

Running head: THE EFFECTS OF MATH ANXIETY

The Effects of Math Anxiety on Mathematical Academic Success during the Freshman Year

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Poster Session presented at the Eastern Educational Research Association Conference,
Jacksonville, Florida, February 2014

Abstract

Math anxiety is a reoccurring problem for many students, and the effects of this anxiety on college students is increasing. The purpose of this study was to examine the association between pre-enrollment math anxiety, standardized test scores, math placement scores, and academic success during freshman math coursework (i.e., pre-algebra, college algebra, and math modeling). The researchers conducted an exploratory observational study using pre-existing data from the *Freshman Orientation Survey*, which contained the 9-item Abbreviated Math Anxiety Scale, and institutional research data. The sample included 180 freshmen students at a university in the southeastern United States. A series of descriptive and frequency analyses and correlational analyses were conducted. The results suggest that standardized test scores and math anxiety had a moderate, negative relationship. In addition, there were predominately negative relationships between math anxiety and final course grades, particularly for pre-algebra. This research could assist instructors and advisors to understand the effects of math anxiety on future academic success and to assist students in their college math coursework.

Many Americans struggle with basic math related skills (Philips, 2007), and, while it may be a commonly held belief that most mathematical skills are not important to an individual's life experiences, research would disagree. Reports have indicated that 58% of American adults do not have the knowledge to calculate a tip for their waiter when out to eat, 71% cannot calculate miles per gallon, and 78% do not know how to calculate the interest paid on a loan (Philips, 2007). Murnane and Levy (1996) reported about half of 17 year olds cannot do the math needed for a job at a modern automobile plant (as cited in U.S. Department of Education, 2008). They concluded that without a special talent these late adolescent individuals do not have the skills they need to earn middle-class wages.

Mathematical achievement is strongly affected by math anxiety among young adults as well as elementary, middle, and high school students (Hembree, 1990; Ramirez, Gunderson, Levine, & Beilock, 2013). Vahedi and Farrokhi (2011) define math anxiety as negative cognitions, avoidance behaviors, and feeling pressured and inadequate in performance that combined interfere with solving math related problems in both general life and academic situations. A majority of individuals in the United States have a fear of and dislike for mathematics, according to survey results (Burns, 1998; Zaslavsky, 1994, as cited in Ramirez et al., 2013). As a result, math anxiety has both individual and national consequences. Individuals with math anxiety often avoid studies in mathematics and therefore limit their career options (Hembree, 1990). According to data from the General Accountability Office (Ashby, 2006), the number of students in the United States pursuing STEM-related (i.e., science, technology, engineering, and mathematics) degrees has declined from 32% during the 1994–1995 academic year to 27% in the 2003–2004 academic year. This avoidance of mathematical skill also limits the country's employee resources in science and technology (Hembree, 1990). The necessary

number of U.S. students for jobs in the STEM fields has been insufficient for decades (U.S. Department of Education, 2008). As a result, the country has relied on scientists and engineers from abroad; the percentage of this reliance increased from 14% to 22% from 1990 to 2000. This increase occurred across the technology field, and, at the doctoral level, it increased from 24% to 38% (U.S. Department of Education, 2008).

Theoretical Framework

Erik Erikson developed a psychosocial perspective of personality development, which suggested there are crises along an individual's lifespan (Corey, 2005). Each crisis is a turning point for an individual to progress forward or to regress. Erikson's stage of industry versus inferiority theorized that children, ages 6 to 12, either gain competence or feel they are inferior in certain skill areas. Consistent with Erikson's industry versus inferiority stage, mathematical problems appear to occur early in a child's education, and, if not addressed, the problems continue. Math anxiety has been shown to start as young as first and second grade (Ramirez et al., 2013). In the United States, difficulty with mathematics learning increases in late middle school before students move into algebra training (U.S. Department of Education, 2008). In the final report of the National Mathematics Advisory Panel, the members stressed that algebra is a central concern due to its gateway to later achievement (U.S. Department of Education, 2008). Math anxiety causes a student to have low confidence in their ability to tackle mathematical problems and as a result they only take the minimum required math courses (Vahedi & Farrokhi, 2011). With this avoidance, students feel inferior to their mathematical anxiety and are unable to move forward in their mathematical potential, which is an essential area of their education.

Review of the Literature

Math Anxiety and Age

In a study conducted by Wigfield and Meece (1988), the worry in relation to math begins to occur between sixth and ninth grade. The researchers found the highest math performance anxiety was evident among ninth grade participants while the least worry occurred among sixth grade participants. This research also aligns with Erickson's industry versus inferiority stage, which has been applied largely to 6th through 12th grade students. At the time and location of this study, sixth graders were clustered with elementary schools. The researchers suggest that because elementary schools do not emphasize evaluation as much as middle and high schools sixth grade participants may have felt less pressure and therefore less worried about their mathematical skill. With less evaluation, it can be hypothesized that these sixth graders did not experience great amounts of inferiority and therefore were able to move forward in their mathematical success until evaluation became stronger. Wigfield and Meece noted that the school districts of this study place their ninth grade students in math courses based on their math performance. As a result, the ninth grade participants may have felt anxiety due to the shift in comparison among groups. Many of these students may have felt inferior to their classmates. While Wigfield and Meece found the greatest difference in anxiety between the sixth and ninth grade participants, the study results reflect small differences across grade levels, indicating little change in anxiety among middle and high school students. Hembree's (1990) research results revealed an inverse relationship for math anxiety and math performance across grade levels.

Math Anxiety and Gender

Some studies have found higher anxiety among women (Betz, 1978); however, Hembree's (1990) research suggested the effect of math anxiety was more prominent among

males at the precollege level. In relation to avoidance behaviors, the males in Hembree's study who had high math anxiety appeared less likely to take further math courses than girls with high math anxiety. The most significant gender difference was among junior and senior high school students. In relation to performance, Hembree's study revealed that the relationship between higher math anxiety and lower math performance among males in 5th through 12th grades was stronger than it was for females of the same age, but this gender difference did not appear among college students. While the study did reveal the presence of higher math anxiety among females rather than males, especially at the college level, the effect of math anxiety on performance was greater for males and the effect of math anxiety on performance disappeared at the college level. In Wigfield and Meece's (1988) study, no differences were found for math anxiety among the sixth through ninth grade boys and girls in which they studied. The researchers concluded that the male and female participants were equally concerned about their mathematical academic success. Female participants reported greater negative affective reactions to math in comparison to males. The researchers suggested these negative affective reactions can cause females to stop taking mathematical courses as the course content becomes more difficult. According to Chipman, Krantz, and Silver (1992), fewer females take mathematics courses and choose career paths that require math skills. From Erickson's theoretical perspective, if females are experiencing negative affective responses to mathematics, it could be that they are feeling incompetent or inferior to their male counterparts and are therefore less industrious in their pursuing mathematical skill and achievement.

While much of the literature on mathematical anxiety is fairly broad, there is more research on math anxiety among elementary and secondary students. Much of the literature related to math anxiety at the college level is outdated. New research would bring contemporary

insight to the overwhelming problem of math anxiety and avoidance in STEM-related degrees across college campuses in the United States. In addition, several studies on math anxiety have conflicting results; therefore, added research can provide insight into additional variables that effect mathematical anxiety. The purpose of this study was to examine the association between pre-enrollment math anxiety, standardized test scores, math placement scores, and academic success during freshman math coursework (i.e., pre-algebra, college algebra, and math modeling) at the collegiate level. The research questions were:

1. What is the relationship between math anxiety and standardized test scores among freshman college students?
2. What is the relationship between math anxiety and math placement scores among freshman college students?
3. What is the relationship between math anxiety and final math course grades among freshman college students?

Methods

Participants

The sample consisted of 180 freshman participants who declared a major within the College and completed the survey in full. Of the 180 participants, 85% ($n = 153$) were female, and 15% ($n = 27$) were male. The number of black participants ($n = 87$; 48.3%) was slightly higher than the number of white participants ($n = 72$; 40%). The remaining 21 participants, 11.7%, indicated “other” as their racial classification. The College is part of a four-year institution in the southeastern United States that is considered a master’s level school. Enrollment at the state university has enrollment of more than 8,200 undergraduate and graduate

students. Table 1 displays the frequency and percentage of participants by their initially declared major within the College.

Table 1

Frequency and Percentage of Participants Categorized by Initially Declared Major

Major	<i>n</i>	%
Early Childhood Education	30	16.7
Middle Grades Education	3	1.7
Secondary Education	6	3.3
Special Education	2	1.1
Health & Physical Education	3	1.7
Nursing	93	51.7
Exercise Science	28	15.6
Health Science	15	8.3
Total	180	100%

Data Collection

Procedures. The researchers conducted an exploratory observational study using pre-existing data from the *Freshman Orientation Survey* (Brown, 2012) and institutional research data. The *Freshman Orientation Survey* was administered at the summer orientation sessions to all incoming freshman who declared a major within the College (i.e., education, nursing, health science, or exercise science). In total, there were five sessions offered throughout the summer. At the conclusion of the survey, participants were given the opportunity to consent to their participation and the use of their responses for research purposes. It took the participants between 10 and 15 minutes to complete the survey. To obtain the institutional research data, the researchers completed an eQuest with the Office of Institutional Research, which included the

participants' college identification number and the list of data variables needed within an Excel file. Once all data were collected, the survey data were merged with institutional research data.

Measure. The 9-item Abbreviated Math Anxiety Scale (AMAS) was administered as part of the *Freshman Orientation Survey*. Each item (e.g. taking an examination in a math course) was rated by participants on a five-point Likert scale, with 1 representing *Low Anxiety* and 5 representing *High Anxiety*. The AMAS has two sub-scales: the Learning Math Anxiety (LMA) subscale and the Math Evaluation Anxiety (MEA) subscale. The Learning Math Anxiety (LMA) subscale consisted of five items that measure participants' anxiety while learning math or during math instruction (Vahedi & Farrokhi, 2011). The Math Evaluation Anxiety (MEA) subscale was composed of four items, which measure the participants' anxiety during the administration of math assessments (Vahedi & Farrokhi, 2011). Vahedi and Farrokhi (2011) conducted a study with 298 undergraduate college students that were enrolled in introductory level math courses to determine reliability and validity of the AMAS using confirmatory factor analysis. The alpha coefficient was .90 for the AMAS. The alpha coefficients of the LMA subscale ($\alpha=.85$) and the MEA subscale ($\alpha=.88$) indicated the subscales were internally consistent. Additionally, the correlational results of their study confirmed the construct validity of the AMAS and its two subscales. Within the present study, reliability analyses were conducted to determine if the items within each scale provided an internally consistent measurement. A Cronbach's alpha coefficient of .50 or greater was established as the criterion for reliability (Thorndike, 1951). The alpha coefficient for the LMA subscale was .86, and the alpha coefficient for the MEA subscale was .79, which indicated both subscales were internally consistent measures.

Institutional Data. For the present study, the researchers collected the standardized test scores, the placement scores, as well as the math course taken during freshman year of college, and the final math course grade earned from the university's Institutional Research database. For standardized test scores, the math subtest scores for the Standardized Aptitude Test (SAT) and the ACT were collected. The math placement scores were determined using one of four methods (T. Howard, personal communication, October 10, 2013).

1. Math Readiness Score which used a formula involving the high school grade point average and the math score from either the SAT or ACT.
2. Math Placement Test which could involve the COMPASS Algebra, COMPASS College Algebra, and COMPASS Trigonometry test scores depending on student performance.
3. Written, pencil-and-paper placement appeal based on the course sought.
4. College level transfer credit which included Advanced Placement scores.

The three courses taken were pre-algebra, college algebra, or math modeling. Pre-algebra is a preparatory math course for the student whose math placement test score disqualifies them to take math modeling or college algebra. The course covers equations, inequalities, and operations with real numbers, functions and their graphs as well as systems of equations. College algebra is a functional approach course that incorporates technology and appropriate applications. The course objectives include functions, and their graphs, inequalities, linear, quadratic, and piecewise defined, rational, polynomial, and logarithmic functions. It is a course designed to give sufficient knowledge of algebra for the continued study of calculus. Math modeling is an introductory course on elementary functions of mathematics including graphical, numerical, symbolic and verbal techniques (Academic Affairs, 2013).

Results

Using SPSS, a series of descriptive statistics and frequency analyses were conducted. Then, a series of correlational analyses (i.e., Pearson r correlations) were conducted for pre-enrollment math anxiety (LMA and MEA subscales), standardized test scores, math placement scores, and academic success during freshman math coursework (i.e., pre-algebra, college algebra, and math modeling). To interpret the strength of a relationship, the researchers used Cohen's (1988) guidelines, which establishes a correlational coefficient between .10 and .30 as a weak relationship, a correlational coefficient between .30 and .50 as moderate, and a correlational coefficient above .50 as strong. A correlational coefficient between -.10 and .10 is considered to have no relationship.

Research Question #1: Standardized Test Scores

For the participants who took the SAT, the mean math score was 460.51 with a standard deviation of 65.37, and the math scores ranged from 330 to 700. The mean math score for the participants who took the ACT was 19.06 with standard deviation of 2.77, and the math scores ranged from 15 to 26. The correlational analysis revealed a moderate, negative relationship between SAT math scores and math anxiety on the LMA subscale ($r = -.357$). For the MEA subscale, the negative relationship between SAT math scores and math anxiety was weak ($r = -.191$). In addition, the relationship was weak and negative between ACT math scores and math anxiety on the LMA subscale ($r = -.187$); however, there was no relationship found between the ACT math scores and the MEA subscale ($r = .032$).

Research Question #2: Math Placement Scores

Of the 180 participants, 51.9% ($n = 108$) took pre-algebra, 16.3% ($n = 34$) took college algebra, and 21.2% ($n = 44$) took math modeling during their freshman year of college. The

remaining 10.6% of the participants were placed in higher math courses beginning with Pre-Calculus course. For participants placed in pre-algebra, the mean LMA level was 2.71 with a standard deviation of 1.04, and the LMA scores ranged from 1.00 to 5.00. The mean MEA level among the pre-algebra participants was 3.70 with a standard deviation of 1.00, and the MEA scores ranged a range from 1.00 to 5.00. For participants placed in college algebra, the mean LMA level was 2.21 with a standardized deviation of 1.01, and the LMA scores ranged from 1.00 to 4.00. For the same participants, the mean MEA levels was 3.64 with a standard deviation of 0.873, and the MEA scores ranged a range of 1.75 to 5.00. For participants placed in math modeling, the mean LMA level was 2.21 with a standard deviation of 0.950, and the LMA scores ranged from 1.00 to 4.60. The mean of the assessment scale was 3.29 with a range of 1.00 to 5.00 and a standard deviation of 1.08. The results revealed a weak, negative relationship between participants' math placement scores and both the LMA subscale ($r = -.206$) and the MEA subscale ($r = -.111$) of the AMAS.

Research Question #3: Final Course Grades

When examining participants who earned an "A" in one of the math classes, the lowest anxiety was found for students who made an "A" in pre-algebra. The mean for the LMA subscale was 2.52 with a standard deviation of 1.00, and the LMA scores ranged from 1.20 to 4.40. The mean for the MEA subscale was 3.38 with a standard deviation of 0.96, which was higher compared to the LMA subscale mean, and the MEA scores ranged from 1.75 to 5.00. The mean for the LMA subscale among participants who took college algebra and earned an "A" was 2.23 with a standard deviation of 0.83, and the LMA scores ranged from 1.00 to 3.60. The mean MEA level was higher for this group ($M = 3.53$; $SD = 0.92$) with scores that ranged from 1.75 to 5.00. For participants who took math modeling and earned an "A", the mean LMA level was

2.42 with a standard deviation of 0.97, and the LMA scores ranged from 1.00 to 4.00. For this same group of participants, the MEA mean was higher at 3.81 with a standard deviation of 0.77, and the MEA scores ranged from 2.00 to 5.00.

Among the participants who failed pre-algebra, the mean LMA level was 2.78 with a standard deviation of 1.16, and the LMA scores ranged from 1.00 to 4.80. The mean anxiety level on the MEA subscale was 3.88 with a standard deviation of 1.03 for students who failed pre-algebra, which represented moderate to high anxiety during math instruction. The MEA scores ranged from 1.25 to 5.00. Participants who failed college algebra had a mean LMA level of 2.48 with a standard deviation of 1.32, and the LMA scores ranged from 1.40 to 4.60. For this same group, the participants were found to have a mean of 3.75 with a standard deviation of 1.09 on the MEA subscale. The MEA scores ranged from 2.50 to 5.00. For the participants who took math modeling and failed the course, the mean LMA level was 2.10 with a standard deviation of 1.18, and the LMA scores ranged from 1.00 to 4.00. These participants had the same mean level as pre-algebra, 3.88, with a standard deviation of 0.70 on the MEA subscale. The MEA scores ranged from 2.50 to 5.00. Interestingly, the sample suggests that participants who earned an “A” as their final grade experienced nearly as high levels of anxiety on the MEA subscale as the participants who failed the course. Table 2 displays frequencies and percentages of final course grades by course.

Table 2

Frequency and Percentage of Final Course Grades by Course

Final Grade	<u>Pre-Algebra</u>		<u>College Algebra</u>		<u>Math Modeling</u>	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
A	15	14.4	22	32.8	26	43.3
B	29	27.9	22	32.8	20	33.3
C	26	25.0	12	17.9	8	13.3
D	14	13.5	6	9.0	0	0.0
F or WF	20	19.2	5	7.5	6	10.0
Total	104	100%	67	100%	60	100%

Findings suggest a negative relationship between math anxiety and the final grade of math coursework during the freshman year, particularly in the pre-algebra course. A weak, negative relationship was found between students' final pre-algebra course grade and both the LMA subscale ($r = -.104$) and MEA subscale ($r = -.183$). For college algebra, no relationship was found between final course grade and the LMA subscale ($r = -.057$) or between final course grade and the MEA subscale ($r = .063$). The relationship was found to be weak and positive between math modeling final course grades and the LMA subscale ($r = .145$); however, there was no relationship found between math modeling final course grades and the MEA subscale ($r = .056$).

Discussion

The researchers recognize that at times anxiety drives a student to do well rather than hindering their success, but the data reflects a higher percentage of students in the latter category. While several of the correlations from this study were too weak to show a relationship, some conclusions can be made. Concerning math anxiety and standardized test scores, participants' anxiety level on the LMA subscale of the AMAS had the strongest, negative correlation. The

mean scores on the MEA subscale of the AMAS were consistently greater for math placement scores compared to the mean anxiety levels on the LMA subscale. Moreover, a major finding of this study was the higher anxiety levels on the MEA subscale for all final course grades in pre-algebra, college algebra, and math modeling. These findings suggest greater anxiety levels occur for students during math assessment than during math instruction.

As math anxiety is a reoccurring issue among students, this research can better educate instructors, faculty, and advisors to understand the effects of math anxiety on future academic success and therefore assist them in their guidance of students during college math coursework. While math anxiety is a result of math-skill related fears, it can have as much to do with the experience of anxiety itself and a student wanting to avoid repeated anxious feelings, especially in public. If educators can help students get through the road block of mathematical inferiority and anxiety and gain confidence in their ability to successfully apply math skills, students can begin to face the challenges associated with math and move forward rather than avoid such challenges as seen currently.

Some limitations existed within this study. The sample size was small and conducted within one College. The participants tended to be female and only represented a few majors. Additionally, not every student took a math course during their freshman year. The rationale for this occurrence may be a student avoiding mathematics due to anxiety; however, there is no evidence supporting this hypothesis. Other variables could affect final course grades other than academic performance and math anxiety. For example, a student may have struggled in the math course due to difficult circumstances occurring outside of the classroom. Lastly, the variety of methods for determining the math placement scores could be a limitation to this study. Further research is needed to determine the generalization of this research. First, a larger more diverse

sample could assist in generalizing the data. The *Freshman Orientation Survey* (Brown, 2012) will be administered during subsequent orientation sessions in order to continue the data collection process and expand the pool of participants. Second, future research could examine the effect of math anxiety among teachers and the math achievement of their students in the P-12 classroom.

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