; deep, flexible knowledge about curriculum goals and about the important ideas that are central to their grade level;

knowledge about the challenges students are likely to encounter in learning these ideas; knowledge about how the ideas can be represented to teach them effectively, and knowledge about how students' understanding can be assessed" (17).

Emphasis on quality classroom teaching is again presented in the book, *Adding It Up*. The book is the product of an 18-month project in which 16 individuals with diverse backgrounds, as a committee chaired by Jeremy Kilpatrick, reviewed and synthesized relevant research on mathematics learning from pre-kindergarten through grade 8. The committee (2001) presents the Mathematical Proficiency Strands:

- Conceptual understanding—comprehension of mathematical concepts, operations and relations.
- Procedural fluency—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately.
- Strategic competence—ability to formulate, represent, and solve mathematical problems.
- Adaptive reasoning—capacity for logical thought, reflection, explanation, and justification.
- Productive disposition—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

The committee expressly states that the strands are NOT independent; the strands are interwoven and interdependent. These strands are similar to the concepts presented by the National Assessment of Educational Progress (NAEP); they identify the three mathematical abilities—conceptual understanding, procedural knowledge, and problem solving. Because the strands are interwoven, it is very important for the teacher to connect student knowledge. "Knowledge that has been learned with understanding provides the basis for generating new knowledge and for solving new and unfamiliar problems" (Kilpatrick, 2001, 120).

A certain level of skill is required to understand new concepts; therefore, "when students practice procedures they do not understand, there is a danger they will practice incorrect procedures, thereby making it more difficult to learn correct ones" (122). For that reason it is "critical that they (students) encounter good mathematics teachers in the early grades" (132).

Because the strands of mathematical proficiency develop together, math proficiency takes time. "To become proficient, students need to spend sustained periods of time doing mathematics—solving problems, reasoning, developing understanding, practicing skills—and building connections between their previous knowledge and new knowledge" (135). One of the greatest deficiencies of U. S. students is the ability to solve problems. To improve in this area, effective instruction needs to be implemented. "Effective instruction depends on the coherent connection over time among lessons designed collectively to achieve important mathematical goals" (315). The quality of teaching does not inhere to any one element. "That every task a teacher poses, its cognitive demand is shaped by the way students use it" (335).

Teachers need to remember that the principles of learning apply to all children, not just those dealing with math anxiety. These universal principle of learning are: a) learning with understanding involves connecting and organizing knowledge; b) learning builds on what children already know; and c) formal school instruction should take advantage of children's informal everyday knowledge of mathematics.

Middle School:

Researchers Hall, Davis, Bolen, and Chia (1999) from the Department of Psychology at the East Carolina University examined gender and racial difference in mathematics performance using 74 fifth- and eighth-grade students enrolled in southeastern United States public school districts. The study group was comprised of 35 Caucasians and 39 African Americans; participants included 38 boys and 36 girls. Students were given the California Achievement Test (CAT). A parent questionnaire assessing parent's self-reported math anxiety, perceptions of their own math skills, highest completed level of mathematics course, education level, and occupational status was also administered.

Expectations were based on previous research that showed:

- Black and Hispanic students started to fall below grade level in the second grade in much larger numbers than did White and Asian American students.
- All racial groups were equal in their liking of mathematics in the early grades, significant differences emerged as students moved up in grade level.
- In 1990 Hyde, Fennema, and Lamon did not find significant differences in mathematical achievement between boys and girls from elementary through junior high school; however, they did find a steady upward trend for men to out-perform women from high school through college.
- Gross found in 1988 that female students were less confident of their abilities to do math than were their male counterparts.
- Ecceles found in 1993 strong evidence that parents' perceptions about their child's ability and interest in academic subjects were related to the child's attitudes and academic performance.
- Parents communicate their beliefs and attitudes about math and its utility through their individual practices which becomes a major part of the child's attitude and performance.

Results from this study showed that parental attitudes among the Caucasian parents about their liking for and the importance and utility of mathematics seemed extremely influential in the student's performance in math. The less anxiety the parents reported about their math performance, the higher the child's scores were on the CAT math sections. Parents appear to form their impressions of their child's ability and interest in academic areas bases on their own biases. Among Black students, none of the parental variables were significantly correlated with the children's academic performance.

Research conducted by Sepie and Keeling (2001) of the University of Canterbry in New Zealand had shown that "anxiety is quite strongly associated with under-achievement in mathematics" (15). However, many studies had measured anxiety as "a broad dispositional trait" rather than specifically related to learning activities typical of the classroom. In this study, 246 eleven and twelve-year olds (132 boys and 114 girls) were divided into groups of over-achievers, achievers, and under-achievers in mathematics. The researchers used several instruments in this study including the Otis Test of Mental Ability, the Progressive Achievement Test for Mathematics, and the Test Anxiety Scale for Children.

Their study generated several conclusions:

- There was an absence of significant difference for gender.
- Under-achievers in mathematics are more clearly differentiated from their achieving and over-achieving peers in mathematics-specific anxiety than in either general or test anxiety.
- The activity of mathematics itself appears to generate anxiety reactions among a number of students who are not necessarily highly anxious in other situations.
- Belief in mathematics anxiety has been widespread for a long time and the results of this study lend empirical support to this belief.

Turner, Meyer, Gheen, Anderman, Kang, and Patrick (2002) found, "By early adolescence some students have begun to purposefully withdraw effort, resist novel approaches to learning, and avoid seeking academic help when they need it. These avoidance strategies, often adopted to deflect attention from low ability, undermine performance" (88). The purpose of this study was to "examine aspects of the learning environment—the goals for achievement that are emphasized in the classroom and instructional practices—that are related to students' reports of the use of avoidance strategies in mathematics" (88).

Using survey to elicit students' views of teaching strategies used in math class, students reported using avoidance strategies significantly less in classrooms perceived as emphasizing learning, understanding, effort, and enjoyment (Turner, 2002). Students also reported fewer avoidance strategies in classrooms which teachers provided instructional and motivational support for learning. Teachers in those classrooms helped students build understanding, gave them opportunities to demonstrate new competencies, and provided substantial motivational support for learning. Instructional discourse patterns that supported students both cognitively and motivationally were characteristic of low-avoidance/high-mastery classrooms. Instructional discourse that emphasized "the final answer" or sharing of the reasoning used did not adequately build understanding or address the motivational concerns of students.

Ma (2003), Director of the Canadian Centre for Advanced Studies of National Databases at the University of Alberta, discovered a lack of empirical knowledge concerning early acceleration of students in mathematics classes. He was especially interested in the development of motivational responses such as attitudes toward mathematics and mathematics anxiety. He did a 6-year longitudinal study of mathematics and science education in public middle and high schools in the United States. The study consisted of 3,116 students grade 7 to 12 from 52 schools. Students were identified as gifted students, honors students, and regular students.

Previous studies had shown that academic acceleration of gifted students produced positive effects. Some research had found "that accelerated students in mathematics not only maintain an interest in mathematics but also improve their education pursuits" (Ma, 2003, 440). The impact of early acceleration of students in mathematics as to math anxiety was largely unknown.

His results showed:

- When gifted and honors students were accelerated, the development of their attitudes toward mathematics was found to be similar to that of their counterparts is the same academic category.
- When regular students were accelerated in mathematics, the development of their attitudes was significantly disadvantaged compared with regular students who were not accelerated.
- For accelerated gifted students, older students showed a significantly faster rate of growth in anxiety than younger students.
- For accelerated honors students, both Black and Asian students showed a significantly faster rate of growth in anxiety than White students.
- For accelerated regular students, students whose home language was English showed a significantly faster rate of growth in anxiety than those whose home language was other than English.
- Student rather than school factors were responsible for the variation in the rate of change in attitudes and anxiety.

Secondary:

The stress of math anxiety continues to grow as students continue in school. Many avoid the study of mathematics as much as possible in their secondary level of education. For others, math anxiety begins with the study of more abstract mathematics.

In a study at Oklahoma State University conducted by Williams (1994), "mathematics anxiety has been postulated to include cognitive and affective components" which is similar to the bi-dimensional cognitive and affective components of test anxiety. She defines the affective dimension, or the emotionality of anxiety, to refer to behavioral or physical reactions to the situation; the cognitive dimension refers to worry about the situation or worry about negative performance expectations.

Williams (1994) studied 175 junior and senior high school students attending public schools in northern Oklahoma. The 84 male and 91 female volunteers from predominantly the white middle-class, participating in a one-day university-sponsored ACT preparation workshop were from urban, suburban, and rural areas. Test anxiety was measured using the Test Anxiety Inventory (TAI) and math anxiety was measured using the Math Anxiety Questionnaire (MAQ).

Results showed that significant negative correlations existed between quantitative student scores and the scores on all four anxiety subscales. For test anxiety, worry was negatively associated with both verbal and quantitative student performance; emotionality was inversely related only to quantitative performance. For mathematics anxiety, worry and emotionality were significantly negatively related only to student quantitative performance scores and not to verbal performance scores.

The author reports, "the worry-emotionality distinction has been one major conceptual tool around which anxiety reduction intervention programs have been built" (Williams, 1994, 307). She suggests that improving study habits may be more helpful in reducing math anxiety due to the greater focus on the quantitative concerns related to the nature of the anxiety.

College:

Math anxiety is readily identifiable in colleges. Some colleges have established labs and clinics to assist students in learning methods to control their anxiety. Tobias is considered by many to be a leader in the research and study of math anxiety, and is quoted in many of the literature reviews preceding math anxiety studies. She has established math anxiety clinics at both Vanderbilt and Arizona universities to help individuals cope with the problems as well as to further research in the area.

Tobias states in her book *Overcoming Math Anxiety* (1993) that math anxiety is a lack of confidence. "Lack of confidence contributes to lack of experience and practice, and this in turn erodes confidence still more" (51). In a recent internet interview concerning her research, she says, "For most people, mathematics is more than a subject. It is a relationship between themselves and a discipline purported to be 'hard' and reserved only for an elite and powerful few." Later in the interview she says, "Math anxiety is a political issue. So long as people believe themselves to be disabled in mathematics and do not rise up and confront the social and pedagogical origins of their disabilities, they will be denied math mental health."

This book is designed to help people find a cure for math anxiety, which she says, involves changing attitudes and exploding myths about who can do mathematics and how mathematics competence is measured. Common math myths are:

1. Mathematics ability is inherent.
2. Mathematics insight comes instantly if it comes at all.
3. Only the very few can do mathematics.
4. Mathematics is a male domain.

She says that math competence is the willingness to learn the math you need when you need it. The way attitudes are changed and math myths are exploded are detailed in the following journal article concerning her research and books.

Tobias (1993) states that it is important for students to be aware of their math-anxiety problems, to have biographical information, and to be assertive in seeking assistance. Student group work and group discussion of assigned exercises are also important to the process of reducing math-anxiety.

She outlines five steps for implementing a math-anxiety reduction program for students. First, she argues that the way to reduce math-anxiety is to admit that it exists.

Students and their instructors must be persuaded that there are ways to reduce math-anxiety. "The truth is people who do well at mathematics are confident, hard-working, experienced, and willing to take risks. The task in developing math mental health is to cultivate these behaviors in many more students" (Tobias, 1993, 91).

Second, develop a math autobiography; that is, identify past mathematics successes and failures, as well as attitudes towards mathematics. Students also need to identify the math attitudes of parents, siblings, and peers. They need to be aware of their feelings during stressful periods as well as successful periods. Students need to be made aware of coping skills and techniques for reducing anxiety and producing relaxation.

Third, group "de-tox" sessions must be created where students can talk to others who share similar feelings. It is most successful when a math instructor and a counselor begin sessions as facilitators and later generate student-driven lessons. Sharing is encouraged and "individuals find themselves helping one another with both the mathematics and the stress" (Tobias, 1993, 92).

Fourth, students keep a two-column journal of their feelings. They are encouraged to keep this record near as they do math assignments. On the left-side of the journal students are encouraged to record their self-statements: "What am I feeling?" What does this remind me of?" "What is making this problem difficult for me?" "What could I do to make it easier for myself?" The journal becomes the subject for discussions during group sessions with the student using the right-side of the journal to record improvement possibilities.

Fifth, students need to participate in assertiveness training. Appendix A displays the "Math Anxiety Bill of Rights" developed by Sandra L. Davis to help students articulate typical concerns about mathematics. Tobias has been implementing math-anxiety reduction programs since the 1970's and has experienced impressive results.

Norwood (1994) at North Carolina State University conducted a study on the effect of the instructional approach on mathematics anxiety and achievement. Her research was based on the premise of the following:

- Current research suggests that weak skills in mathematics frequently accompany the incidence of mathematics anxiety.
- Reducing mathematics anxiety and building skills in mathematics were processes thought to be done simultaneously.
- Some researchers estimate that 68% of the students enrolled in college mathematics classes experience high levels of mathematics anxiety.
- Mathematics anxiety does not appear to have a single cause. Inability to handle frustration, excessive school absences, poor self-concept, parental and teacher attitudes toward mathematics, and emphasis on learning mathematics through drill without understanding are all factors leading to mathematics anxiety.
- Some research has led to the conclusion that the method of teaching math contributes to mathematics anxiety. Mathematics should be taught relationally instead of instrumentally. Instrumental teaching of mathematics "views mathematics as a limited set of rules and problem types, and that performing a mathematics task involves recognizing it as one of particular type for which the student already knows the rule." Relational mathematics refers to the "knowing what to do and why."
- A relationship exists between teacher mathematics anxiety and teaching practices. Math anxious teachers tend to use more traditional teaching methods and more reliance of rules.

Two different instructional approaches were used in this study conducted at a northeast community college. Based on poor college entrance placement test scores, 123 students were placed in one of two groups. One instructional group emphasized the memorization of rules and formulas; the other group implemented concept oriented instruction.

The following implications were identified from the results of the study:

- The college students who participated in one of the two instructional treatments showed gains in mean scores on the posttest for mathematics achievement. Although the difference in the adjusted posttest means was not significant, both groups experienced notable gains in mathematics achievement. This result implies that either of the two instructional approaches could be used to improve students' mathematics achievement in arithmetic.

- The instrumental (highly structured lecture) instructional approach tends to reduce mathematics anxiety more effectively than a less structured relational instructional approach, at least for developmental-type arithmetic courses. Students suffering from high levels of mathematics anxiety do not trust their own instincts, and therefore do not prefer to work independently or through a discovery-type approach to learning mathematics.
- Since there appears to be a moderately negative relationship between mathematics anxiety and mathematics achievement, a reduction in mathematics anxiety should be followed by an increase in mathematics achievement.

Zettle (2000) from the Department of Psychology at Wichita State University in Kansas has done extensive research in the area of anxieties. He states, "while math anxiety commonly has been regarded as a subtype or form of test anxiety, there appear to both conceptual and empirical reasons for not viewing the two as equivalent" (2000, 246). He continues to say that math anxiety is most meaningfully conceptualized as a reaction to both mathematical content and to evaluative situations, such as testing of math skills. As it relates to mathematical content, math anxiety may be associated with feelings of perfectionism and inferiority as well as concerns about gender roles and identity.

In his examination of trait and test anxiety with that of mathematics anxiety, 192 urban Midwestern university students enrolled in college algebra completed surveys to determine levels of each type of anxiety. Trait anxiety was measured using the State-Trait Anxiety Inventory (STAI); test anxiety was measured using the Test Anxiety Inventory (TAI); and mathematics anxiety used the Mathematics Anxiety Rating Scale (MARS).

Results from the study included:

- The relationship between math anxiety and test anxiety was stronger than that between math anxiety and trait anxiety.
- The relationship between math anxiety and test anxiety was found to vary as a function of gender. Significantly higher levels of both math and test anxiety were noted for women as well as a significantly stronger relationship between math and test anxiety than between math and trait anxiety.
- The majority of self-identified math anxious participants indicated an interest in receiving services for math anxiety.

In a study with Houghton researching the relationship between mathematics anxiety and social desirability as a function of gender, Zettle (1998) concludes females may be socialized to focus greater attention on their internal states and sense of psychological well-being. It may be more socially acceptable for females than it is for males to admit to experiencing math anxiety. Considering these possibilities, Zettle (1998) conducted a study of 229 students enrolled in sections of introductory psychology at a midsize, urban Midwestern university. Of the participants, 103 were male and 126 were female. The Mathematics Anxiety Rating Scale (MARS) was used to measure mathematics anxiety whereas, the Edwards Social Desirability Scale and the Marlowe-Crowne Social Desirability Scale were used to measure social desirability.

The results of this study showed:

- No gender differences were obtained on the two measures of social desirability.
- Female participants reported slightly higher levels of math anxiety, however, the difference was not statistically significant.
- The number of male college students experiencing math anxiety may be underestimated to the extent that it is less socially acceptable for them to present themselves as being math anxious and/or being deficient in their math skills.

The researchers expected to obtain a gender difference in scores; however, a gender difference in math anxiety was not found in this study. They suggest that more research should be conducted.

In his study covering acceptance and commitment therapy, Zettle (2003) states that mathematics anxiety is a specific phobia that has been treated using a process of systematic desensitization or a variation of it. Acceptance and commitment therapy (ACT) is a new process that may have possibilities as a successful treatment. ACT is "a verbal psychotherapy grounded philosophically in functional contextualism that has the ongoing act-in-context as its core analytic unit" (2003, 98). The general goal of ACT is to simultaneously promote psychological acceptance and discourage experiential avoidance. The purpose of this study was to compare the effectiveness of these two treatment plans.

Originally the 30 females and 7 male participants were randomly assigned by a coin toss to receive either systematic desensitization or ACT. Four students failed to attend the introductory session and nine others dropped out before completing all of the six scheduled sessions. In comparing the results of the study it was discovered that both interventions were associated with statistically equivalent and significant reductions in math anxiety. Zettle (2003) notes that many previous studies reported significant improvements in mathematical skills as a benefit of alleviating math anxiety. This study did not experience that benefit.

Research conducted by Towsend and Moore (1998) from the University of Auckland, New Zealand, emphasized self-concept and anxiety in University students studying statistics within a co-operative learning structure. The study consisted of 153 second-year students enrolled in an educational psychology course. The instruments used to gather data were a 27-item mathematics self-concept scale designed by Gourgey to reflect attitudes, beliefs, and feelings about one's ability to learn mathematics, a 10-item mathematics anxiety scale designed by Betz to assess levels of anxiety related to doing mathematics, and an open-ended comment document, a procedure recommended by Schatzman and Strauss, to compare confidence levels for doing statistics at the beginning of the course compared to the end of the course.

One of the conclusions of their study that applies to my research was "when provided with a supportive learning environment, with opportunities for co-operative group problem-solving involving positive interdependence, face-to-face promotive interaction and individual accountability, self-concept in mathematics will increase as will students' feelings of confidence, but it is likely that feelings of anxiety will not decrease in the short term" (Townsend, 1998, 51).

Perry (2004), the Department of Mathematics and Physics at Springfield College, examined case studies of students with different levels of math anxiety. He defines math anxiety as "an inability by an otherwise intelligent person to cope with quantification, and more generally, mathematics. Frequently the outward symptoms of math anxiety are physiological rather than psychological. When confronted with a math problem the sufferer has sweaty palms, is nauseous, has heart palpitations, and experiences paralysis of thought" (2004, 321).

It is his view that the most common form of math anxiety is the moderate and intermittent variety found in a student who has mixed feelings towards the subject of mathematics. For many students, math anxiety begins at an early age. "If a student has a single insensitive math teacher, that can create a recurring anxiety problem which may be difficult to overcome" (Perry, 2004, 322). However, the reoccurring theme of "the bad math teacher" becomes a scapegoat for not addressing the problem of math anxiety. It is human nature to find a convenient target for one's frustrations and anxieties.

One case study provided a possible insight into the problem of math anxiety for many students. "A lot of teachers show you how to do something, but leave out the why. Sometimes if you know the why, it is easier to come up with the how" (Perry, 2004, 322). This criticism is an ongoing complaint for many students. Previous research has proposed, "some of the blame for the generally poor instruction in elementary schools must ultimately lie with teachers who aren't sufficiently capable, and who often have too little interest in or appreciation of mathematics" (323). The concept of teacher math anxiety is discussed further in a study conducted by Harper discussed later in this paper.

Perry (2004) states that there is no simple solution for reducing or eliminating math anxiety. He believes however, that a student's superficial understanding of mathematics limited to computational skills, with little conceptual understanding and little mental framework within which to organize knowledge, results in a student quickly forgetting what has been learned. Without the conceptual understanding, building a framework of knowledge for future learning does not exist.

One student summarized at the end of the study:

> I believe that the student's responsibility is to try as hard as possible and also to respect other classmates as well as the teacher. And I also believe that it is the student's responsibility to seek help after class when he/she is confused. As to the teacher's responsibilities, I believe it is the teacher's responsibility to focus on every student's learning, not just a select few. And I also believe that if you want to be a successful teacher, you have to have patience.

The author closes his report by saying, "the most effective coping strategies are natural and direct. Students need to acknowledge their mathematical difficulties and formulate a plan to overcome them, including seeking appropriate assistance when necessary" (Perry, 2004, 323).

Ashcraft and Kirk (2001), the Cleveland State University, have done several studies examining elements of math anxiety. Their study examines the relationship between math anxiety, the working memory, and math performance. Most research involving math anxiety notes that individuals with high math anxiety take fewer math courses, earn lower grades in the classes they do take, and demonstrate lower math achievement and aptitude than their counterparts with low math anxiety.

Previous studies had shown that high-math-anxiety participants showed slower, more effortful processing on a procedural aspect of performance with higher error rates than did low-math-anxiety individuals. Reports from other research have shown that the most effective treatment interventions for math anxiety, behavioral and cognitive-behavioral approaches, also presented evidence of post-treatment increases in math achievement or competence scores to levels approaching those of low-anxiety students. Ashcraft and Kirk (2001) hypothesized that these results occur because of the effect of math anxiety has on the working memory of the brain.

It is now believed that working memory is central to processes such as reading, reading comprehension, reasoning and retrieval from long-term memory. A well-known model presented by Baddeley is that the various components of these mental processes are attributed to one or another of the three major subcomponents—the central executive, the auditory rehearsal loop, or the visuo-spatial sketchpad. It is theorized that the intrusive thoughts and worry characteristic of high anxiety are thought to compete with the ongoing cognitive task for the limited processing resources of working memory.

Because high-anxiety individuals must expend greater cognitive effort to attain the same level of performance achieved by low-anxiety individuals, processing efficiency is lower for high-anxiety individuals.

Ashcraft and Kirk (2001) administered the short form of the Mathematics Anxiety Rating Scale (MARS) and Salthouse and Babcock's listening span (L-span) and computation span (C-span) to 66 lower level undergraduate psychology students. Their conclusion was that "there is an on-line reduction in the available working-memory capacity of high-math-anxiety individuals when their anxiety is aroused. This reduction should depress levels of performance in any math or math-related task that relies substantially on working memory" (2001, 232). When math anxiety is aroused, it functions exactly like a dual-task procedure. Therefore, math anxiety has an impact during original learning of difficult mathematics, but it also disrupts the on-going, task-relevant activities of working memory, slowing down performance and reducing accuracy.

Student Teachers/Teachers:

Math anxiety is not limited to the students in classrooms. Harper (1998), Judson College, and Daane, University of Alabama, conducted a study of 53 preservice elementary teacher enrolled in undergraduate elementary mathematics methods courses at a mid-sized southeastern university. The instruments used for all students were the Mathematics Anxiety Rating Scale (MARS), a 98-item used to measure the anxiety associated specifically with mathematics; the Factors Influencing Mathematics Anxiety (FIMA), a 26-item checklist developed by the authors of the research; and the Methods

Course Reflection (MCR), a 7-item designed to determine the influence on math anxiety of working with a partner, working in cooperative learning groups, working with centers, using manipulatives, doing problem solving activities, writing about mathematics in journals, and doing fieldwork. In addition eleven students having the greatest differences between their MARS pre-and post-test scores were interviewed.

Their findings suggested that many preservice elementary teachers have math anxiety and for many the anxiety began in elementary grades. Many of the causes of math anxiety "have stemmed from rigid and structured classroom instructional practices" where students feel pressured to give the "right" answer in a allotted amount of time. The researchers suggest that teachers "learn more creative ways of presenting problem solving activities to children in a manner that will be motivating. These need to be real-life problem situations in which children are interested" (Harper, 1998, 37).

In another study conducted by Sloan (2002), Athens State University, Daane and Giesen, University of Alabama, 72 preservice elementary teachers at a mid-sized southeastern university; all had completed at least two college mathematics courses. In this study the researchers implemented the MARS and the Style Analysis Survey (SAS), a 110-item designed to identify how individuals prefer to learn, concentrate, and perform in both educational and work environments.

From previous research the team knew:

- Math anxiety is prevalent among pre-service teachers (Hembree, 1990).
- Teacher possessing higher levels of mathematics anxiety may unintentionally pass on these negative feelings to their students (Wood, 1988).
- Math anxiety may stem from teaching methods that are conventional and rule bound (Tobias, 1993).
- This rule-based methodology is most often employed by elementary teachers who possess high levels of math anxiety and negative attitudes toward mathematics (Bush, 1989; Karp, 1991).

- Instructors who teach mathematics primarily through lecture and rote memorization of algorithms often neglect to meet the learning styles of all students and, therefore, may unintentionally perpetuate math anxiety (Hodges, 1983; Zaslavsky, 1994).
- Math anxiety is most prevalent among tactile-kinesthetic learners (McCoy, 1992).
- Math anxiety is positively correlated with auditory preferences (Onwuegbuzie, 1998).

The research team discovered that a positive correlation exists between math anxiety and a global (right-brain dominant) learning style. Since students learn faster and with greater ease when teachers gear instruction to students' learning style, teachers must work to provide various strategies of instruction tied to learning styles of their students.

Additionally, Jackson and Leffingwell (1999), University of Texas at Arlington, collected information from 157 elementary teaching students over a three semester period of time in the form of written responses. It was concluded from the results that anxiety-producing situations occurred most often at:

1. Elementary level, especially grades 3 and 4
2. High school level, especially grades 9 through 11
3. College level, especially freshman year

In many situations, instructors were identified as the source of the problem. Instructor behaviors that produced anxiety were categorized as overt and covert behaviors. Overt behaviors were observable and could be verbal or nonverbal. These behaviors could be a frown, a derogatory comment, or insisting that a student work a problem on the board even when the student stated a lack of understanding. Covert behaviors were implied such as standing near a student and not recognizing a request for assistance or producing a deep sigh when a student asked for clarification. "Whether the instructor behaviors were overt or covert, they interfered with the students' ability to concentrate in mathematics classes. Since mathematics requires sequential-thinking skills, any stress in the mathematics classroom will have even more adverse effects because of the nature of the subject" (Jackson, 1999, 585).

From this study, Jackson and Leffingwell (1999) concluded that instructors can take an active role in reducing performance anxiety and can facilitate learning and enjoyment in mathematics by:

- Disclosing that they may have overcome math anxiety as students and discussing specific strategies of remediation that they have used to be successful in mathematics;
- Making a conscious choice to project to students their own interest in, and enjoyment of, mathematics;
- Offering additional reinforcement and time to students who suffer from anxiety and need help;
- Making mutual respect a pervasive rule to ensure that the classroom environment is psychologically safe;
- Offering one-on-one tutoring sessions for students who have many questions that cannot be dealt with during class time, thereby helping students focus on pertinent questions during the tutorial sessions;
- Giving written and verbal supplemental reviews of key terminology and processes as examination time approaches;
- Seeking assistance from supportive professional colleagues when they feel overwhelmed by the teaching experience;
- Offering alternative times for testing so that students can obtain support from instructors one-on-one and reduce their own levels of anxiety; for example, students might take their tests individually before or after school (586).

Adults:

Math anxiety is not restricted to the classroom; it also contributes to career and lifestyle choices. Miller and Bichsel (2003), Pennsylvania State University at Middletown, acknowledged that previous studies have identified the temporary retrieval, processing, and storage of working memory is a variance in math ability. In addition, state (anxiety occurring in a specific personally stressful or fearful situation) and trait (a tendency to feel anxious across all types of situations) anxiety affect task performance.

Math anxiety is related to both state and trait anxiety; math performance contains a component that elicits a specific form of anxiety.

Individuals with higher levels of anxiety take longer to perform reasoning tasks and are less accurate than individuals with lower levels of anxiety. Poorer performance and longer response times lower working memory capacity. Research investigating which aspect of working memory is impacted by anxiety has predominantly found that anxiety disrupts the verbal component more than the visual task component.

For their study, the researchers recruited 100 adults; 62 females and 38 males ranging in age from 18 to 66. The sample consisted of 42 college students, 30 college graduates, 2 with less than 2 years of college and 26 with no college education. Instruments that were used were the mathematics subtests of the Woodcock-Johnson Test of Achievement, the Math Anxiety Rating Scale, The State-Trait Anxiety Inventory, verbal working memory was assessed via computer, and visual working memory was assessed by computer and paper-folding tasks.

Their conclusions are:

- Math anxiety is an important predictor of math performance.
- Math anxiety does not function like other types of anxiety, at least not as related to performance.
- Math anxiety is associated with visual working memory more than on verbal working memory.
- Females reported high levels of anxiety.
- Males' math anxiety affects their performance on basic math, but not on applied math.

Chapter IV

ANALYSIS AND INTERPRETATION OF THE LITERATURE:

In her book ***Overcoming Math Anxiety (1993)***, Tobias presents four "math myths." A review of the literature would warrant credibility to her statement. Many people in this country accept these concepts as fact; however, much of the new research is proving these concepts to be myths. Adherence to these concepts as fact, rather than the myths, they are is one of the contributing factors for the development of math anxiety.

Myth #1: Mathematics ability is inherent.

Stevenson and Stigler state repeatedly in their book, *The Learning Gap (1992)*, that parents and students in the United States see lack of mathematical comprehension as a lack of ability; whereas the Asian cultures see little or no relationship between ability and student growth in mathematics. The Asian cultures place more emphasis in effort than ability. The study presented by Ho (2000) and fellow researchers showed a similar result. Expectations of the parents and the community play a much stronger role in student progress than the ability of the individual student.

Math classes in my school district are leveled according to ability; the curriculum covered in the different class levels vary accordingly. Levels begin with Advanced Placement classes, through general education classes, basic classes, preparatory classes, and special education classes. Students are placed in a specific level of class based on previous performance. The p remise is that students are placed in classes where the curriculum and teaching style will meet student needs. Realistically this practice is a tracking of students by perceived ability. Once a student is tracked, movement out of that track rarely occurs. Students perform based on the track they have been assigned. Teachers, parents, and students assume an ability level based on the tracking system that exists.

If student placement in classes was based on effort, there would be no need for the leveling. Students expending effort to learn should be able to comprehend and learn the math concepts with support from the teacher, classmates, and parents. Theoretically, for a student to be placed in any mathematics class, the prerequisite materials have already been achieved, proving that the student has the ability to learn the material. So if the student has learned the previous material, effort is the contributing factor for success in the present class.

We have parent-teacher conferences twice a year in my school. Often during these conferences, a parent will make a reference to the student's lack of success in my math class as a reflection of the parent's lack of success in math. Rarely will parents accept the idea that the difficulty is due to the student's study habits. Most parents prefer to believe in an inherent lack of ability as the problem rather than the lack of quality study. Tracking by the school, the parental belief in genetically determined mathematical ability, and inefficient student study skills all contribute to the acceptance, in this country, of mathematics as an inherent ability.

Myth #2: Mathematics insight comes instantly if it comes at all.

Learning a new skill requires time, practice, and effort. Stevenson and Stigler (1992) point out that people in this country accept the need for practice and drill to achieve excellence in sports, music, or dance, but few parents or students favor spending more time at home on academic activities. To me, this seems to be a contradiction in beliefs. If it is necessary to expend more time and effort to develop proficiency in one skill, why wouldn't the same, or at least similar, time and effort be necessary in all skill development?

Since many in this country believe math skill and math insights to be a matter of ability, a different level of effort is applied to the learning and teaching of mathematics. People have been lead to believe that when studying mathematics, a person either "gets it or they don't." Stodolsky (1985) discovered in her research that elementary teachers presented material in math classes differently than they did in social studies classes. Math classes were much more teacher-centered with heavy emphasis on text-book curriculum and memorization of processes and procedures. Does this represent an ability to learn or an ability to quickly memorize?

Students spent more time in isolated practice during math classes than in other subject areas. Spending large amounts of time in isolated study has several negative affects on the learning process:

a) Isolation allows students to practice a newly learned procedure. However, if the procedure is not understood properly, the student is practicing the procedure incorrectly.
b) Isolated study does not allow students to receive timely feedback for questions that arise. If the questions are not answered, the learning of the material is stalled.

c) Isolations does not allow student to share the newly discovered concept(s) with others. The sharing and vocalization produced during student-to-student discourse helps "cement" the concept in the students' memories.

Stevenson and Stigler (1992) found that in comparison, Asian teachers were guides in the learning process of students. Teachers presented a problem to be solved and guided the students through the development of a solution. Asian teachers assume that all students in the classroom have the ability to learn. These teachers also assume that students will put forth every possible effort to learn the material. Student who do not put forth the effort loose the respect of their peers. This cannot be said of students in this country, at least not in the classrooms I've seen. One needs to ask why would mathematics insights occur instantaneous if skill building takes practice; practice is valuable only if the correct process is practiced; and sharing ideas aids comprehension and learning. All of these considerations require a generous amount of time.

Myth #3: Only the very few can do mathematics.

Statistics show that fewer students participate in mathematics classes in college than in high school; fewer students take math classes in high school than in middle school. The majority of elementary students say they like math; fewer students say they like math in middle school; and the count continues to decline as students progress through the educational system in the United States. Math anxious individuals avoid the study of mathematics as much as possible and opt out of mathematical careers. When students avoid math classes, they deprive themselves of the opportunity to learn mathematics.

During middle school, some students discover that learning mathematics becomes more difficult. It is at this time that the mathematical concepts studied are more abstract. Since the learning becomes more difficult, students assume, from what they believe about themselves or what they have been told about themselves, that they do not have the ability. Many students believe the math myths about inherent ability and instant insight. Since the learning of mathematics is more demanding and requires more effort at this level, it is easier to believe in the myths than produce the extra effort necessary to learn the more abstract concepts.

Numerous studies have shown avoidance techniques to be developed by students when mathematics becomes difficult for them. Avoidance techniques are generated for the purpose of deflecting attention from the lack of comprehension or from the lack of effort. Many avoidance techniques develop in early adolescence when the study of mathematics becomes more abstract. It is at this same time when many teachers provide less time for students to spend on mathematical manipulatives in the classroom. Time spent on manipulatives allows students to develop comprehension of the abstract concepts while working with concrete objects. Instead, the abstract concepts are presented as memorized algorithms and students are expected to accept these concepts based on the word of the teacher. Memorized algorithms do not provide students with the understanding to use the algorithm efficiently. Lack of understanding and comprehension is another element in the development of math anxiety.

The difficulty to learn mathematics becomes more pronounced when the teaching style of the instructor and the learning style of the student do not complement each other. This situation leads to a self-fulfilling prophecy for the student, i.e. I can't do this; I told you I can't do this; I'm not going to do this. When students have the opportunity to make choices concerning classes to take in high school, the choice is to not take math classes.

Fewer students pursue mathematics because fewer students feel comfortable with the manner in which mathematics is taught in the upper levels of our educational system. Now that I am teaching in the high school, I have had the opportunity of discussing this with foreign exchange students in our building. Students from Germany, Denmark, Japan, Taiwan, Brazil, and Nigeria readily admit that math is taught very differently in this country than what they are accustomed to in their countries. In many of those other countries, Algebra and Geometry are taught in a more integrated manner. The exchange students also comment that there is more homework in their countries. Students in their countries don't "get to complain about the homework assignments." The idea of not taking math classes is not even considered by the exchange students I have known. Some of the exchange students have taken classes over again just to compare their past math experience in their country to their "American experience."

Myth #4: Mathematics is a male domain.

Historically, our society has tended to consider some careers and educational pursuits to be either male or female domains. We can all identify subjects that are considered male domains; mathematics usually ranks at the top, or near the top, of that list. As a high school student, I was told by my counselor to avoid taking any additional math classes because it wasn't feminine. My eighth grade students always thought it was funny that in our school, the Language Arts and Social Studies teachers were men, and the Science and Math teachers were women. "That's just weird!" Even the women's rights movement of the 1980's had difficulty breaking down these stereotypes.

In the learning of mathematics, gender differences have been addressed through a large quantity of research. Zettle (1998) proposed that a gender difference in the study of mathematics is an element of social desirability. He hypothesized that women readily admit to anxieties whereas men see such as a weakness, a deficiency, or both, in their ability. When conducting his research, Ho and his colleagues (2000) found little difference between male and female students in China when comparing rates of mathematics success and math anxiety. In an effort to reduce population growth, China has a one-child law. He believes that this law has created an environment where parental, teacher, and societal expectations for male and female students are equal. He believes that if gender differences exit, such differences are created by societal beliefs, practices, and expectations, not by mathematical ability. The growing number of females in math careers would support Ho's (2000) hypothesis.

Tobias (1993) says that to reduce math anxiety an individual must first admit the fallacy of math myths and then be willing to learn mathematics. The student can learn mathematics by developing coping strategies for dealing with the anxiety and identifying self-talk that leads to increased anxiety. Research has shown that it is anxiety that reduces the efficiency of the brain's working memory in the learning process. Both math anxiety and test anxiety develop when the learning process is interrupted or slowed by the lack of efficiency in the working memory. The blocking of the working memory by anxiety occurs in both males and females; however, Zettle (1998) believes that our society allows females to admit to math anxiety more than males. If, as a male, you are expected to learn mathematics, the male student puts forth extra effort to learn it; whereas, the female student looks for other options of study.

Chapter V

IMPLICATIONS FOR PRACTICE:

Originally, the purpose for my research was to find good pedagogy for eliminating, or at least reducing, math anxiety. Although I was unable to discover any pivotal "best" teaching strategy or practice, two concepts continue to be identified in this process—building comprehension of the mathematical concepts, and making connections between mathematical concepts—assist comprehension which should reduce anxiety. Both the cognitive and affective components of math anxiety must be addressed in order to reduce the anxiety and improve the efficiency of the working memory. Ashcraft and Miller (2001) both point out at the conclusion of their research that students must be able to build on their experiences. Comprehension of mathematical concepts develops over continued exposure to mathematical thinking used in the study of the subject. For any of these events to occur, the student must be able to see the connection each mathematical concept has to another.

Suggestions from the literature:

How should a teacher go about presenting mathematics in the classroom for this to happen? Townsend (1998) says that the teacher must create a supportive learning environment. When students learn in a supportive environment, he says, math anxiety may remain constant but math attitudes improve, students have increased confidence in their ability, and ultimately student performance improves.

Norwood (1994) points out that students with high levels of math anxiety are not successful in constructivist or discovery learning environments. Students with high levels of math anxiety do not trust their own instincts. Those students need more guidance when faced with a discovery-type approach to learning mathematics. Possibly, the teacher-as-guide format presented by Stevenson and Stigler (1992) would be a better classroom method for mathematics classrooms.

Additionally, many of the research teams suggest that teachers vary their approaches to teaching mathematics especially when presenting new material. It is their belief that varied approaches will reach the different learning styles that students have. These research teams also suggest that teachers, especially in the middle school grades, create more time for students to work with manipulatives. These types of practices would require teachers to move away from the more traditional dependence on lecture forms of teaching and memorized algorithms.

Since many teachers present mathematics in the manner they were taught, the manner modeled by their cooperating teacher when student teaching, or simply "the way they have always taught it," a change in the student teacher curriculum in the colleges would need to be made. Some colleges present a variety of teaching styles to students; however, many colleges rely on the student developing a style that is comfortable.

Research conducted by Ma (2003) examining the effects of acceleration of students in mathematics on attitudes towards math and math anxiety showed that regular students who were accelerated developed more negative attitudes and more math anxiety towards mathematics than did gifted students. Acceleration for gifted students may be beneficial, but schools need to be very careful that the student is identified properly. For the regular student, heterogeneous groupings would be more beneficial to their successful learning of mathematics.

As seen in my classroom:

I graduated from a college that relied on me developing "my own teaching style." I was one of those new teachers who originally modeled my teaching style after that of my college professors—I didn't like the way I had been taught mathematics in high school. It did not take me long to reach the realization that I was not being successful in meeting my teaching goals. I immediately started participating in as many workshops as I could possibly find that would allow me to discover different strategies for teaching mathematics. By the time I began graduate classes, I was confused and frustrated.

The concepts I was introduced to in my master's classes and the research I conducted have helped me to develop a new teaching style. I have been doing many of the recommendations presented by Jackson and Leffingwell (1999). Their recommendations have given me reassurance that I am making progress in the direction I want to go.

Additionally, the work done by Professor John Henning on classroom discourse has provided strategies for improving my teaching. I now have students work in groups of 2 or 3 at least once a week. The goal of the groups is to give students time to share their newly discovered mathematical ideas with each other. Students talk to each other in language they understand; they ask each other questions that would not be asked in front of the large class; and they ask for teacher clarification when a misunderstanding occurs or if they want justification in front of their peers. This type of group activity provides students with the opportunity to make connections between the new information and their previous knowledge of mathematics. A better understanding of the concept occurs because students are generating the connections between the new material and the previous knowledge for themselves and their peers.

The mathematical proficiency strands presented by Kilpatrick and his team (2003) stress the interrelationship between conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. While working in small groups students frequently ask each other questions about mathematics that would not be addressed in front of the large class. Their questions assist each member of the group by improving their mathematical knowledge and proficiency. Students asking the questions receive a timely response from their peers aiding in the conceptual understanding; students answering the questions develop better procedural fluency and adaptive reasoning.

Additionally, by working in smaller groups the level of anxiety is reduced. Students discover that they are not alone in their struggle to understand; and they discover ways to view the material from the perspective of other individuals. Such discoveries improve the students' productive dispositions and attitudes towards the study of mathematics. Since anxiety is reduced, the working memory of the brain is better able to assimilate the information and learning becomes more productive.

To engage my Algebra students in further discussion, I periodically have students share answers to assignments with a student sitting near them instead of me just reading off the answers. Again, the students are required to talk together seeking clarification, justifying their answers and computational methods, and sharing their strategies for solving the problems. Once again, the discovery that others share their difficulties in learning the material is very powerful in reducing anxiety. However, it is important to remember that research has shown that it is best to implement a variety of teaching strategies in the classroom to accommodate the many different learning styles of the students.

For my Geometry classes, I make sure that I present new material in a manner that requires students to reach a conclusion based on what they have just discovered applied to what they already know. I want them to see that the theorems have relationships to each other; that theorems are more than just memorized facts. I want them to apply what they already know to the new situation. Students tell me that they feel more confident when faced with assessment situations because they can remember when the concept was introduced and their participation in its development.

Using manipulatives in the learning of mathematics is highly supported by research. However, obtaining manipulatives to use in the classroom is often difficult. As a compromise, I have students sketch the assigned Geometry problems on the board when discussing solutions. Students can volunteer to put the sketches on the board individually or with the support of a classmate. The students are learning that by sketching the problems, they are able to identify properties and relationships that were previously unobserved. Such practices are not manipulatives in the true sense of the term; however, as students share their observations with class members, the goal of making the concepts more concrete is somewhat fulfilled.

The last strategy I have recently implemented is making corrections on quizzes. The district curriculum requires that I adhere strictly to the text. I must cover a set amount of curriculum in a prescribed amount of time. This does not allow me to develop the material in the manner I would like. Therefore, I try to provide a minimum of two quizzes per chapter. Since I strongly believe that the purpose of a quiz is to prepare students for the exam, I grade quizzes within a 24 hour time period and students are requested to make corrections where appropriate. If a mistake has been made, I simply mark the answer wrong. The student can use notes, the text, or another student to find what is wrong. The student is not allowed to change the original answer, but is requested to identify the new answer by circling it. The student then receives half credit for each correction when an explanation has been provided. Students say they like having "a second chance" to learn the material even if they only receive half credit. They realize that it will not change their grade much but it does provide them with positive information prior to the chapter assessment. Students tell me they have more confidence and less anxiety when presented with the chapter test.

I have to believe that my strategies have some credibility. My classes at Kennedy High School have the maximum number of students allowed per class period. Students recommend my classes to their friends. In addition, when student performance results on the district trimester finals are plotted on a scatter plot, my student scores generate a positive correlation to those of other students in the Cedar Rapids Community School District.

Chapter VI

CONCLUSION:

Math anxiety has cognitive, physical, and affective components. The physical component is recognizable by sweaty palms, nausea, rapid heart rhythm, and shortness of breath—all of which are the body's response to anxious feelings. The affective component is displayed through lack of confidence in one's ability to accomplish the required mathematics computations, avoidance of studying mathematics, limitations of career choices, and an over-all sense of helplessness when confronted with mathematical situations. The cognitive component occurs when the anxiety reaches a level that reduces the efficiency of the working memory in the brain while learning new mathematical concepts. Tobias, a respected authority on math anxiety, believes that everyone will experience some level of math anxiety sometime during his/her lifetime.

I began this research with the confidence that I would discover the "best" teaching strategy for eliminating, or at least reducing, the math anxiety of students in my classroom. Sadly, I did not make such a discovery. Much research has been conducted concerning math anxiety; however, due to the many components of the problem no definitive conclusive procedure has been determined. Some of the research focuses on the cognitive element, some on the affective, and some on the physical depending on the researchers' field of study.

Dr. William Schmidt, chairperson of the TIMSS commission in the United States, stated in an interview that no single teaching format is better than another for improving math performance. However, from an educational viewpoint, I discovered a consensus of opinions that good teaching strategies, as defined by the National Council of Teachers of

Mathematics, can reduce math anxiety for those students willing to expend the energy and effort in the learning of mathematics.

The teaching strategies that reduce math anxiety for many students are:

- Identifying relevancy of the math concept to use in other math classes and career situations;
- Providing a variety of lesson types which allows students to approach the material from different perspectives;
- Making connections between new concepts and previously learned material which allows students to build on their prior experiences both in and out of the classroom;
- Allowing students opportunities to discuss math concepts with each other to clarify their math knowledge.

Students have an opportunity for discourse, for developing relevancy of mathematical concepts and for using mathematical concepts in appropriate ways while participating in realistic problem-solving situations. However, discovery-learning environments cause higher levels of anxiety when students do not know how to apply previously learned mathematics to new pursuits. This is another reason why teachers need to vary teaching strategies and teaching styles.

For the last two years, I have implemented, to the best of my ability, these teaching strategies in my classroom. When I compare the results of my student scores to those of other students on the trimester district final exams; the number of students requesting my classes each trimester; and the success rate of my students in subsequent math classes, these strategies are producing positive results for many of my students.

Appendix A

MATH ANXIETY BILL OF RIGHTS
By Sandra L. Davis

I have the right to learn at my own pace and not feel put down or stupid if I'm slower than someone else.

I have the right to ask whatever questions I have.

I have the right to need extra help.

I have the right to ask a teacher or TA for help.

I have the right to say I don't understand.

I have the right not to understand.

I have the right to feel good about myself regardless of my abilities in math.

I have the right not to base my self-worth on my math skills.

I have the right to view myself as capable of learning math.

I have the right to evaluate my math instructors and how they teach.

I have the right to relax.

I have the right to be treated as a competent adult.

I have the right to dislike math.

I have the right to define success in my own terms.

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