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A STUDY OF PERCEPTIONS OF MATH MINDSET, MATH ANXIETY, AND VIEW OF MATH BY YOUNG ADULTS

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A STUDY OF PERCEPTIONS OF MATH MINDSET, MATH ANXIETY, AND VIEW
OF MATH BY YOUNG ADULTS

by

Tami Hocker

A doctoral dissertation submitted to the
College of Education
in partial fulfillment of the requirements
for the degree Doctor of Education
in Curriculum and Instruction

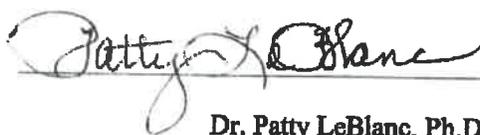
Southeastern University
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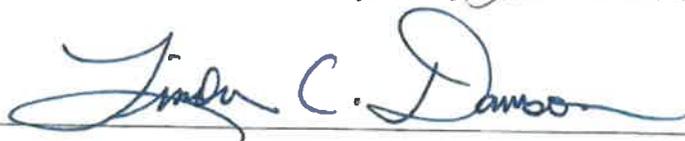
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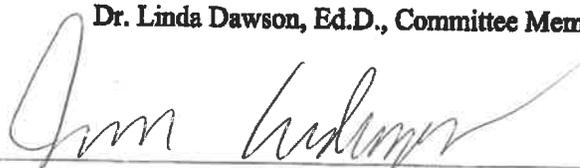
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Dedication

“To God be the glory forever and ever! Amen.” (Galatians 1:5, *New International Version*). Christ was my guide through this doctoral and dissertation process. He carried me through the times when I did not feel I had the strength to go on. He celebrated with me when I finally reached the light at the end of each tunnel. I look forward to His revelation of how I can best impact math education with the knowledge and skills developed through the doctoral program at Southeastern University.

Acknowledgments

I would like to thank the faculty of the doctoral program at Southeastern University for their devotion to growing me and the rest of Cohort A into the strong servant leaders that we have become. I am truly blessed to have been a part of this amazing program. After over 30 years working in mathematics education and leadership, this program has allowed me to grow as a lifelong learner, and I look forward to using the knowledge gained to support future growth in mathematics educational practices.

Thank you, Dr. LeBlanc and Dr. Deck for encouraging me in 2010 to consider getting my Ed.D. This dissertation is the beginning of the fruit of your efforts. Dr. LeBlanc, I thank you for your guidance and support in many roles throughout my program. Academic Advisor, Professor, Dissertation Committee Chair, mentor, and cheerleader are but a few of the positions you have filled in my life. I hope that someday I can impact as many lives as you have. Your efforts in our Ed.D. program will flow exponentially throughout not only our cohorts of students at SEU but through servant leadership roles that we fill; your wisdom will flow down into the schools and the communities that they serve. Thank you for holding me accountable to producing the best products possible and not allowing me to compromise. I know that no other professor would have spent the majority of their 4th of July holiday helping me with edits on my chapters.

Thank you, Dr. Gollery for your wisdom and guidance on the data analysis for this research. Your insight into how to approach the data set led to a plethora of interesting and significant findings. I appreciate your willingness to text back and forth at all hours of the day and evening as we finalized details and strategies. Your excitement was contagious!

Dr. Dawson, thank you so much for giving of your time and expertise to guide the research and final reports. Your passion for reaching the at-risk population of young adult students helped to filter my focus and final product. I look forward to continuing to work with you to impact curriculum and educational practices to support the success of the at-risk students.

Thank you, Cathy Williams and Kathy Sun for sharing your expertise as I developed my survey measurement tool. Cathy, your mentoring and guidance in developing the experimental research curriculum in math mindset was a key factor in developing the significant resource that it proved to be.

To Cohort A, we have been through many triumphs and trials and we are blessed to have each other. I consider you my life-group and I now have life-long friends. I look forward to hearing how each of us uses the new knowledge and gifts that the Lord has given us.

To my family, I can't thank you enough for being patient with me and supporting me through the past three years working towards completing this goal. At times I know it

seemed as though the process would never end, but you believed in me and my ability to reach my goal. Brennon, Collin, Chelsie, and Loren, you now have mom back. I will no longer drag my computer and books along on our family vacations and work into the wee hours of the night. God has blessed me with all of you in my life.

To my parents, I thank you for raising me to love the Lord and instilling in me the passion for helping others. You are the firm foundation that I have always had in my life, and it has allowed me to grow and flourish.

To Lori, who talked me through high points and low points in this process, thank you for the support and understanding. You understood when I needed to hear words of encouragement and when I just needed a hug.

Last and most importantly, I thank my husband and soul mate, David for allowing me to spread my wings and undertake this journey. Thanks for being flexible and allowing me to take over the living room with all of my books and paperwork. I know you made sacrifices to allow this to happen, and they did not go unnoticed. With you, by my side, we accomplished this pinnacle. I look forward to celebrating with you what God has helped us to accomplish.

ABSTRACT

This study's purpose was to determine whether instruction in growth math mindset led to change in perceptions of 18-22-year-old at-risk students in math mindset, math anxiety, and view of math. The experimental curriculum was created by the researcher with the guidance of experts in mathematics and education and focused on the impact of brain growth and learning supported by positive math mindset. Young adult public charter high school at-risk students were surveyed before and after completion of the experimental intervention to measure their perceptions in the domains of Math Mindset, Math Anxiety, and View of Math. The results revealed significant differences in the treatment group's pre-to post-test perceptions in all three math domains ($p < .001$). Comparison between the experimental and control groups were conducted, revealing significant differences between the two group in all three domains of math. These results point to the effectiveness of the experimental curriculum and instructional techniques to positively impact students' perceptions of Math Mindset, reduction of Math Anxiety, and improvement in View of Math.

Keywords: [mindset, mathematics, math anxiety, view of math, math curriculum, education, at-risk]

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Chapter 1: Introduction

A plethora of research has scrutinized the phenomenon of math anxiety for several decades spanning from the early 1950's. Math anxiety is prevalent at all age levels in schools and in society (Andrews & Brown, 2015; Brunye et al., 2013; Geist, 2015; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Huberty, 2009; Meloney & Beilock, 2012; Miller & Mitchell, 1994; Perry, 2004). With high-stakes mathematics exams' functioning as gatekeepers to educational progression, learners in the 21st-century face more demanding situations dependent upon math skills than in the past (Altman, 2014; Huberty, 2009; Trotter, 2006).

Substantial numbers of American youth underperform in mathematics, leading to limitations for educational prospects and career options (Hart et al., 2015). According to recent research, math anxiety and math mindset (perception of ability to accomplish math) can affect education as early as preschool (Geist, 2015; Pawlina & Stanford, 2011). Unfortunately, many individuals have grown accustomed to hearing and accepting statements from family, peers, and acquaintances that address a lack of skills or abilities to perform in math. Many of these persons suffer from a fixed mindset concerning the ability to learn mathematics; they see math as a discipline in which getting the correct answer to problems is the most important measure of learning (Blad, 2015; Boaler, 2016; Sparks, 2015).

According to Boaler (2016), an overemphasis on the right answer in the American mathematics assessment system is the leading contributor to the United States' falling

behind other countries in mathematics performance. Research on the effects of mathematical mindset and mathematical performance supports students' need for experimentation and interaction with math (Boaler, 2016). A student with a growth mindset believes that he/she can learn math and understands that learning math requires exploration and problem-solving. A student with a fixed mindset believes he/she cannot learn math and that math success is based on getting the correct answer. Students who do not possess a growth mindset in math adhere to the idea that some individuals are born with the capability to do math well, and others are not; they tend to believe that hard work and perseverance do not lead to mathematical ability (Blad, 2015; Boaler, 2016; "Mindsets," 2013; Pawlina & Stanford, 2011; Sparks, 2015; YouCubed, 2016), unlike other disciplines, talents, and aptitudes.

Background and Review of Relevant Literature

Panic, anxiety, stress, trauma, fear, dread, phobia, and tension are all descriptors used by individuals who have an aversion or trepidation towards mathematics (Brunye et al., 2013; Meloney & Beilock, 2012). Many researchers have confirmed these states of mind from research participants, and these descriptors are just a start (Miller & Mitchell, 1994; Buckley, Reid, Goos, Lipp, & Thompson, 2016; Ma, 1999).

Decades have been spent studying the influences of math anxiety as well as the conditions that contribute to the phenomenon and efforts to remediate (Andrews & Brown, 2015; Brunye et al., 2013; Geist, 2015; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Huberty, 2009; Meloney & Beilock, 2012; Miller & Mitchell, 1994; Perry, 2004). America suffers from underperformance in the fields directly related to mathematics (Boaler, 2016). High-stakes mathematics exams lead to extreme pressure

and stress, and outcomes can limit future choices in educational opportunities as well as careers (Altman, 2014; Huberty, 2009; Trotter, 2006). A critical need exists for shifts in mathematics assessment practices and teaching strategies in mathematics in American education (Boaler, 2013; Boaler, 2016). Miller and Mitchell (1994) state,

Unfortunately, describing mathematics anxiety as an irrational fear is inappropriate, and the term mathphobia is a misnomer. A phobia is an irrational fear or dread of something, and for sufferers of mathematics anxiety, there is nothing irrational in their thinking. Their fears are often soundly based upon years and years of painful experience with mathematics in general, and tests in particular. (p. 353)

Anxiety Relating to Mathematics

According to Huberty (2009), “Anxiety is a normal human emotion that can be detrimental in a school setting, but good communication and support can help minimize its negative impact” (p. 12). Teenagers in twenty-first century classrooms suffer from anxiety symptoms that are directly related to high-stakes mathematics testing and performance expectations (Huberty, 2009). According to Perry (2004), “Math anxiety is an extremely common phenomenon among college and university students” (p. 321). Requiring students to undergo examinations that drive their future success and options leads to high levels of anxiety facing the millennial generation (Huberty, 2009). Anxiety in mathematics can lead to a lack of success in school, avoidance of courses and careers that involve math or problem-solving, and negative physical and emotional difficulties (Brunye et al., 2013; Geist, 2015; Hopko et al., 1998; Huberty, 2009; Meloney & Beilock, 2012; Miller & Mitchell, 1994; Perry, 2004; Trotter, 2006).

Growth and Fixed Mindsets

Carol Dweck (2008) spent more than 20 years researching how students react to different forms of praise from parents and educators. Dweck's research found that more than 80 percent of parents felt it was important to praise their children. According to Dweck, praise that honors intelligence and performance can lead to students with fixed mindsets. This type of praise supports a fixed mindset because students are often praised for their ability and not for their efforts. Students do not see the importance of working hard and persevering when they feel their intelligence level is a stagnant characteristic with which they are born.

“Students who value effort are said to have a growth mindset. They perceive ability as a malleable skill” (Hochanadel & Finamore, 2015, p. 48). A growth mindset is “oriented towards learning, not measuring the self” (“Mindsets,” 2013, p. 17). “Students with a growth mindset understand that mistakes and effort are critical to learning” (Dweck, 2008, p. 56).

According to Hochanadel & Finamore (2015), Dweck's research demonstrated the benefits of training students how to change their brains in order to develop perseverance and a growth mindset. When adults focus on giving praise for perseverance and hard work, children develop a growth mindset and tend to build their problem-solving abilities when faced with adversity or new situations. Educating students on the importance of trying new things and making mistakes can develop and train their brains in new ways to approach situations and problems (Blad, 2015; Boaler, 2013; Boaler, 2016; Hochanadel & Finamore, 2015; “Mindsets,” 2013; Pawlina & Stanford, 2011; Sparks, 2015). When studying growth mindset, Pawlina & Stanford (2011) reported

student empowerment through development of mental strategies to apply in challenging situations.

Supporting Positive Mindset

According to Carol Dweck in her interview for *Educational Horizons*, “We’ve found that you can teach kids a growth mindset directly by teaching them about the brain and how it changes with learning. When we teach kids the growth mindset, their motivation changes and their grades increase” (“Mindsets,” 2013, p. 17). When students are challenged and are required to formulate new ways to attack a problem, they grow and build new connections in their brains through firing new synapses from one neuron to the next (Boaler, 2013; Boaler, 2016; Dweck, 2008; “Mindsets,” 2013; Pawlina & Stanford, 2011; Sparks, 2015).

One of the most important strategies for helping students develop a growth mindset is to use praise focused on effort and perseverance rather than on scores on tests or on correct answers (Boaler, 2016; Dweck, 2008). This type of praise helps students to see the value of working hard and scrutinizing their mistakes. Boaler (2016) encouraged teachers to teach students that they can acquire math understanding through making errors and learning from the process. When students do not make errors, they are often playing it safe and staying in their comfort zone of already mastered material (Boaler, 2013; Boaler, 2016; Dweck, 2008). Both educators and parents must clearly understand the importance of students’ having opportunities to explore mathematical concepts without being evaluated as right or wrong (Blad, 2015; Boaler, 2013; Boaler, 2016; YouCubed, 2016).

Blad (2015) discussed the research accomplishments of the Project for Education

Research That Scales (PERTS) at Stanford University and pointed out the need for educators to be trained in how to normalize or desensitize students when facing failure. Students must understand that making mistakes is a normal part of the learning process, but especially in learning mathematics. If teachers designed their math lessons with open-ended problem-solving scenarios rather than with questions having a set solution, then students would grow their brains and toolkits for future troubleshooting (Blad, 2015; Boaler, 2013; Boaler, 2016; Dweck, 2008; Hochanadel & Finamore, 2015; "Mindsets," 2013; Pawlina & Stanford, 2011; Sparks, 2015).

Even though several researchers concentrated on the impact of mindset in education (Blad, 2015; Boaler, 2016; Chen & Wong, 2015; Claro, Paunesku, & Dweck, 2016; Dweck, 2006; Dweck, 2008; Hochanadel & Finamore, 2015), few studies have examined how mindset affects the academic progress of struggling young adult students who are attempting to earn a high school diploma despite past challenges in educational performance. Schools and legislators have dedicated many resources towards efforts to prevent at-risk youth from dropping out of the educational system; perhaps classroom sessions on the importance of mindset towards reaching their goals could be one of the most effective options.

Conclusion

Mathematics educators must learn from research-based techniques and strategies to lower math anxiety, improve students' views of math, and develop students' growth mindsets. Teachers must emphasize problem-solving skills and conceptual understanding necessary for the demands of twenty-first century business and society. Research supports the benefits of teaching students the importance of mindset in exploring

mathematics (Boaler, 2016; Dweck, 2008). Future and current mathematics educators need to be trained to implement growth mindsets that lead students to appreciate the importance of perseverance and errors in building a stronger knowledge base (Blad, 2015; Boaler, 2013; Boaler, 2016; Dweck, 2008; Hochanadel & Finamore, 2015; "Mindsets," 2013; Sparks, 2015).

Purpose Statement

The purpose of this study is to determine whether or not instruction in growth math mindset leads to changes in perceptions of math mindset, math anxiety, and views of math in 18-22-year-old students.

Research Questions

1. Does participation in mathematical mindset instruction affect young adults' perceptions of mindset towards math?
2. Does participation in mathematical mindset instruction affect perceptions of math anxiety levels of young adults?
3. Does participation in mathematical mindset instruction affect young adults' view of math as a discipline?

Research Hypotheses

H 1: There is a significant difference between changes in perceptions of math mindset of young adults who participate in mathematical mindset instruction compared to those who do not participate in mathematical mindset instruction.

H 2: There is a significant difference between changes in perceptions of math anxiety in young adults who participate in mathematical mindset instruction compared to young adults who do not participate in mathematical mindset instruction.

H 3: There is a significant difference between changes in views of math as a discipline among young adults who participate in mathematical mindset instruction compared to young adults who do not participate in mathematical mindset instruction.

Methods

The sample for this study was composed of students from five Florida public charter schools serving at-risk students with enrollments ranging from 125 to 275. At-risk students are described as students who are not on schedule to graduate with their original cohort group, and many have dropped out of school in the past. Sixty-nine students from two randomly selected campuses were randomly assigned to the treatment group sample, and 100 students from three campuses were randomly assigned to the control group sample. The campuses were located in four counties in Florida, and the immediate communities ranged from urban to rural. Participants were young adults ages 18-to-22 enrolled in any math course during the 2016-2017 school year.

The curriculum for the math mindset intervention was developed by the researcher and implemented by math teachers trained by the researcher on instructional techniques supporting positive math mindset and techniques necessary to complete the five hour experimental math mindset curriculum. The math content in the lessons focused on the foundations of understanding math mindset as well as the math standards assessed on the Florida Algebra I End of Course Exam.

Students in the experimental group attended their regular math classes on days when the experimental intervention was not scheduled, while the control group participants attended only their normal math classes. The regular mathematics curriculum at all five campuses was the same. The control group had regular

mathematics instruction and test preparation activities. The experimental group had their regular mathematics instruction and test preparation activities; however, the experimental curriculum replaced their math instruction on the days scheduled.

Students in the control and experimental groups completed pre- and post-surveys developed by the researcher measuring three domains: perceptions of math mindset, math anxiety, and perceptions of math. The survey was piloted, edited, and validated before use with the experimental and control groups in the research. The pre-test was administered before the implementation of the experimental treatment. The post-test was given at the end of the treatment sessions for the experimental group. The pre-test and the post-test were administered to the control group during the same portion of the grading period as the experimental group.

Delimitations

The following were the delimitations of the study. First, the students chosen for the study were only those students who were 18-to-22 years old and not inclusive of all students on the campuses. Second, the survey tool was created by the researcher and was not a standardized tool. Third, the survey responses were reports of students' self-perceptions. Fourth, the curriculum used for the experimental treatment was created by the researcher and was not standardized.

The survey instrument and experimental curriculum were developed based on research of math mindset and math anxiety. Cathy Williams, the Executive Director of YouCubed, and Dr. Patty LeBlanc, a professor at Southeastern University (SEU), mentored the researcher in the process. Experts in math mindset, math instruction, education, and research gave feedback to validate the survey/test tool.

Limitations

The following was the limitation of the study. Due to the nature of the at-risk population samples used for this study, sufficient standardized math achievement data were not available during the research period to collect math performance scores before and after the intervention.

Definitions of Key Terms

Fixed Mindset- A belief that intelligence and abilities are finite and do not increase with efforts and perseverance (Boaler, 2016; Dweck, 2006).

Growth Mindset-A belief that intelligence and academic success can be improved through perseverance through mistakes and struggles when undertaking new and challenging material (Boaler, 2016; Dweck, 2006).

Incremental Intelligence Theory-a learning theory that explores intelligence and learning potential that can be increased by perseverance and hard work. This learning theory was referred to as intelligence theory (Blackwell, Trzesniewski, & Dweck, 2007), incremental theory of intelligence (Blackwell, Trzesniewski, & Dweck, 2007; Chen & Wong, 2015), and self-efficacy (Gutman & Midgley, 2000) before and after Carol Dweck began labeling this type of learning theory as “mindset” (Boaler, 2013; Boaler, 2016; Claro, Paunesku, & Dweck, 2016; Dweck, 2006; Dweck, 2008; Hochanadel & Finamore, 2015; "Mindsets," 2013; Pawlina & Stanford, 2011; Paunesku et al., 2015; Sparks, 2015).

Math-gender Stereotype-A belief that mathematics is a content area in which males do better than females.

Neural Plasticity-The ability of the brain to build and grow new neural connections throughout life.

Self-efficacy-The belief of an individual in his/her ability to accomplish a goal or task successfully.

State Anxiety-A type of anxiety defined by Ng & Lee as “transient feelings of negative arousal” (2015, para. 4) usually resulting from something deemed as a threat or danger.

Trait Anxiety-Trait anxiety refers to a person's disposition to perceive an item or situation as threatening (Ng & Lee, 2015).

View of Math-An attitude expressed towards the subject of mathematics.

Working Memory-Working memory (WM) is a cognitive system that enables temporary storage and manipulation of information in the brain. WM is necessary for such complex tasks as comprehension, learning, and reasoning (Ma, Chang, Chen, & Zhou, 2017, p. 1).

Chapter 2: Review of Literature

The purpose of this study was to determine whether or not instruction in growth math mindset leads to changes in perceptions of math mindset, math anxiety, and perceptions of math in 18-22-year-old students. This literature review focuses on the historical background and research on mindset, math anxiety, and views or perceptions of math to provide the context for this dissertation research study.

Mindset

According to Dweck (2008), having a growth mindset is essential for individuals to excel and prosper to their full potential. Boaler (2016) emphasized that students with a growth mindset believe that they can increase their math abilities through hard work; students with a fixed mindset believe that individuals are born with a set math ability and that no matter how hard that individual works, if he/she is not born with a strong math ability, he/she will not excel in math. Boaler also labeled mathematics as the single content area that distributes strong and abundant fixed mindset labels and messages (2016).

“A blend of family attitudes, cultural ideas, and personal [sic] frustration often lead students to believe that math ability is a fixed trait like eye color” (Blad, 2015, p. 1). Individuals with a fixed mindset who hold these beliefs avoid situations that might lead to making errors. They see errors as a sign of weakness or lack of intelligence. Fixed-mindset individuals focus on performance, grades, and the perceptions of their peers. These students often exhibit math anxiety due to the ongoing pressures to impress others

that they place upon themselves (Boaler, 2013; Boaler, 2016).

When Stanford University researcher Professor Carol Dweck was in elementary school, she experienced a teacher who exhibited a fixed mindset. The teacher passed that message on to her class by seating students in the order of their performance in the class. Those students who performed the best on assessments, including math exams, were allowed to carry out coveted tasks. Dweck admitted she was seated first in her class but always felt the threat of that position's being taken away from her. This classroom was not a nurturing environment that supported exploration. Dweck admitted to Trei (2007) that this performance-based labeling experience sparked her interest in exploring how intelligence is measured and the potential for student learning (Dweck, 2006; Trei, 2007).

Research that explored learning potential that can be increased with perseverance and hard work previously used the labels of intelligence theory (Blackwell, Trzesniewski, & Dweck, 2007), incremental theory of intelligence (Blackwell et al., 2007; Chen & Wong, 2015), and self-efficacy (Gutman & Midgley, 2000). Dweck labeled these theories of learning as "mindset" (Boaler, 2013; Boaler, 2016; Claro, Paunesku, & Dweck, 2016; Dweck, 2006; Dweck, 2008; Hochanadel & Finamore, 2015; "Mindsets," 2013; Pawlina & Stanford, 2011; Paunesku et al., 2015; Sparks, 2015).

A number of studies pointed to mindset as a viable theory of learning. Blackwell et al. (2007) conducted two studies researching learning theories in early adolescents' math achievement. The first of these studies was a five-year longitudinal study that followed four cohort groups of moderately high-achieving students through their junior high 7th- and 8th-grades (n = 373) to study student achievement in math and its relationship to the researchers' theory of intelligence or mindset. The researchers

followed the student cohort groups from the beginning of 7th-grade to the end of 8th-grade. The cohort students were moderately high-achieving math students based on their mean math exam scores ($\geq 75^{\text{th}}$ percentile) from 6th-grade on the Citywide Achievement Test (CAT), a nationally normed exam (NYC Department of Education, n.d.). Cohort students had the same math teacher and the same curriculum. Each student filled out a survey at the beginning of their 7th-grade school year that assessed their views on mindset (“theory of intelligence”), learning goals, effort beliefs, and perceptions of helpless responses to failure. The researchers collected students’ math semester grade averages at the end of each term during their two-year participation in order to assess math achievement (Blackwell et al., 2007). In this longitudinal study, Blackwell et al. used the students’ 6th-grade percentile scores on the CAT exam as a baseline and the semester grades in math classes at the end of each term during the study to measure math learning outcomes. Using the initial survey items gathered at the beginning of 7th-grade, the researchers gathered subscale scores on mindset (theory of intelligence), effort beliefs, perceptions of helpless responses to failure versus positive problem-solving strategies, and learning goals (from the Patterns of Adaptive Learning Survey (PALS)). Analysis of the data based on the 6th grade baseline CAT scores and the fall and spring term grades from 7th and 8th grade revealed that students with a fixed mindset regressed in math performance over time, while students with a growth mindset saw success as measured by their semester grades in math classes. In addition, the research revealed statistically significant correlations between positive mindset (incremental theory of intelligence) and positive effort beliefs ($p < .01$); positive mindset and low helpless attributions ($p < .01$); positive mindset and learning goals ($p < .01$); and positive mindset and positive problem-

solving strategies ($p < .01$) (Blackwell et al., 2007). The researchers stated, “these variables were all significantly positively correlated with one another (r s ranged from .34 to .72, $p < .01$). Thus, mindset (an incremental theory of intelligence), learning goals, positive beliefs about effort, non-helpless attributions, and strategies in response to failure formed a network of interrelated variables” (Blackwell et al., 2007, p. 250). The strength of the findings would have been greater if the academic achievement measurement tools had been consistent instead of using the CAT in 6th grade and the semester grades in 7th grade; however, these significant findings support the importance of continued research focusing on interventions that help students understand mindset. In addition, grades are highly subjective and tend to be spuriously influenced by factors not actually related to achievement; use of standardized methods of testing would have provided greater insight into the relationships between mindset and achievement. Finally, correlational research, while often revealing, does not imply causality, nor directionality. One can only conclude that math achievement is related to mindset in this correlational study.

In a second more condensed study, Blackwell et al. conducted an eight-week intervention with 7th-grade students who tested at or below the 35th percentile on the 6th-grade CAT exam. The same survey from the previous five-year longitudinal study was used to gather subscale scores in mindset (theory of intelligence), learning goals, effort beliefs, and helpless responses to failure. Students were randomly assigned to an experimental intervention group ($n = 48$) or a control group ($n = 43$). The curriculum utilized in the intervention group focused on the ability of students to grow their brains through hard work and perseverance. The curriculum presented in the control group

targeted traditional study skills. The control and intervention sessions were conducted once a week for eight weeks during an advisory class with presentations that lasted 25 minutes for a total of 200 minutes (Blackwell et al., 2007).

Results of the second study by Blackwell et al. (2007) revealed that during the shift from elementary school to junior high school, mindset was a significant predictor of math grades using the 6th grade CAT exam as a baseline and comparing term grades in 7th and 8th grades ($p < .05$). Higher scores on the growth mindset survey items as students entered 7th-grade was significantly related to higher math grades during the 8th-grade ($p < .05$) (Blackwell et al., 2007). In addition, the researchers used seven tests measuring helpless attributions, learning goals, two measures of efforts beliefs, and three measures of positive strategies as mediating variables of math grades. Each of the seven tests exhibited statistically significant results in relation to math grades ($p < .05$) (Blackwell et al., 2007). These findings from the second study support the importance of further research on the effects of mindset interventions on low-achieving middle school students. The results from both Blackwell et al. studies illustrate the significant relationship of growth mindset training to math grades for both low and moderate achieving students in middle school. Unfortunately, the researchers were unable to compare the baseline CAT standardized math achievement score to standardized math scores in the 7th and 8th-grade levels after the interventions for analysis which would have added profoundly to the findings.

According to Paunesku et al. (2015), mindset interventions to improve learning had been studied on a small scale, but little data existed on a large scale. For this reason, they chose to target a large sample of high school students ($n = 1,594$) using an online

curriculum addressing sense-of-purpose and growth mindset interventions in 13 secondary schools. The participating schools were diverse and included public charter schools (n = 4), traditional public schools (n = 8), and private schools (n = 1) in the sample. The schools were in the east, west, and southwest regions of the United States and representative of various levels of economic status. Of the 13 schools used for the study, five schools served very few low socioeconomic students, and six schools served a population with more than 50% of students receiving free or reduced lunch. Participating schools used a study coordinator who worked with staff to ensure that students participated in an online mindset intervention during two separate 45-minute sessions approximately two weeks apart (Paunesku et al., 2015). Students were informed before participating in the research that the study was “part of an ongoing Stanford University study about why and how students learn” (Paunesku et al., 2015, p. 786).

After the high school students had logged into the research website, they were randomly assigned by the computer to one of four 45-minute interventions: a control group, a growth mindset intervention, a sense of purpose intervention, or an intervention combining both growth mindset and a sense of purpose. During the first 45-minute session, groups were assigned to either the growth mindset intervention or the control condition. The growth mindset intervention shared the message that students could increase their academic ability through hard work and perseverance during challenging situations or when mistakes occur. The control group session focused on functions of the brain and did not address the neural plasticity of the brain. The sense of purpose intervention promoted reflection on reaching meaningful goals that promote the good of others through hard work and determination in academics. The fourth condition blended

the information from the mindset intervention and the sense of purpose session into one 45-minute intervention (Paunesku et al., 2015).

All students included in the research analysis completed the assigned online sessions and had pre- and post-intervention class grades in core academic courses (English, math, science, and social studies). Researchers gathered pre- and post-measures of mindset, the students' perceived purpose of academic tasks, and GPA scores for core academic courses (Paunesku et al., 2015). As reported by Paunesku et al., pre-intervention GPA of the control and intervention groups were not significantly different in the four academic core areas, indicating that the groups were similar in achievement levels before the intervention.

Analysis of the data illustrated a significant positive correlation between pre-intervention GPA scores and growth mindset scores ($p < .001$); in other words, the higher the students' GPA scores were, the higher the students' reported growth mindset scores. The researcher also found a significant positive correlation between pre-intervention GPA and sense of purpose scores ($p < .008$); this result indicated that the higher the student pre-intervention GPA scores, the higher the sense of purpose scores. Using linear regression and controlling for prior mindset beliefs, analysis revealed a statistically significant correlation between the growth mindset intervention and students' beliefs supporting the malleability of academic learning ability or positive mindset ($p < .005$). However, the sense-of-purpose intervention and the combined growth mindset/sense of purpose intervention were not significantly correlated with beliefs in mindset indicating that the sense of purpose and mindset interventions interacted with students differently (Paunesku et al., 2015). Combining the mindset and sense-of-purpose content in the

combined intervention may have overloaded the students with too much information or may have resulted in less rigorous coverage of the essential information on mindset that resulted in the statistically significant results in beliefs alterations in the pure mindset condition. Further research may be necessary to investigate these phenomena.

Linear regression revealed a statistically significant positive relationship between student perceptions of importance of academic tasks in growth and learning among the sense of purpose intervention group ($p < .018$); while the growth mindset intervention group did not ($p < .078$). These results indicated that students who held higher sense of purpose beliefs also exhibited higher perceptions of academic task importance; there was no significant relationship between perception of growth mindset and the importance of academic tasks. The combination of the growth mindset/sense of purpose intervention was not significantly predictive of GPA for the participants in that group (Paunesku et al., 2015).

Paunesku et al. subsequently disaggregated the GPA scores for at-risk high school students ($n = 519$) from the original sample of 1,594 students. These students exhibited pre-intervention GPA scores at 2.0 or below for the fall semester of the study and/or had failed one or more core content courses. Statistically significant positive correlations in post-intervention GPA scores of at-risk students were observed in the growth mindset intervention group ($p < .048$) and the sense-of-purpose intervention group ($p < .021$), but were not significant for the combined intervention or the control group (Paunesku et al., 2015). These findings supported the findings from the first analysis of the larger data set by Paunesku et al. When analyzing the satisfactory completion rates in core courses for at-risk students in all mindset intervention groups, Paunesku et al. found statistically

significant correlations ($p < .007$) between the likelihood of the students passing a core course and participation in the mindset intervention. These findings indicate that exposure to just 45 minutes of intervention on mindset could lead to better academic performance in at-risk high school students. These significant results illustrated the relationship between growth mindset instruction and academic performance among at-risk students.

The bulk of mindset research has concentrated on American students that may not apply to all youth. A study by Chen & Wong (2015) researched mindset and academic achievement of Hong Kong's 1st- and 2nd-year education students ($n = 418$) from two different universities that were considered average in academic competitiveness. The students were education students who attended one of two universities in Hong Kong. More females ($n = 226$) than males ($n = 192$) participated in the study due to the composition of the students in the education department; the average age of participants was 19.88 years. Students voluntarily completed a seventeen-item survey created by researchers assessing goal orientations and mindset at the end of their Sociology of Education course. Seventeen survey items in four categories measured the areas of students' performance approach, endorsement of mastery, performance avoidance goals, and mindset (Chen & Wong, 2015). Students responded to items measuring their performance-approach goals beliefs including this exemplar: "I just want to avoid doing poorly in this class" (Chen & Wong, 2015, p. 718). Students responded to items measuring their mastery goals beliefs including this exemplar sample: "I hope to have gained a broader and deeper knowledge when I am done with this class" (Chen & Wong, 2015, p. 718).

The data analysis by Chen & Wong revealed several statistically significant findings. The self-reported beliefs of the students' mastery goals were positively correlated with growth mindset (incremental theory) ($p < .01$), performance-approach goals ($p < .01$), and GPA ($p < .01$). Beliefs in performance-approach goals were also positively correlated with beliefs in growth mindset (incremental theory) ($p < .01$) and GPA ($p < .01$) (Chen & Wong, 2015). In addition, a positive correlation existed between participants' growth mindset and GPA ($p < .05$) (Chen & Wong, 2015). These results indicated significant positive relationships between participants' positive growth mindset and participants' positive mastery goals, positive performance-approach goals, and higher GPA scores.

In an international high school study, a national database of 10th graders enrolled in public schools in Chile was utilized by Claro, Paunesku, & Dweck (2016) to correlate mindset measures and standardized mathematics test scores ($n = 168,203$) and standardized language test scores ($n = 168,553$). Subjects represented a sample of 75% of all Chilean 10th graders enrolled in public education and 98% of all public school campuses in Chile. The data were gathered from the Chilean Government's 2012 10th-grade standardized math and language skills exams and a required student survey which included items measuring mindset from a previous tool used by Dweck (2002) (Claro et al., 2016).

The research by Claro et al. (2016) identified a highly significant positive correlation between mindset and 10th-grade achievement in mathematics ($p < .001$) and 10th-grade language achievement ($p < .001$). Student mindset explained 11.8% of the variance ($r = 0.343$) on a composite average of language and mathematics scores; the

highest socioeconomic level group explained 11.3% of the variance on the composite average of language and mathematics scores. Further analyses stratified student data according to SES income levels. Interestingly, a significant correlation existed between family income and the reported mindset of 10th-grade students ($p < .001$) (Claro et al., 2016). Students with high SES showed stronger beliefs in the importance of a growth mindset than low SES students. In fact, Claro et al. (2016) reported, “Students from the lowest-income families were twice as likely to endorse a fixed mindset as students from the top-income families and schools” (p. 8666). This finding supports further investigation of the impact of instruction on the importance of growth mindset on academic performance with low-income students who are at-risk.

According to Claro et al. (2016), “These findings also document for the first time, to our knowledge, a relationship between mindsets and economic disadvantage” (p. 8667). Claro et al. (2016) further reported a significant negative correlation between mindset and family income in predicting math and language combined test scores ($p < .001$). “Students from low-income families (the lowest 10%) who had a growth mindset showed comparable test scores with fixed mindset students whose families earned 13 times more (80th percentile)” (Claro et al., 2016, p. 8667). Claro et al. reported that a growth mindset “is a comparably strong predictor of achievement and that it exhibits a positive relationship with achievement across all of the socioeconomic strata in the country” (2016, p. 8664). In the lowest decile of family income of the research participants, approximately 60% reported having a fixed mindset while approximately 30% of the participants in the highest decile of family income reported a fixed mindset. Participants in the highest decile of family income were twice as likely to report a growth

mindset as members from the lowest decile (Claro et al., 2016). Claro et al. (2016) reported this study as the first that illustrated that a growth mindset predicted achievement throughout a national student sample.

A study of 5th and 6th-grade African-American students living in poverty was conducted by Gutman & Midgley (2000) who extracted data from a survey used in a longitudinal study in Michigan (n = 901). In Gutman & Midgley's study, 62 African-American students' responded to a survey measuring academic self-efficacy using items from the Patterns of Adaptive Learning (PALS). The survey items asked questions that illustrated whether or not students felt they could be successful in challenging situations (Gutman & Midgley, 2000). The feelings of competence expressed by students in the PALS were considered key components of having a positive mindset (Dweck, 2006). This study's results found statistically significant correlations ($p < .01$) between 5th and 6th-grade African-American students' self-reported academic self-efficacy and their overall grade point average as well as with the combined mean grades of math, science, language arts, and social studies at the end of the 5th and 6th grades. The 5th and 6th-grade African-American students' mindset/academic self-efficacy, and feelings of competency revealed statistically significant positive correlations to academic performance in their combined grade point averages in the four content areas of math, science, language arts, and social studies (Gutman & Midgley, 2000). These findings point to the need for further study of the effects of mindset on the mathematics performance of students in this population and similar populations that are underrepresented in STEM fields.

According to Dweck, "Each person has a unique genetic endowment. People may start with different temperaments and different aptitudes, but it is clear that experience,

training, and personal effort take them the rest of the way” (2006, p. 5). Basing her statement on thirty years of research on the effects of mindset, she stated, “The views you adopt for yourself profoundly affect the way you lead your life” (Dweck, 2006, p. 6). This research led to Dweck’s coining of two categories of mindset: 1) a fixed mindset with talents that are set and finite, and 2) a growth mindset in which potential exists to cultivate and grow abilities. Individuals with a fixed mindset feel the pressures of proving themselves on every task they undertake, and they may avoid challenging situations once they have already shown success (Dweck, 2006; Dweck, 2008). Individuals with a growth mindset realize that they must struggle and make errors as they tackle new and challenging material to strengthen their knowledge and skill (Boaler, 2016; Dweck, 2006).

Researchers have demonstrated significant relationships between mindset and academic performance in a variety of student populations ranging from early elementary to adults. Research also points to connections between mindset and academic performance of specific demographic groups of students including low socioeconomic levels, minorities, and young adults (Blackwell et al., 2007; Boaler, 2016; Chen & Wong, 2015; Claro et al., 2016; Dweck, 2006; Gutman & Midgley, 2000; Paunesku et al., 2015).

Math Anxiety

Math Anxiety has been an educational concern and research focus for several decades. In 1953, Taylor added three items to the Taylor Manifest Anxiety Scale to gather data specific to math anxiety (Taylor, 1953). The first standardized math anxiety survey tool was the 98-item Mathematics Anxiety Rating Scale (MARS), created by Richardson and Suinn (1972) using a 5-point Likert scale. Seeking to develop a more

succinct tool, Fennema–Sherman (1976) developed the Mathematics Anxiety Scale (MAS), and Sandman (1980) developed a six-item tool named the Anxiety Towards Mathematics Scale (ATMS). Soon after these shorter surveys were developed, Plake & Parker (1982) released a 24-item condensed survey of the MARS entitled the Math Anxiety Rating Scale Revised (MARS-R). A tool frequently used in later math anxiety research was a 25-item version of the MARS referred to as the sMARS by Alexander & Martray (1989). Another brief survey tool for measuring math anxiety was created by Hopko, Mahadevan, Bare, & Hunt (2003) which included nine items referred to as the Abbreviated Math Anxiety Scale (AMAS). An abundance of research has been conducted using math anxiety as a variable (Andrews & Brown, 2015; Ashcraft & Kirk, 2001; Ashcraft & Faust, 1994; Boaler, Williams, & Confer, 2015; Buckley, Reid, Goos, Lipp, & Thompson, 2016; Geist, 2015; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Hopko et al., 2002; Ma, 1999; Meloney & Beilock, 2012; Necka, Sokolowski, & Lyons, 2015; Perry, 2004; Ramirez, Gunderson, Levine, & Beilock, 2013; Supekar, Iuculano, Chen, & Menon, 2015; Supekar et al., 2013; Suri, Monroe, & Koc, 2013; Young, Wu, & Menon, 2012).

According to Huberty (2009), approximately 30% of adolescents suffer from severe testing anxiety across a variety of content areas. With regard to mathematics anxiety, Boaler (2015) stated that one-third of students across all socioeconomic groups and achievement levels experience severe anxiety during timed math tests. Boaler (2015) further stated that all content areas require some level of memorization of information or facts, but that math is the only subject in which students are expected to regurgitate memorized facts quickly to earn good scores. Boaler (2015) shared an example in which

a mathematical recall blunder during an interview of a British politician resulted in a media frenzy that ridiculed the politician and called for more emphasis on memorization of math facts in British schools; this focus on basic math facts can lead to a false perception by students that fast recall abilities are the key to performance in math. Boaler (2016) described her personal experiences in math education with this statement, “I learned math facts through using them in different mathematical situations, not by practicing them and being tested on them” (p. 1). Boaler (2016) admitted that she, like many brilliant mathematicians, is slow at mathematical calculations.

Ramirez, Gunderson, Levine, & Beilock (2013) conducted a study of first (n = 88) and second grade (n = 66) students in an urban setting from five public elementary schools; data were gathered from a larger research project studying the affective factors impacting early childhood learning. The mean age of the students was seven, and the ages ranged from four to eight. The average income of the households of the students was about \$14,000 above the poverty level in 2009. The study focused on the effects of math anxiety levels on three different measures of working memory in the participants (Ramirez et al., 2013). To measure math anxiety levels, Ramirez et al. (2013) used eight items from the Mathematics Anxiety Rating Scale for Elementary Children (Suinn, Taylor, & Edwards, 1988) but adapted them to the appropriate grade level. Typical problems found in first- and second-grade math workbooks were used such as “There are 13 ducks in the water, there are 6 ducks on land, how many ducks are there in all?” (Ramirez et al., 2013, p. 191). Researchers asked the “children to make their responses about each question using a sliding scale that featured a calm face on the far right, a seminervous face in the middle, and an obviously nervous face on the far left” (Ramirez

et al., 2013, p. 191). Students were allowed to choose spaces in between faces, and the researchers assigned a scale ranging from 1 to 16 accordingly for each area of space. Using the responses from the eight adapted MARS-E items, items were scored by averaging the numerical scores of the eight items to yield a Child Math Anxiety Questionnaire (CMAQ) score (Ramirez et al., 2013).

The first measure of working memory used by Ramirez et al. was a forward and backward scanning subtest score referred to as the Digital Span from the Wechsler Intelligence Scale for Children-Third Edition (WISC-III) (Wechsler, 1991). “The forward digital span task is a commonly used measure of immediate verbal short-term memory, and the backward digit span task has been generally used as a [sic] measure of executive attention in neuropsychological and developmental research” (Ramirez et al., 2013, p. 190). In the forward scanning test, the students were asked to repeat patterns of numbers in order; in the backward scanning tasks, students were asked to repeat the digits in reverse order (Ramirez et al., 2013). According to Ramirez et al., working memory (WM) “is thought to be composed of memory processes, measured by forward digit span, and executive attention processes, measured by backward digit span” (p. 190); These two scanning motion scores encompassed both components of working memory (Ramirez et al., 2013).

A second measure of working memory utilized in the 2013 Ramirez et al. study was the Woodcock-Johnson III Applied Problems subtest (Woodcock, McGrew, & Mather, 2001), which was designed to measure academic skills for individuals from 2-to-90-years-of-age. This test presented the 1st and 2nd-grade participants with math word problems that increased in difficulty. The test continued until the test taker achieved a

base level of six correct responses and increased in rigor until the individual missed six problems in a row (Ramirez et al., 2013).

A third test of working memory used by Ramirez et al. was the Woodcock-Johnson III subtest for Letter-Word Identification (Woodcock et al., 2001). The same process for baseline and ceiling performance that was utilized in the Applied Problems subtest was used for this test to examine the child's ability to identify letters of the alphabet and word formations through a battery of increasingly difficult scenarios (Ramirez et al., 2013).

Ramirez et al. gathered all data in one-on-one sessions with participants in a quiet setting on campus during the first three months of school. The math anxiety items were dispersed in a larger set of questionnaires taken by students (Ramirez et al., 2013).

Ramirez (2013) later reported "CMAQ scores did not correlate with children's digit span scores while controlling for grade level" (p. 193). When forward and backward digit span scores were combined, a statistically significant relationship was found between working memory (WM) and math anxiety ($p = .026$) (Ramirez et al., 2013). In students with high math anxiety, a prominent negative relationship was found between math achievement and math anxiety; in other words, students with high math anxiety levels had significantly lower math achievement scores (Ramirez et al., 2013).

Ramirez subsequently separated the analysis of student performance on performance tasks into easy-item and difficult-item performance; utilizing the easy-items as the dependent variable, the main effect for working memory was significant ($p < .01$), but math anxiety was not ($p > .05$). This result indicated that the easy-items were related to significantly higher results in WM scores, but were not related to significantly higher

math anxiety levels. When using the hard-items as the dependent variable, working memory was significant ($p < .01$) and math anxiety was significant ($p < .05$), indicating that hard-items were related to negative effects on WM scores and higher math anxiety (Ramirez et al., 2013). Ramirez et al. (2013) stated, “When high WM children have high math anxiety, their performance is specifically impaired on those math problems that typically require more complex, WM-demanding strategies” (p. 195). Ramirez et al. further stated, “Our work suggests that making students aware of alternative problem-solving techniques that can withstand the impact of math anxiety on WM may be one such way to lessen the math anxiety-math performance relationship” (p. 199). Activities focused on alternative problem-solving techniques in challenging mathematical situations have also shown to be effective in increasing math performance among low-achieving students (Blackwell et al., 2007; Moely et al., 1992)

Modern technologies allows researchers to explore how the brain works and to report reactions to problem-solving situations. Two widely-cited research studies investigating the neurobiological mechanisms in the brain affected by math anxiety were conducted by Supekar, Iuculano, Chen, & Menon (2015) and Young, Wu, & Menon (2012). Their findings revealed neurological evidence that can be used to research the effects of math anxiety.

According to Supekar et al. (2015), math anxiety in early childhood may lead to adverse consequences academically and professionally. The researchers conducted a pre-/post-test study utilizing one-on-one targeted math tutoring sessions with right-handed third-grade students ($n = 28$) three times a week for 40-50 minutes each over an eight week period (Supekar et al., 2015). Due to the study’s emphasis on neurological

changes, Supekar et al. (2015) made sure that all participants did not suffer from mental, physical, or neurological illness before participation in the study.

Supekar et al. (2015) gathered math anxiety scores for the third-grade participants using the Scale for Early Mathematics Anxiety (SEMA). The SEMA was administered pre- and post-tutoring to assess self-reported math anxiety levels. The tutoring sessions consisted of 22 lessons focusing on arithmetic problem-solving which started with addition of two single-digit values and increased in difficulty to multi-digit multiplication. The lessons emphasized manipulatives, math games, and conceptual understanding rather than memorization. Supekar et al. (2015) “examined behavioral as well as functional brain responses and circuits in each child before and after tutoring, and compared across the high math-anxiety (HMA) and low math-anxiety (LMA) groups” (para. 5). Supekar et al. (2015) utilized magnetic resonance imaging (MRI) during participants’ arithmetic problem-solving sessions and used the median SEMA pre-tutoring score value to split participants into HMA and LMA groups. The ages, IQs, and achievement in reading, math, and working memory were comparable for both the HMA and LMA groups and were considered control variables (Supekar et al., 2015).

Supekar et al. (2015) collected pre- and post-tutoring functional Magnetic Resonance Imaging (fMRI) and MRI imaging; the fMRI is a procedure for collecting and mapping brain functions during an activity. “The fMRI task consisted of an arithmetic problem-solving task (Addition task) and a number identification task (Control task)” (Supekar et al., 2015, para. 9). Participants in the study underwent two fMRI experiments while performing 12 non-arithmetic and 12 arithmetic identification problems. Students were given situations such as $4 + 5 = 8$ or $4 + 4 = 8$ and were

requested to indicate whether or not the arithmetic statements were correct. Different arithmetic and non-arithmetic statements were used in the post-fMRI experiments. Formatting and visual presentation of the statements as well as the duration of exposure time presented to the students stayed constant across all pre- and post-administrations for all groups.

Results of the SEMA data revealed a statistically significant ($p < .02$) decreases in math anxiety levels after participants completed eight weeks of math tutoring. Statistically significant ($p < .009$) interactions occurred between the pre- and post-tutoring and the HMA and LMA groups. The HMA students exhibited statistically significant ($p < .002$) decrease in math anxiety as measured by the SEMA after completion of tutoring; however, the LMA students did not show statistically significant ($p < .747$) change in math anxiety (Supekar et al., 2015). The researchers found that decreased math anxiety levels after tutoring correlated ($p < .026$) with math anxiety levels from pre-tutoring measurements; HMA students showed the most reduction in negativity and anxiety towards math after completing the tutoring sessions (Supekar et al., 2015). This study from Supekar et al. (2015) indicated that targeted tutoring sessions on problem-solving and perseverance strategies for as little as 5.5 to 6.5 hours could result in significantly lower math anxiety in students exhibiting high math anxiety. Interestingly, even though the research showed statistically significant math performance gains for students in both accuracy ($p < .001$) and reaction time ($p < .001$), these gains did not correlate to the math anxiety levels of the students (Supekar et al., 2015).

Young, Wu, & Menon (2012) found neural correlations with math anxiety levels through the use of MRI studies in children from the third grade ($n = 46$) in the San

Francisco area. Young et al. (2012) reported their research study as the “first to identify the neural basis of math anxiety in young children and demonstrate its impact on brain functioning and connectivity at one of the earliest stages of formal acquisition of math skills” (p. 492).

To determine trait anxiety, parents of the 3rd grade students completed The Child Behavior Checklist for 6-18-year-olds (CBCL/6-18) (Achenbach, 2001); trait anxiety occurs across multiple situations and is not a normal emotional state (Young et al., 2012). Like Supekar et al. (2015), Young et al. used the Scale for Early Mathematics Anxiety (SEMA) survey tool to determine math anxiety levels. The SEMA was used to measure differences in math anxiety throughout the study and to divide the participants into groups of high math anxiety (HMA) and low math anxiety (LMA) (Young et al., 2012).

Each child in the Young et al. study went through fMRI scans including: (1) simple arithmetic addition and subtraction problems and (2) complex arithmetic addition and subtraction problems. The participants were shown arithmetic statements in each of these conditions and asked to use a button box to indicate whether the statements were stated correctly or incorrectly. All arithmetic conditions presented the simple and complex problems in a consistent format with identical response requirements. The SEMA scores were used to analyze performance differences in the HMA and LMA groups as well as brain interaction increases and decreases observed during the fMRI scans related to math anxiety (Young et al., 2012).

Results of the study revealed that the HMA group illustrated a trend of lower accuracy on arithmetic performance. The main effect of operation (addition or subtraction) was significantly different ($p < .001$), with participants demonstrating more

accuracy on addition problems than on subtraction problems. The comparison between simple problems versus complex problems was also significantly different ($p < .001$), with participants showing higher accuracy on the simple arithmetic problems than on the complex ones (Young et al., 2012).

Young et al. reported significant findings for response times and problem types ($p < .038$) with the LMA group showing longer response time differences than the HMA group between simple and complex arithmetic problems. Young et al. also reported a statistically significant main effect of response time and operation ($p < .008$) with subtraction problems taking more time than addition. In addition, Young et al. found a statistically significant main effect of response time compared to problem type ($p < .001$) with participants solving complex problems more slowly than simple problems.

Young et al. compared fMRI responses for the HMA and LMA groups during the math problem-solving to ascertain the neural associations of math anxiety. “In comparison with the LMA group, math problem-solving [sic] in the HMA group was associated with significantly greater activation in the right amygdala extending posteriorly into the anterior hippocampus” (Young et al., 2012, para. 18) ($p < .01$). Young et al. stated, “These results demonstrate that math anxiety in 7-to-9-year-old children is associated with significant differences in activation of brain areas that mediate affective and cognitive information processing” (2012, para. 21). These results illustrated that elevated levels of math anxiety correlated with hyperactive amygdala responses within sections of the brain controlling emotions and a reduction in amygdala connectivity that supports learning ($p < .01$). “Critically, the HMA and LMA groups did not differ on measures of trait anxiety, which suggests that the observed behavioral and

brain differences arose from math anxiety rather than from general anxiety” (Young et al., 2012, para. 21). This study provided evidence that math anxiety is unique and affects individuals in physical ways within the brain.

In a thesis study of math anxiety of low-performing high school math students (n = 174), Clark (2004) explored math situations that led to different levels of math anxiety. Student participants (n = 174) had failed at least one high school level math course and were 1 to 3 years behind their peers in math progress. Clark (2004) administered the Math Anxiety Rating Scale for Adolescents (MARS-A) (Suinn, 1988) to students during their math courses at four Los Angeles County high schools. The participating schools had an average Algebra failure rate of 60% and were located in communities comprised of 98% Latin-American and African-American community members (Clark, 2004). Of the 174 participants, 84 were male, and 90 were female with a grade level distribution of 12th graders (n = 2), 11th graders (n = 34), 10th graders (n = 33), and 9th graders (n = 105). All students selected for the study were enrolled in a course they were repeating, a course for math remediation, or an alternative education class in math (Clark, 2004).

Clark (2004) administered the MARS-A 98-item assessment of math anxiety to study participants during their math courses. The MARS-A has normative data for middle and high school American populations, which allowed the researcher to compare survey results to norms of math anxiety. The researcher shared a definition of anxiety and allowed students to share any examples of anxiety that they had experienced, then the MARS-A items were read one at a time in each class allowing enough time for students to respond on a Scantron sheet. The mathematics teacher was a neutral observer during the administration of the survey (Clark, 2004).

Clark (2004) found no statistically significant differences in math anxiety responses on the MARS-A of male and female participants. In this study, a low math anxiety status was assigned to students scoring at the 20th percentile or lower, and a high math anxiety label was given to those students scoring at the 75th percentile or higher on the MARS-A. Clark (2004) reported that on the MARS-A, “Latin-American and African-American students experienced overall higher levels of anxiety when compared to the norm group” (p. ix); however these differences were not significant in the math anxiety changes based on ethnicity, indicating that ethnicity and gender were not mediating variables in this study.

Sixteen of the MARS-A survey items reported significantly higher levels of math anxiety scores ($p < .05$). The significant items are depicted in Table 1 (Clark, 2004).

Table 1

Survey Items from the MARS-A Significant Correlations to High Levels of Math Anxiety among Low-Performing High School Math Students (n = 174)

Item #	Item	Pearson <i>r</i>
74	Thinking about an upcoming math test one day before	.702*
75	Thinking about an upcoming test one hour before	.676*
46	Reading and interpreting graphs or charts	.644*
73	Thinking about an upcoming math test one week before	.638*
96	Being asked to explain how you arrived at a particular answer for a problem	.637*
72	Being given a homework assignment of many difficult math problems which is due the next time class meets	.637*
80	Asking your math teacher after class about something you did not understand	.633*

61	Having a friend try to teach you how to do a math problem and finding that you cannot understand what is being said	.627*
88	Opening a math or statistics book and seeing a page full of problems	.625*
86	Figuring out how much material you will need to do a project so that you will not waste time	.622*
82	Picking up a math textbook to begin a difficult reading assignment	.617*
55	Hearing two of your friends talking about the best way to figure out the actual cost of a product	.615*
65	Working a math problem that is important in your life, like figuring out how much you can spend on recreational activities such as movies after buying other things you need	.612*
64	Deciding which courses to take in order to come out with enough credit hours for promotion or graduation	.608*
77	Checking the time and figuring out whether or not you can stop in two more stores and still meet a friend at the exact time you said you would	.607*
53	Taking an examination (quiz) in a math course	.604*

*($p < .05$) (Clark, 2004, p. 65-66)

The results of these analyses showed a strong relationship to math assessments and math anxiety. This study appears to support the claims of Boaler (2016) that teachers use assessment practices in math classrooms that contribute to the math anxiety levels of students. However, Clark (2004) also reported several items related to high math anxiety surrounding performance situations, which provided evidence for supporting the need to explore math performance-related pedagogy in the classroom. Even performance items such as number 65 of the MARS-A which dealt with real-life uses for math such as budgeting, caused anxiety among the high school students.

The statistically significant ($p < .05$) items with the lowest reported math anxiety

scores on the MARS-A for the participants in Clark’s (2004) research dealt with addition, counting money, and being given a math book. See Table 2 below for those items (Clark, 2004).

Table 2

Survey Items from the MARS-A Significant Correlations to Low Math Anxiety among Low-Performing High School Math Students (n = 174)

Item #	Item	Pearson <i>r</i>
67	Being given a set of addition problems to solve on paper	.390*
5	Adding up 976 + 777 on paper	.386*
12	Being asked to make change	.386*
23	Receiving a math book	.355*
9	Counting a pile of change	.335*

*($p < .05$) (Clark, 2004, p. 67)

Findings by Clark (2004) support the findings from other research that lower levels of math anxiety are associated with basic arithmetic operations (Ashcraft & Faust, 1994; Elliott, 1990; Hopko et al., 2002). Performance and problem-solving activities in math and math assessments resulting in high levels of math anxiety also support other research findings (Hopko et al., 2002; Supekar et al., 2015; Young et al., 2012). This report illustrates the need to address math anxiety-inducing events in low-performing high school level students of both genders and all ethnicities.

In 1998, Hopko, Ashcraft, Gute, Ruggiero, & Lewis conducted a study in which they recruited and offered extra credit to undergraduate psychology students (n = 90) to complete the Abbreviated Math Anxiety Rating Scale (sMARS) followed by completion of reading comprehension tasks which involved mathematics content and distractors.

The researchers placed undergraduate psychology students in three groups of 30 participants based on their self-reported math anxiety using the sMARS survey tool two weeks before conducting experimental testing. The three groups represented low math anxiety, medium math anxiety, and high math anxiety (Hopko et al., 1998). The researchers utilized three different reading comprehension conditions and distributed the students so that all math anxiety levels were equally represented in each condition. The conditions included readings that were nonmath-specific (condition 1), math specific (condition 2), and readings with related distractor items (condition 3) (Hopko et al., 1998).

Baseline Test Anxiety (TAI) scores measuring test-taking anxiety and State-Trait Anxiety Inventory (STAI) scores measuring state and trait anxiety were obtained for students assigned to conditions 1 and 2, and all participants received practice training for their assigned conditions. The readings for all three conditions were recorded and timed, but participants were not aware of the timing (Hopko et al., 1998).

Hopko et al. (1998) found statistically significant main effects for the math anxiety group in the related distractor scenario ($p < .01$), in the unrelated distractor scenario ($p < .01$), and in the x string distractor ($p < .05$). “In all distractor conditions, post hoc comparisons indicated that low-math-anxious individuals completed the tasks in significantly less time than participants categorized as either medium or high math anxious. No differences between the latter two groups were identified” (Hopko et al., 1998, p. 349). A statistically significant main effect for distractor type was also uncovered ($p < .01$) in a post hoc analysis revealing that the x string paragraph’s reading times were significantly shorter for all anxiety groups. This result indicated a

relationship between the longer reading times and distractors that were related to the readings, both math and nonmath. The interaction of anxiety groups and distractor types were statistically significant ($p < .05$), demonstrating that math anxiety levels led to differences in performance on the reading activities based on distractor types. The reading times were very similar for all groups on the x string paragraphs, but the reading times increased as math anxiety increased in both the unrelated and related distractor conditions (Hopko et al., 1998).

Hopko et al. (1998) also found a statistically significant main effect for error rates on the comprehension test scores and paragraph types for all three experimental conditions ($p < .001$). “For each distractor condition, math-related paragraphs were predictive of high error rates [sic] when compared with nonmath paragraphs” (Hopko et al., 1998, p. 350). The main effect analysis for math anxiety and errors was statistically significant ($p < .05$). Post hoc analysis revealed that medium- and high-anxiety groups created errors significantly more often than the low-anxiety group (Hopko et al., 1998). These results provide evidence that math text is harder to read and comprehend than nonmath content; math content takes longer to process, especially for students with high math anxiety.

In a later study in 2002 by Hopko et al., researchers used carbon dioxide (CO_2) gas to induce anxiety in participants in order to investigate differences between math anxiety and physiological anxiety related to performance on arithmetic tasks and word/phrase sorting decisions. Hopko et al. (2002) gathered pre-experimental Revised Math Anxiety Rating Scale (MARS-R) scores of undergraduate psychology students ($n = 64$) from a larger sample ($n = 814$) of MARS-R pre-tests, selecting the top 10% of the

scores to form the high math anxiety (HMA) group, and the lowest 25-35% of the scores to form the low math anxiety (LMA) group. Male and females were equally represented and were assigned randomly to either the control or CO₂ exposure groups. The ethnicity of students was 92% Caucasian, 3% African-American, 2% Asian, and 3% other. This research investigated students' performance that was directly related to math anxiety versus general physical anxiety resulting from the exposure to CO₂. Hopko et al. (2002) monitored physical anxiety by measuring heart rate in beats per minute (BPM) and skin conductance.

Researchers assigned participants randomly to the control or CO₂ groups then gained consent and medical interviews. Before the experiment, participants completed the SAT-Q and a math skills test followed by skin conductance readings and heart rate monitoring during a 5-minute relaxation period to establish baseline readings (Hopko et al., 2002).

The CO₂ experimental group was subjected to 7% CO₂ enriched air for 25 seconds, and the control group inhaled normal room air for 25 seconds before each task completion. Directly following stimulus (CO₂/air)/task completions, the researchers gathered students' reported discomfort using the Units of Discomfort Scale (SUDS) (Wolpe, 1969), which measures dimensions of 1) discomfort, 2) aversiveness, and 3) arousal (Hopko et al., 2002). Following SUDS reporting, participants were given instructions for one of two performance tasks (word-sorting/arithmetic) which required them to choose a response as accurately and quickly as possible. Participants engaged in practice trials followed by their first performance task (Hopko et al., 2002). Participants again experienced their assigned stimulus (CO₂/air) followed by the second task. SUDS

scores were gathered directly after completion. After completion of both performance tasks, a final heart rate and skin conductance rating were measured during a 5-minute timeframe followed by measurement of panic attack symptoms reported on the Diagnostic Symptoms Questionnaire (DSQ) (Hopko et al., 2002).

The main effect of the arithmetic response time was significant across the combined HMA and LMA groups (HMA, LMA) ($p < .01$). *Post hoc* analysis revealed that mean scores for response times on complex arithmetic problems surpassed those reported for simple arithmetic problems and response times for complex multiplication problems were longer than times recorded for complex addition problems (Hopko et al., 2002).

Researchers reported a significant main effect of anxiety group ($p < .01$); high anxiety participants exhibited higher error rates than low anxiety participants across both experimental and control groups (Hopko et al., 2002). Hopko et al. (2002) utilized a “2 (anxiety group) x 2 (gender) x 2 (gas condition) x 4 (word type) mixed factorial design” (p. 657) to analyze response time and error rates. A statistically significant main effect was found for word type ($p < .01$), but no significant finding between anxiety groups and word type conditions were uncovered (Hopko et al., 2002). These results provide evidence that high anxiety interfered with student performance in mathematics problem-solving, but not for the word-sorting condition.

Hopko et al. (2002) found significant differences between groups, with participants in the CO₂ group reporting significantly higher symptoms of anxiety/stress ($p < .01$) than control group participants. In addition, the researchers also reported that participants from the CO₂ group reported greater discomfort, arousal, and aversiveness

scores ($p < .01$) than the control group (Hopko et al., 2002). These findings support the conclusion that the anxiety produced by the CO₂ stimulus occurred during all conditions and that the anxiety negatively affected performance. These findings for the CO₂ group mirrored the results from the high math anxiety group. Since all math anxiety levels were included in the CO₂ group as well as in the control group, results support a difference between math anxiety and other forms of anxiety.

Ashcraft & Faust (1994) conducted two experiments investigating math anxiety among undergraduate students ($n = 130$). In the first investigation, Ashcraft & Faust (1994) told volunteers they were participating in a study of attitudes towards math and split the participants randomly into two groups; one group took a paper-and-pencil version of the MARS ($n = 65$), and the other group took the MARS on a computer screen ($n = 65$). MARS scores were analyzed to evaluate math anxiety levels of the two groups. Ashcraft & Faust sought to find out whether taking the MARS on the computer caused more anxiety than taking the paper version. The second investigation tested students on mental arithmetic problems online, to determine whether problem presentation on the computer screen would influence the anxiety levels for students differently from the paper-based version of the same content (Ashcraft & Faust, 1994).

Ashcraft & Faust (1994) found that the MARS scores for the groups in experiment one were within the expected range of scores for the MARS based on the normative data; but a statistically significant ($p < .05$) finding of higher scores on the MARS among the computer testing group compared to the paper testing condition indicated that the online presentation of the measurement tool might have raised anxiety.

In their second experiment, Ashcraft & Faust (1994) were aware that the presentation of the mental arithmetic condition on a computer could lead to an elevation in anxiety not related to math anxiety, so participants were split into four different conditions: 1) HMA students who took the MARS followed by the mental arithmetic condition, 2) HMA students who took the mental arithmetic condition followed by the MARS, 3) LMA students who took the MARS followed by the mental arithmetic condition, and 4) LMA students who took the mental arithmetic condition followed by the MARS (Ashcraft & Faust, 1994).

The order of presentation of the mental math task variable was not significant and did not affect response times. Ashcraft & Faust placed the MARS scores of participants into four groups based on math anxiety scores; group 1 had the lowest math anxiety scores, and group 4 had the highest math anxiety scores on the MARS. Ashcraft & Faust reported that group 1 consistently exhibited the fastest response times on the arithmetic conditions and group 3 exhibited the slowest, but the main effect of math anxiety was not significant. Ashcraft & Faust stated that all interactions of anxiety level, mental math task, and true/false responses were significant and that overall relations of the three factors were also significant; unfortunately, the researchers do not share a *p*-value for the level of significance. As with other similar research, Ashcraft & Faust reported that the math anxiety levels collected during the complex arithmetic conditions were higher than those collected during the simple arithmetic conditions; in addition, working memory was taxed by the more complex arithmetic conditions. Again Ashcraft & Faust failed to report *p*-values for these interactions, but do share that response time and math anxiety level analysis were non-significant. Clearly more research needed to be done to follow

up some of the findings with changes in the variables and conditions to explore the differences exhibited. This study, however, revealed that although there was an initial difference in MARS scores based on presentation modality, the research results were not significantly different due to the use of online presentation. Perhaps the manipulation of the order of the MARS testing and the math tasks to control for the online presentation led to skewed results.

Ashcraft and Kirk (2001) examined the relationship between working memory and math anxiety. The research utilized undergraduate psychology students ($n = 66$) from an urban university in one 90-minute session; participants were assessed on math anxiety, working memory, attitudes towards math, and computational skills. The researchers administered the short Mathematics Anxiety Scale (sMARS) to gather math anxiety scores and Salthouse and Babcock's (1990) computational span (C-span) and listening span (L-span) to measure working memory. The span tasks required students to simultaneously deal with comprehension or computation and storage of data for processing/recall in working memory (Ashcraft & Kirk, 2001).

Ashcraft and Kirk reported that high math anxiety participants demonstrated significantly ($p < .01$) lower scores on working memory than low math anxiety participants. The interaction between math anxiety and span type (C-span/L-span) was not significant, indicating that high math anxiety students showed a lower working memory in both mathematical- and language-based span tasks (Ashcraft & Kirk, 2001). After further multiple regression analysis, the researchers found that the lower scores in C-span tasks were significantly related to math anxiety, but the lower scores in L-span tasks were not significantly related to math anxiety (Ashcraft & Kirk, 2001). These

findings support separation of math anxiety from general anxiety in effect on performance; the conclusions can be drawn that that math anxiety lowers math problem-solving ability.

Findings from Ashcraft & Faust (1994), Ashcraft & Kirk (2001), Hopko et al. (1998) Ramirez et al. (2013), and Supekar et al. (2015) all used different methods, scenarios, populations, and samples in their efforts to study how math anxiety affects memory and performance. Their findings support Boaler's (2014) claims that stress and anxiety block working memory and prevents students from utilizing known math facts. Ramirez et al. (2013), found this phenomenon to be true for students as young as four years of age. Supekar et al. (2015) found significant findings for the relationship between math anxiety and memory in third-grade students. Ashcraft & Faust (1994), Ashcraft & Kirk (2001), and Hopko et al. (1998) found a similar result among college students; the math anxiety phenomenon appears to exist throughout the spectrum of an individual's learning development through adulthood.

College level research in math anxiety is prevalent due to the ease of recruiting students as participants, but researchers have transferred their focus onto younger students with a concentration on early elementary grades and transitions from elementary to middle school. Studies on math anxiety for high school students are not abundant, and even fewer studies exist on math anxiety suffered by at-risk students who are young adults trying to acquire a high school diploma. The findings from Young et al. (2012) and Supekar et al. (2015), along with research conducted by Blackwell et al. (2007), indicate a need for further research on reducing math anxiety and building positive math mindsets in students. Further research on how building a positive math mindset in at-risk

young adults would be a logical fit for further research based on past findings and the need for research in this area.

View of Math

According to Boaler (2015), mathematics has a huge image problem. Boaler (2016) observed the negativity that TV media shrouds around the topic of mathematics. She disapproved of the number of disparaging descriptions of mathematics her two teenage daughters were exposed to in television shows targeting the adolescent population. According to Boaler, “Math is conveyed as a really hard subject that is uninteresting, inaccessible, and only for ‘nerds’; it is not for cool, engaging people, and it is not for girls” (2016, p. xii). Although research studies have concentrated heavily on math anxiety and the impact of mindset in math education, studies on student views of mathematics as a discipline and content area are less prevalent and tend to be older. The studies on student views of math have focused primarily on gender and race influences (Rech, 1994) and span from elementary student participants (Cvencek, Meltzoff, & Greenwald, 2011), to middle school students (Midgley, Feldlaufer, & Eccles, 1989), to college students (Elliott, 1990).

In a 2011 study of students in grades 1-5 ($n = 247$) attending public and private elementary schools located in Seattle, Washington, Cvencek et al. (2011) paid volunteers \$10 to participate in a study self-reporting gender as male/female, math-gender stereotype, and math self-concept. Math-gender stereotype occurs when the content area of math is identified as better suited for one sex than another, typically male. The children were from upper- to middle-class families with grade level (grades 1-5) sample sizes ranging from 48-50; males and females were equally distributed across grade levels

(Cvencek et al., 2011). The study sample was solicited by mail sent to targeted schools. The students returning the consent form comprised the study sample, which was approximately 7% African-American, 10% Asian, and 83% White (Cvencek et al., 2011).

Cvencek et al. gave students an instrument measuring how each student associated himself/herself with math. The instrument was adapted from the Implicit Association Test (IAT) (Greenwald, McGhee, & Schwartz, 1998) to be appropriate for use with young children; utilizing pictures of male and female students on a computer screen, researchers verbally asked students whether a given word was a boy or a girl word. The researchers first had students sort names into boy and girl names and transitioned into words such as “reading” and “math,” having them select boy or girl categories. An IAT was modified by researchers to address math self-concept by requesting students to classify conditions as *me*, *not-me*, *math*, or *reading* words (Cvencek et al., 2011). A math-gender stereotype measurement tool using images from the Pictorial Scale by Harter and Pike (1984) asked questions such as “Which student likes math?,” then required students to choose a male or female image and then indicate whether that student liked math a little or a lot by clicking on a small or large circle.

Cvencek et al. reported statistically significant differences between males and females on the implicit IAT measure with male students associating math prompts as male compared to female students associating math as female ($p < .001$). This finding was supported by the self-report; males were more likely to choose their same-sex image as “liking to do math more” (Cvencek et al., 2011, p. 771) than female students ($p < .001$) (Cvencek et al., 2011). In this study, both genders associated math with boys more often than with girls.

On the math self-concept measurements, Cvencek et al. found that the implicit measurement instrument revealed statistically significant differences between males and females with males associating *math* with a male picture more frequently than females associated *math* with a female picture ($p < .01$). “On the self-report measure, boys identified more with a picture of a same gender character who was solving a math problem than did girls...($p < .01$)” (Cvencek et al., 2011, p. 771-772).

The research from Cvencek et al. revealed that math-gender stereotype and math gender identity issues are apparent as early as grades 1-2 with male students associating math with males significantly more often than grade 1-2 females associated math with female students ($p < .001$). This same trend held with the self-report measures. Male students in grades 1-2 chose male characters as liking to do math more than female students in grades 1-2 chose female characters ($p < .01$) (Cvencek et al., 2011). These findings were replicated in studies of successive grade levels studied ($p < .05$) (Cvencek et al., 2011). Results of this study support the need for educators to identify effective strategies supporting the importance of math in everyday life from an early age before gender identifications can become skewed.

In a study focusing on students transitioning from elementary to middle school (The Transitions at Early Adolescence Project), Midgley et al. (1989) completed a two-year study using questionnaires in their math classes during the fall and spring of participants' 6th grade elementary school year and the fall and spring of their 7th grade junior high school year. Participating students ($n = 1,301$) were 90% Caucasian and came from middle-income communities in twelve school districts in the southeastern region of Michigan (Midgley et al., 1989).

All participating students were tested during the fall of 7th grade using the Michigan Educational Assessment Test (MEAP), a statewide exam in mathematics and reading. Participants were grouped into high or low-achievement levels based on their mathematics MEAP scores. Students placed in the high achievement groups showed mastery of at least 75% of the mathematics objectives on the MEAP. Students mastering less than 75% of the mathematics objectives on the MEAP were placed in the low-achievement group (Midgley et al., 1989).

Midgley et al. used Parsons's (1980) questionnaire to measure students' perceptions of the importance and usefulness of math as well as the intrinsic value of math. The questionnaire included a subscale score for student perceptions of student/teacher relationships, which was referred to as Teacher Support. Students were placed into four groups based on their mean scores on the Teacher Support subscale scores during the spring of their 6th and 7th grade years. "Repeated-measures multivariate analysis of variance (MANOVA) was used to test the effects of semester (fall vs. spring), school year (sixth vs. seventh grade), and the interaction of semester and school year for each of the dependent measures" (Midgley et al., 1989, p. 984).

Midgley et al. reported a number of statistically significant findings. The interaction of year change and perceived teacher support was significantly associated with the reported intrinsic value of math ($p < .001$) and with the reported usefulness/importance of math ($p < .001$). Students' math intrinsic values were significantly correlated across the grade levels showing a decline from 6th grade to 7th grade ($p < .001$). Students' score differences for math usefulness/importance value were significantly related from 6th to 7th grade ($p < .001$) with a decrease in reported

usefulness/importance of math. “As predicted, students whose teachers are perceived to be high in support both years show very little change in their valuing of math across the transition” (Midgley et al., 1989, p. 984). Students who scored low on the teacher support measure demonstrated a significant decline over time in their value of math ($p < .001$). The interaction of semesters and perception of teacher support revealed statistically significant findings for the intrinsic value of math ($p < .05$) and the useful/importance of math ($p < .001$) (Midgley et al., 1989). Students’ views of how supportive their teachers were from 6th grade into 7th grade significantly related to how they perceived the intrinsic value and usefulness/importance of math. This view of teacher support by students can lead to either a strong value of the importance of math or a decreasing value for the subject; clearly, elementary school years are important times to support positive attitudes about mathematics and learning.

Interestingly, there was no significant interaction between grade level and gender; however, there was a statistically significant interaction between student perception of the value of math and student math achievement as measured by the MEAP ($p < .05$) (Midgley et al., 1989). These findings indicated that students’ views of the importance of math are significantly related to their math achievement. The relationship between math achievement and the students’ perceived importance of math was not significantly different for males and females. These findings provide strong evidence of the need for improving student perceptions of the importance of math and teacher support leading to student achievement in math.

In 1994, Rech conducted a study of the math attitudes of Black students in the 4th grade ($n = 133$) from three elementary schools and in the 8th grade ($n = 118$) from one

junior high school in a large Midwestern district. The populations of Black students at the elementary schools ranged from 61.5% to 77%; approximately 40% of the junior high student enrollment was Black. Rech utilized subscales from the Mathematics Attitude Inventory (MAI) by Sandman (1980) to measure the math attitudes of participants on 1) Anxiety Toward Math, 2) Value of Math in Society, 3) Self-Concept of Math, 4) Motivation in Math, 5) Enjoyment of Math, and 6) Perception of Math Teacher. Students' scores on the California Achievement Test (CAT) were gathered to measure students' academic achievement in language arts, reading, and math.

All students at the participating schools took the MAI and CAT, and Rech (1994) compiled the scores for the Black students. "Multivariate and univariate tests were performed to investigate the differences of group means between and among factors" (Rech, 1994, p. 214). Groups were generated according to composite academic achievement, grade level, and gender. Due to small cell size, the researcher split students into high and low academic achievement groups. Rech (1994) used a three-way multivariate analysis of the groups: gender (male/female), grade-level (4th/8th), and academic achievement (high/low) to determine differences between the groups using the six math attitudes as dependent variables.

Rech (1994) found a statistically significant relationship between academic achievement and grade-level ($p < .05$). The data illustrated no statistical significance between gender and grade level or academic achievement. No significant three-way correlations of the independent variables of gender, grade-level, and academic achievement were observed.

The univariate analysis revealed a statistically significant relationship between gender and enjoyment of math and self-concept of math ($p < .008$), with higher scores by males than females. Table 3 below presents a summary of the relationships revealed between gender and views of math from the study.

Table 3

Relationships of Gender on Math Attitude Measures (n = 251)

Variable	<i>f</i> -value	<i>p</i> -value
Self-Concept	7.860	.006*
Enjoyment of Math	7.886	.005*

$p < .0083$ (Rech, 1994, p. 215)

Further analyses of the significant relationship between overall academic achievement and grade-level ($p < .05$) revealed significant correlations with Perception of Teacher ($p < .001$), Anxiety in Math ($p < .001$), Self-concept in Math ($p < .005$), and Enjoyment of Math ($p < .001$). See Table 4 for a summary of the interactions of grade level and math attitudes. This study showed strong and significant relationships between student attitudes towards math and academic achievement in both elementary and junior high students and among both males and females. This study corroborates the relationships between math anxiety and students' academic achievement (Ashcraft & Faust, 1994; Clark, 2004; Hopko et al., 1998; Hopko et al., 2002; Ramirez et al., 2013; Supekar et al., 2015; Young et al., 2012).

Table 4

Relationships of Grade Level and Academic Achievement on Math Attitudes (n = 251)

Variable	<i>f</i> -value	<i>p</i> -value
Perception of Teacher	17.56	.001**

Anxiety in Math	12.07	.001**
Value of Math	6.04	.015*
Self-Concept	8.25	.004**
Enjoyment of Math	10.90	.001**
Motivation in Math	3.96	.048*

* $p < .05$ ** $p < .0083$ (Rech, 1994, p. 216)

The interaction of grade level was statistically significant for high-achieving students on the four measures of math attitudes: 1) Enjoyment of Math ($p < .001$), 2) Perception of Teacher ($p < .001$), 3) Self-concept in Math ($p < .002$), and 4) Math Anxiety ($p < .01$). Rech (1994) also found statistically significant relationships between grade level of low achieving students and Math Anxiety ($p < .015$). Table 5 depicts the data for simple interaction effects on grade level and academic achievement on variables of mathematics attitudes measures. The data revealed that high achieving 8th-grade students scored lower on the math attitudes subscales than the high-achieving 4th graders. This finding supports further investigation of changes in views of math and math anxiety as students move into higher grade-levels. Students in this study apparently reduced their appreciation for math as they moved into the second half of their education.

Table 5

Relationships of Academic Achievement on Math Attitudes (n = 251)

Variable	Group	SS	f-value	p-value
Perception of Teacher	Lower Achieving	49.05	2.71	.101
	Upper Achieving	279.79	15.47	.001**
Anxiety in Math	Lower Achieving	79.31	6.04	.015*
	Upper Achieving	88.06	6.71	.010*
Self-Concept in Math	Lower Achieving	4.99	0.42	.518
	Upper Achieving	117.00	9.85	.002*
Enjoyment of Math	Lower Achieving	22.40	1.05	.307
	Upper Achieving	523.47	24.52	.001**

* $p < .05$ ** $p < .0083$ (Midgley et al., 1989, p. 216)

Elliott (1990) studied a random sample of basic algebra students ($n = 140$) enrolled in their first college math course in one of seven Maine university campuses. Students were classified as traditional or nontraditional based on age; students 18-to-20-years-of-age were classified as traditional, and students over 25 years-of-age were labeled nontraditional (median age was 31) (Elliott, 1990). The sample was comprised of four equal-sized groups ($n = 35$): traditional females, traditional males, nontraditional females, and nontraditional males.

The researcher used the Causal Attribution Scale adapted from Fennema, Wolleat, & Pedo (1979) to measure students' perceptions of origins of failures and accomplishments in math. The subscales in this instrument included: "Success Due to Ability, Failure Due to Lack of Ability, Success Due to Effort, Failure Due to Lack of Effort, Success Due to Task Ease, Failure Due to Task Difficulty, Success Due to Luck, and Failure Due to Luck" (Elliott, 1990, p. 161).

Elliott (1990) used the Mathematics Confidence Scale adapted from Fennema & Sherman's 1976 Confidence in Learning Mathematics Scale. This instrument was developed to quantify level of confidence of individuals in their abilities to perform and learn in math (Elliott, 1990). An exemplar item for this tool was "Mathematics always has been one of my most difficult courses" (Elliott, 1990, p. 161).

To measure students' perceptions of the usefulness of math in their lives, Elliott (1990) used a revised version of the Perceived Usefulness of Mathematics Scale (Fennema & Sherman, 1976). Students were scored on two domains, Usefulness Content and Usefulness Goal. Usefulness Content measured how students viewed the usefulness of math subject matter; an exemplar for this domain was "Using mathematics will be

necessary in earning my living” (Elliott, 1990, p. 162). The second domain of Usefulness Goal measured how closely math applied to supporting their need to reach a desired goal in life. A sample item for Usefulness Goal was “Passing my math courses is important in achieving my career goal” (Elliott, 1990, p. 162).

To measure student math achievement, Elliott (1990) developed two research instruments, the Pretest for Mathematics Achievement exam measuring arithmetic and algebra and the Posttest for Mathematics Achievement measuring content covered in the basic algebra course in which students were enrolled. All students took the Pretest for Mathematics Achievement exam at the beginning of the semester in their basic algebra course. The post-test was administered at the end of the course and addressed standards addressed in the basic algebra course. There were no significant differences in scores on these math pre-test and post-test scores between the two groups; nontraditional students’ math achievement was similar to the traditional students (Elliott, 1990).

To study the interactions of pre-test math achievement and affective predictor variables on the independent variable of the post-test math achievement scores, Elliott (1990) used multiple regression. Elliott (1990) reported that for female nontraditional students, the Success-Luck score on the Perceived Usefulness of Mathematics Scale was the strongest predictor of changes from pre- to post-test on the math achievement dependent variable ($p < .05$). High Success-Luck scores correlated with higher math achievement. For male nontraditional students, the Failure-Effort score was significantly related to math achievement changes pre-test to post-test ($p < .05$). None of the affective predictor variables on the Mathematics Confidence Scale were significant predictors of math achievement pre- to post-test for male or female traditional students. The pretest

scores for all student groups were statistically significant predictors of student math achievement on the post-test ($p < .05$). Among the nontraditional students, there were no significant predictors of Usefulness Content or Usefulness Goal and math achievement, diverging from what the researcher had hypothesized. An important takeaway from Elliott's (1990) research was that nontraditional students who began the course at a disadvantage with lower pre-test performances were able to perform at a similar rate on the post-test as traditional students. These nontraditional students mirror some of the same obstacles in their lives as at-risk high school students. Many at-risk and nontraditional students have spent time away from academics and have returned to continue their education. Elliott's (1990) findings support the need for more research to determine how the affective domain interacts with math academic progress in students who stray from a continuous path in their education.

Summary

This review of literature has summarized relevant studies of math mindset, math anxiety, and view of math. Relationships among these phenomenon and how they are related to math achievement were highlighted for the purpose of showing the importance of further research on math achievement of at-risk young adult students and math mindset, math anxiety, and view of math.

Chapter 3: Method

The purpose of this research study was to determine whether growth mindset instruction in math led to changes in math mindset, math anxiety, and view of math in 18-22-year-old young adult students. This chapter explains methods utilized in this quantitative study, detailing the research context, research participants, instrumentation used for data collection, procedures for collection and data analysis, and an overall summary of the methodology.

Study Sample and Context

The sample for the study consisted of students from five Florida public charter schools serving an at-risk population. The term “at-risk” refers to students who are not on target to graduate with their original cohort group; many have dropped out of the school system in the past. The enrollment of the five targeted schools ranged from 125 to 275 students. Two schools were randomly assigned by the researcher to the experimental group sample, and three schools were randomly assigned to the control group sample. The schools were located in four different Florida districts and drew their enrollment from urban, suburban, and rural communities. The study targeted students aged 18-to-22 enrolled in any math course in the fall semester of the 2016-2017 school year. The experimental group participants were 18-to-22-year-old students selected from two of the campuses, one suburban and one urban. The control group consisted of 18-to-22-year-old students enrolled in math courses from three campuses, one rural, one suburban, and one urban.

Instrumentation

The pre- and post-test survey instrument served as the dependent variable in this study and was used to gather data on perceptions of math mindset, math anxiety, and view of math from both the experimental and control groups. The instrument was designed by the researcher with mentoring and input from Cathy Williams, Executive Director of YouCubed from Stanford University. The survey/test was reviewed for validity by three experts in mathematics, four experts in education, and two experts in research. After approval by SEU's IRB, the survey/test was piloted (n = 53) at two school campuses that served the same at-risk student population from which the experimental and control populations were derived. The pilot campuses were public charter schools that served at-risk students from 16-to-22-years-of-age with an overall enrollment of 125-275 students. The school board and principals from the piloting campuses granted permission for the administration of the surveys/tests before the pilot. The pilot results demonstrated that the instrument adequately measured the targeted math domains and led to further refinement of the survey/test instrument.

The final version of the pre/post-test survey included 20 survey items (see Appendix A). The first three items addressed the gender of the participants, how many math courses they had successfully completed, and their assigned student ID numbers. The remaining 17 items addressed three domains: 1) Math Mindset (six items), 2) Math Anxiety (five items), and 3) View of Math (six items). A Likert scale was used to measure perceptions of the three domains and were the same for the 17 items: 6) Strongly Agree, 5) Agree, 4) Somewhat Agree, 3) Somewhat Disagree, 2) Disagree, and 1) Strongly Disagree (Appendix B displays the survey/test items by domains).

The online survey/test was created and delivered to participants via SurveyMonkey. Students accessed the pre- and post-tests through a password-protected link in their learning management system (LMS). The math teacher at each site provided instructions on completing the surveys after the oral consent information was shared by the teacher from a script.

Intervention

The researcher developed the curriculum for the math mindset intervention in conjunction with a mentor who was the executive director of YouCubed, an online website sponsored by Stanford University to share research-based educational practices and curriculum resources for mathematics education.

The experimental math mindset curriculum included a minimum of five hours of face-to-face learning activities focused on instilling in students the importance of mindset, problem-solving challenges, and explorations in mathematics. Teachers who conducted the curriculum were instructed not to praise students for getting answers correct nor to tell them that they were smart because they figured out an answer or solution; instead, teachers were directed to praise students for sharing errors they made when attempting solutions and persevering through difficult problems. The initial sessions of the curriculum focused on the research behind mindset and growth in brain synapses through short video clips, discussions, presentations, and engaging activities. Interactive math investigations comprised the core of the experimental curriculum with built-in collaboration among peers and informal assessments of students' understanding. The activities were structured to allow flexibility of processing time and additional

exploration as needed by individual students. Math content in the lessons focused on key areas of numeracy and algebraic reasoning to support state standards assessed in Florida.

Students in the experimental group attended their regular math classes on days when the experimental intervention was not scheduled. The experimental group participated in their regular mathematics instruction and test preparation activities; however, the experimental curriculum replaced the normal math instruction on the scheduled days. The control group participants attended their normal math classes and participated in no additional intervention. Apart from the intervention of the experimental group, the mathematics curriculum at all five campuses was the same and included regular mathematics instruction and test preparation activities presented through a blend of online and face-to-face methods.

The math teachers of the experimental treatment received training on proper implementation of the growth mindset intervention treatment activities and instructional techniques. Training included lesson plans, specific activities, instruction on mindset, and instruction on praise. Teachers were instructed to encourage students not to fear making mistakes, but to feel secure in math exploration and skill building. The instructors of the experimental treatment were directed not to praise students for correct answers or to tell students that they were smart. Instead, teachers were trained to praise students for hard work and perseverance. Special praise focused on students' willingness to share mistakes made in attempts to solve problems. No specific training was provided to the math teachers of the control group with regard to math curriculum or to praise.

Participants of the experimental treatment engaged in one hour of mindset instruction and four hours of math activities designed to support awareness of the

importance of hard work and mindset in developing their mathematics abilities. Assessment in experimental sessions consisted of responses to mathematical problem-solving scenarios that demonstrated understanding. Most situations allowed for individual processing as part of a pair or small group. Students had the freedom to continue working on problems after the session timeframe concluded. No time limits were imposed on task completion, but there were assigned times during which the entire group moved from one task to the next. The experimental treatment's implementation was observed throughout the sessions by the researcher to ensure integrity and level of implementation of the curriculum. The researcher remained a neutral and passive observer. The classroom teachers conducted all activities during the treatment implementation.

Data Collection

The researcher obtained permission to conduct the study from the five schools' school boards and principals. Permission was also granted by SEU's Institutional Review Board to collect data for this research study from the targeted groups of the public charter schools.

Participants assigned to both the experimental and control groups took the survey pre- and post-test to measure perceptions of math mindset, math anxiety, and view of math. The surveys were administered electronically at the students' campuses in their math classrooms during math class (control group) or the experimental sessions (experimental group). The math teachers assigned all students in the experimental and control groups a student identification number before administering the surveys; the

number was used to match the pre- and post-test scores and to gather demographic information.

Experimental group participants who completed the minimum five hours of experimental treatment were asked to complete a post-test after the intervention. Data from the experimental group among students who did not complete at least five hours of the training were not included in the data analysis.

All control group participants were asked by their math teachers to complete the pre- and post-test surveys measuring perceptions of math mindset, math anxiety, and view of math at the same approximate time of the school year as the experimental group. Only control group participants who completed both the pre- and post-test were used in the data analysis.

Analysis Methods

Demographic data on gender and number of successfully completed math courses were compiled from the students' self-reported pre/post-tests. The assigned ID numbers were used to pair pre- and post-test survey items for the experimental and control groups; all submissions that did not have a matched pair were omitted from analysis.

Because some test items were designed in a positive direction and some were designed in a negative direction (see Appendix B), test responses were re-coded to enable comparisons between the experimental and control groups by item and by domain. Three test items in the Math Mindset domain (items 3, 15, and 18) and one item in the View of Math domain (item 13) were re-coded as reverse response values; therefore, an initial item response of 6 became a 1, 5 became a 2, and so forth. For example, item 3 in the Math Mindset domain states "My math intelligence can be changed." If a student

responded with a 6 (strongly agree), then the 6 was re-coded by the researcher as a 1 (strongly disagree) to align with the test's overall coding protocol. As a result of the mixing of positive and negative item stems, interpretation of the survey/test results was complex. By design, a decrease in response values in Math Mindset indicated an increase in positive math mindset and a decrease in fixed math mindset tendencies. In the Math Anxiety domain, a decrease in response values was interpreted as a decrease in math anxiety. Similarly, a decrease in response values in View of Math implied a decrease in rigid and inflexible perceptions of math as a discipline.

To assess internal consistency and any differences on the pre-test between the treatment group and the control group responses, Cronbach's alpha was used for comparisons. A t-test of independent samples was conducted comparing mean values of the pre- and post-test scores on each of the domains (Math Mindset, Math Anxiety, and View of Math) for the experimental and control groups. In addition, the total composite scores across all items from pre- to post-test of the control and experimental groups were compared using t-tests of independent samples. Cohen's *d* value was used to determine the effect size of *t*-values for the composite scores, the experimental score gains, and the control group gains from pre- to post-test.

Summary

This quantitative study assessed differences in math mindset, math anxiety, and views of math among 18-22-year-old young adult at-risk students after five hours of experimental math curriculum that focused on growth mindset in mathematics. The research design of this study was randomly assigned, pre/post-test control group design.

Experimental and control groups were compared using t-tests of independent samples. The mean scores of the pre- and post-tests of the control and experimental groups were compared using t-tests of independent samples on the composite scores and the domains of Math Mindset, Math Anxiety, and View of Math. Effect size was determined using Cohen's d value. Results of the study are presented in chapter 4.

Chapter 4: Results

The purpose of this study was to determine whether instruction in growth math mindset led to changes in math anxiety, perceptions of math, and perceptions of math mindset in at-risk 18-22-year-old students. The independent variable in this study was the intervention consisting of participation in a five-hour supplemental course in math designed to develop a growth mindset in math. The dependent variables included pre- and post-test scores on a researcher-designed survey tool measuring the three domains (Math Mindset, Math Anxiety, and View of Math) and a composite score for the combined domains using a six-point Likert scale. The survey items included positively framed items and negatively framed items; for analysis purposes, the positively framed items were re-coded for domain comparison purposes. The following research questions and hypotheses were formally stated:

Research Questions

4. Does participation in mathematical mindset instruction affect young adults' perceptions of mindset towards math?
5. Does participation in mathematical mindset instruction affect perceptions of math anxiety levels of young adults?
6. Does participation in mathematical mindset instruction affect young adults' view of math as a discipline?

Research Hypotheses

H 1: There is a significant difference between changes in perceptions of math mindset of young adults who participate in mathematical mindset instruction compared to those who do not participate in mathematical mindset instruction.

H 2: There is a significant difference between changes in perceptions of math anxiety in young adults who participate in mathematical mindset instruction compared to young adults who do not participate in mathematical mindset instruction.

H 3: There is a significant difference between changes in view of math as a discipline among young adults who participate in mathematical mindset instruction compared to young adults who do not participate in mathematical mindset instruction.

Demographic Results

A total of 48 students in the experimental group and 63 students in the control group participated in both the pre- and post-surveys during the study. Table 6 shares the demographic information gathered from the surveys.

Table 6

Demographics of Gender and Math Credits Earned by Group

Group	Gender		0 math	1 math	2 math	3 math	4+ math
	Male	Female					
Treatment (n = 48)	56%	44%	27%	22.9%	23%	14.6%	12.5%
Control (n = 63)	54%	46%	12.7%	10%	44%	20.6%	12.7%

Both the experimental and control group participants were evenly distributed by gender. In the treatment group, 50% of the students had completed less than half of their required math courses required for graduation. In the control group, less than 25% of the

students had completed half of their math credits required for graduation. Interestingly, both groups had the same percentage of students who had passed all math courses required for graduation but who were enrolled in math test prep courses to help them pass the math graduation exit exam. The majority of the control group was clustered around 2-3 credits of math completed, while the treatment groups were clustered more evenly in the 0-2 credits of math completed. No missing data were evident in experimental or control participants' responses on the pre- and post-test items.

Internal Reliability

Cronbach's alpha was used to determine the internal consistency (reliability) of participants' responses to the pre-test, the post-test, and the composite scores of the survey. Table 7 depicts the results.

Table 7

Internal Reliability of Survey Items

Measure	Cronbach's alpha <i>Treatment</i> (<i>n = 48</i>)	Cronbach's alpha <i>Control</i> (<i>n = 63</i>)
Pre Test	.71***	.79***
Post Test	.82***	.79***
Composite	.84***	.88***

*** $p < .001$

One can see that all of the Cronbach's alpha values are high, and the results for the composite analyses indicated that the two groups (Treatment/Control) were very similar ($\alpha > .80$). These findings indicate that the instrument (survey) for this study demonstrated good reliability.

Pre-test Comparisons

Pre-test survey scores for experimental and control groups were analyzed using a t-test of independent samples to determine whether there were any significant differences between the experimental and control groups. Table 8 depicts the results of the analysis.

Table 8

Pre-test Comparison of Treatment/Control Groups

Treatment/Control	Mean Difference	<i>t</i>	ES(<i>d</i>)
Pre-test	0.03	0.24	0.35

The mean score difference of the pre-test scores of the treatment group and the control group were not significant ($p = .81$). The magnitude of difference in the mean scores between the two groups was small ($d = .35$), meaning that the two groups were not significantly different at the beginning of the research. This finding indicated that any significant changes in the differences between pre- and post-test scores between the experimental and control groups were a result of the experimental treatment.

Post-test Comparisons

The post-test scores for the treatment and control groups were analyzed using a t-test of independent samples and Cohen's *d* to determine differences between the experimental and control groups. Table 9 depicts the results.

Table 9

Post-test Comparison of Treatment/Control Groups

Treatment/Control	Mean Difference	<i>t</i>	ES(<i>d</i>)
Post-test	0.40	3.17***	0.61

*** $p = .002$

The findings of the differences in the post-test scores of the two groups

demonstrates that participation in five hours of the experimental treatment instruction in math mindset significantly impacted student changes in positive perceptions of Math Mindset, Math Anxiety, and View of Math. The magnitude of difference in the mean scores between the two groups was moderate ($d = .61$) for this sample of students.

Composite Pre/Post Comparisons

The researcher conducted a composite evaluation of the overall impact of the experimental treatment in math mindset instruction on students' perceptions of math across all survey items using a t-test of independent means. Table 10 depicts the results.

Table 10

Composite Pre-test to Post-test Differences by Group

Group	\bar{x}		SD		Mean Difference (Pre/Post)	t	ES(d)
	Pre	Post	Pre	Post			
Treatment	3.94	3.46	0.55	0.69	0.48	5.00***	0.77
Control	3.91	3.86	0.67	0.63	0.05	1.42	0.06

*** $p < .001$

The post-test scores for the treatment group on the composite survey items were significantly different from the pre-test scores, while the post-test scores for the control group were not significantly different from the pre-test scores. The reader will note that the decreased scores on the post-test indicated positive changes in perceptions of math due to the re-coding of positive and negative survey items as described in chapter 3.

The previous finding that the pre-test scores were not significantly different (Table 3), combined with these results, strongly supports the effectiveness of five hours of experimental math mindset instruction in producing significant changes in the treatment group's responses across all three domains under study (Math Mindset, Math

Anxiety, and View of Math). Results of the Cohen’s d analysis indicated a large effect size for changes from pre- to post-test for the treatment group and a small effect finding pre/post-test for the control group.

Experimental Group Domain Effects

To analyze the impact of the experimental treatment in math mindset instruction in the domains addressed on the survey, a t-test of dependent samples was conducted to compare pre-test scores to post-test scores for the treatment group. Cohen’s d was conducted to examine the effect size of the impact of the experimental treatment in math mindset instruction in each of the three domains (Math Mindset, Math Anxiety, and View of Math). Table 11 shares the results of the analysis.

Table 11

Treatment Group Pre-test to Post-test Comparison by Math Domain (n = 48)

Domain	Pre Test Mean (SD)	Post Test Mean (SD)	Mean Difference (Pre Test/Post Test)	<i>t</i>	ES(<i>d</i>)
Math Mindset	3.20 (0.71)	2.61 (0.79)	0.59	4.64***	0.79
Math Anxiety	4.36 (1.23)	3.89 (1.25)	0.47	3.08***	0.38
View of Math	4.32 (0.48)	3.97 (0.73)	0.35	4.10***	0.57

****p* < .001

The mean scores in all three domains decreased for the treatment group from the pre-test to the post-test. Due to the re-coded survey data, a decrease in response values on the post-test in Math Mindset indicated a decrease in fixed math mindset tendencies and/or an increase in positive math mindset. A decrease in the Math Anxiety domain response values indicated a decrease in math anxiety. A decrease in View of Math domain response values implied a decrease in rigid and inflexible perceptions of math as a discipline. These significant decreases in mean values are a strong indication that the

treatment students' reported increase in positive Math Mindset, decrease in Math Anxiety, and improved View of Math was the result of the experimental math curriculum intervention.

Research Results by Question and Hypothesis

The section which follows discusses the research study results and addresses the stated questions based on the findings.

1. Does participation in mathematical mindset instruction affect young adults' perceptions of mindset towards math?

H_a 1: There is a significant difference between changes in perceptions of math mindset of young adults who participate in mathematical mindset instruction compared to those who do not participate in the mathematical mindset instruction.

Table 12 displays results of the t-test of independent samples and Cohen's d used to compare the mean differences between treatment and control groups' perceptions of Math Mindset.

Table 12

Pre-test/Post-test Comparisons of Math Mindset by Groups

Group	Pre-test	Post-test	Mean Difference (Pre/Post)	<i>t</i>	ES(<i>d</i>)
Treatment	3.20	2.61	0.59	4.64***	0.79
Control	3.39	3.35	0.04	0.56	0.05

****p* < .001

The significant mean score difference in students' responses from the pre-test to post-test indicated a significant improvement in the treatment group's positive math mindset and/or a decrease in their fixed math mindset. The control group scores showed no significant difference. Cohen's d revealed that the magnitude of difference in

treatment students' perceptions of mindset towards math from the pre-test to the post-test was large ($d = .79$). This finding supports the hypothesis that five hours of experimental math mindset instruction contributed to the significant increase in positive math mindset of the treatment group.

Since the mean score difference in treatment group students' perceptions from the pre-test to the post-test on the Math Mindset domain was found to be statistically significant ($p < .001$), and the mean score difference in control group students' perceptions from the pre-test to the post-test condition of the study for the Math Mindset domain was found not to be significant, the alternative hypothesis (H_a) is retained.

2. Does participation in mathematical mindset instruction affect math anxiety levels of young adults?

$H_a 2$: There is a significant difference between changes in perceptions of math anxiety in young adults who participate in mathematical mindset instruction compared to young adults who do not participate in mathematical mindset instruction.

Table 13 displays results for the t-test of independent samples and Cohen's d used to compare differences between treatment and control students' perceptions of Math Anxiety.

Table 13

Pre-test/Post-test Comparison on Math Anxiety by Groups

Group	Pre-test	Post-test	Mean Difference (Pre/Post)	t	ES(d)
Treatment	4.36	3.89	0.47	3.08***	0.38
Control	3.99	3.90	0.09	2.30	0.32

*** $p < .001$

The results for the two groups are significantly different. The significant ($p < .001$) mean score difference in students' responses from the pre-test to post-test of the treatment students indicated a significant reduction in levels of math anxiety. The control group scores showed no significant difference. Cohen's d estimated the magnitude of difference in treatment students' perceptions of math anxiety from the pre-test to post-test as moderate ($d = .38$). This finding supports the conclusion that five hours of experimental math mindset instruction likely contributed to a moderate decrease in the reported math anxiety of the treatment group students.

Since the mean score difference in the treatment group's perceptions from the pre-test to the post-test in the Math Anxiety domain was statistically significant ($p < .001$) and the control group's perceptions of Math Anxiety were not significant, the alternative hypothesis (H_a) is retained.

3. Does participation in mathematical mindset instruction affect young adults' perceptions of math as a discipline (view of math)?

H_a 3: There is a significant difference between changes in perceptions of math as a discipline of young adults who participate in mathematical mindset instruction compared to young adults who do not participate in mathematical mindset instruction.

Table 14 contains results for the t-test of independent samples and Cohen's d used to compare differences between the treatment and control groups' perceptions of View of Math.

Table 14

Pre-test/Post-test Comparison on View of Math by Groups

Group	Pre-test	Post-test	Mean Difference (Pre/Post)	<i>t</i>	ES(<i>d</i>)
Treatment	4.32	3.97	0.35	4.10***	0.57
Control	4.44	4.43	0.01	0.08	0.01

*** $p < .001$

The significant difference in experimental and control groups' responses from the pre-test to post-test indicated a significant improvement in the treatment group's overall view of math as a discipline. The control group's scores showed no difference. Cohen's *d* estimated the magnitude of difference in treatment students' perceptions of view of math from the pre-test to the post-test as moderate ($d = .57$). This finding supports the conclusion that five hours of experimental math mindset instruction contributed to a decrease in rigid and inflexible perceptions of the treatment group students' view of math as a discipline compared to the control group and that the effect size was moderate.

Since the mean score difference in treatment group students' perceptions from the pre-test to the post-test condition of the study for the View of Math domain was found to be statistically significant ($p < .001$) and the mean score difference in the control group's was found not to be significant, the alternative hypothesis (H_a) is retained.

Analyses by Survey Item

A t-test of dependent means was conducted to identify the survey items within each domain that resulted in significant changes from pre-test to post-test among experimental group participants. Table 15 displays the results, and Appendix A shows the text of each survey item. Appendix B lists the text of the survey items by domain.

Table 15

Treatment Group Survey Item Pre-Post Comparisons (n = 48)

Domain	Survey Item	Pre \bar{x}	Post \bar{x}	Mean Difference	t	ES(d)
Mindset	3	2.521	1.958	0.56	3.58***	.58
Mindset	6	4.729	3.729	1.00	4.61***	.75
Mindset	9	3.354	2.792	0.56	2.17*	.35
Mindset	15	2.792	2.104	0.69	3.26***	.54
Anxiety	8	4.521	3.667	0.85	3.76***	.53
Anxiety	11	4.271	3.625	0.65	2.68**	.40
Anxiety	14	4.75	4.188	0.56	3.40***	.41
View	7	4.979	4.146	0.83	4.08***	.69

* $p < .05$ ** $p < .01$ *** $p < .001$

Survey items 3, 6, 9, and 15 revealed significant differences between pre-test and post-test in the domain of Math Mindset of the treatment group. These Math Mindset items measured the students' beliefs in their ability to grow their math abilities and math knowledge base. The four Math Mindset items significant for the treatment group are listed below in numeric order.

- My math intelligence can be changed.
- Some people do well at math and others do not, no matter how hard they try.
- There is a limit to what I can learn in math.
- I can understand math concepts better if I keep exploring when I miss problems.

The largest effect size in this domain was associated with item 6, "Some people do well at math and others do not, no matter how hard they try." The researcher conducted an informal follow-up interview session with nine randomly selected experimental participants two months after the intervention was completed. The interviews revealed that all the students agreed that their math intelligence could be changed. The significant

change in Math Mindset in the treatment groups' perceptions for these items supports the impact of the five-hour experimental treatment.

Survey items 8, 11, and 14 revealed significant differences from pre- to post-test in the domain of Math Anxiety for the treatment group. These Math Anxiety items measured the students' generalized perceptions of their personal math anxiety levels. The three significantly different Math Anxiety items of the treatment group are listed below.

- I get nervous when performing math work.
- I worry I will not get the grades I need in math.
- I get very stressed about passing high-stakes mathematics tests.

The largest effect size in the Math Anxiety domain for the treatment group was moderate and associated with item 8, "I get nervous when performing math work." The results of the treatment groups' responses supported the conclusion that just five hours of the experimental curriculum and instruction significantly lowered math anxiety levels among at-risk students. Typically, these students have faced years of adverse experiences in math classrooms. Curriculum and instructional techniques that build confidence in mathematics provides the tools at-risk students need to reach graduation and career goals. Survey item 7 revealed a significant difference from pre- to post-test in the domain of View of Math for the treatment group. The item that was significant for the treatment group was, "Math problems usually have a specific way they must be solved." Item 7 exhibited the second largest effect size for the treatment group. The treatment group reported better understanding of diverse ways to solve math problems.

For comparative purposes, a t-test of dependent means was conducted on the survey item responses pre- to post-test for the control group. The results are shown in Table 16. Interestingly, item 4 from the View of Math domain was the only survey item demonstrating a significant difference from pre- to post-test ($p < .05$). That item stated, “Math problems usually involve specific procedures that must be followed.” This item was not significant among the treatment group, supporting the positive changes within the treatment group related to more flexible thinking about math.

Table 16

Control Group Survey Item Pre/Post Comparison (n = 63)

Domain	Survey Item	Pre \bar{x}	Post \bar{x}	Mean Difference	t	ES(d)
View	4	5.08	4.81	0.27	2.34*	.31

* $p < .05$

Chapter Summary

The study was conducted to evaluate the impact of mathematics mindset curriculum and instruction on at-risk young adult students’ perceptions of three domains of mathematics (Math Mindset, Math Anxiety, and View of Math). The researcher designed the curriculum and a survey tool measuring the domains under study that was administered by classroom teachers to two groups (experimental and control). Comparisons of survey results between and within the two groups were conducted to determine the overall impact of the curricular intervention on perceptions of math for each of the three math domains and overall composite perceptions. Preliminary analyses depicted an intact data set with very high internal consistency (reliability $\alpha > .80$) of student responses to survey items among both the treatment and control groups.

Table 17 contains a summative description of the composite findings and results related to the research questions and hypotheses 1, 2, and 3 for the study's treatment group.

Table 17

Treatment Group Summative Findings Pre/Post

Measure	Mean Difference	<i>t</i>	ES(<i>d</i>)
Composite (All Domains)	0.48	5.00***	0.77
Math Mindset Domain	0.79	4.64***	0.79
Math Anxiety Domain	0.47	3.08***	0.38
View of Math Domain	0.35	4.10***	0.57

*** $p < .001$

The mathematical mindset intervention exerted a statistically significant impact on students' perceptions of math in a composite analysis of all 17 survey items ($p < .001$); the composite survey approaches a large effect size ($d = .77$). Conversely, the finding for the control group was not significant ($p = .18$) and revealed a very small magnitude of effect ($d = .05$). These findings indicate that five hours of experimental math mindset instruction positively impacted students' perceptions of math mindset, math anxiety, and view of math.

Of the math domains assessed in the study, all three manifested significant differences between the experimental and control groups pre- to post-test. Of the study's three domains, Math Mindset manifested the highest effect size ($d = 0.79$) with a significant change ($p < .001$) from the pre-test to post-test on the perceptions of students in the treatment group. None of the three math domain scores of the control group revealed significant changes in students' perceptions from the pre-test to the post-test. These results provide strong evidence that participation in five hours of experimental

math mindset instruction led to improvement in student participants' perceptions in each of the three domains (Math Mindset, Math Anxiety, and View of Math).

Four survey items revealed significant increases in the treatment students' pre- to post-test scores in the domain of Math Mindset. Three survey items revealed significant increases in the treatment students' pre- to post-test scores for the domain of Math Anxiety. One survey item revealed significant increases in the treatment students' pre- to post-test scores for the domain of View of Math, but this item was not significant among the control group students. One survey item revealed significant increases in the control students' pre- to post-test scores for the domain of View of Math, but this item was not significantly different for the treatment group students.

The results of this study point to the effectiveness of the math mindset intervention on positive changes in young adults' perceptions of math mindset, math anxiety, and view of math. Discussion of these results may be found in chapter 5.

Chapter 5: Discussion

As previously stated, this study was conducted to explore the relationship between instruction in growth mindset and changes in math mindset, math anxiety, and view of math of at-risk 18 to 22-year-old students. This chapter discusses the educational problem addressed by the research and the global results from the analyses. Recommendations for future research conclude the chapter.

Research Design and Instrumentation

This study evaluated the impact of five hours of instruction on growth mindset combined with math activities that promoted exploration, problem-solving, and concept development. The curriculum utilized in the experimental treatment proved to be highly effective in all three targeted domains of math mindset, math anxiety, and view of math among at-risk young adult students. The math curriculum significantly increased the participants' growth mindset of math, lowered their levels of math anxiety, and improved their views of math as a discipline.

The survey tool designed by the researcher to measure students' perceived math mindset, math anxiety, and view of math was reliable and useful for collecting the targeted data. The tool was easily accessed by students and took only five to ten minutes to complete. The survey tool proved to be a reliable instrument available for other teachers and researchers to utilize to assess students' math perceptions and the impact of different math curricula and instruction among secondary students and adults. Currently, no other valid measurement tool is available that measures all three math domain areas.

The availability of this simple and concise instrument opens the doors for all high school math educators to evaluate the impact of any curriculum or instructional strategies implemented in math instruction.

The study's randomly assigned treatment and control groups were not significantly different on the pre-survey composite scores, allowing for controlled comparisons between the changes in perceptions of the groups in the three domains (Math Mindset, Math Anxiety, and View of Math) and overall composite perceptions of math. The normal math curriculum that all schools in the study used was the same and therefore was a controlled variable. True experimental designs are rarely accomplished in public school settings. This study provides definitive evidence that even a small amount of time addressing growth mindset in math instruction is beneficial for at-risk young adults.

All three domains of math mindset, math anxiety, and view of math improved significantly from pre- to post-test of the survey among the treatment group. However, the Math Mindset domain of the survey revealed the most prominent changes in the treatment groups' reported perceptions from pre- to post-test. Four of the six survey items in the Math Mindset domain demonstrated significant decreases in mean scores, indicating positive changes in a growth mindset. The Math Anxiety domain also revealed a significant change in the treatment group's perceptions of math anxiety from pre- to post-test. Three of six survey items in the math anxiety domain demonstrated significant decreases in the mean of re-coded scores, providing evidence of the impact of five hours of experimental instruction in math mindset in the Math Anxiety domain. These results support the use of math mindset instruction in the education of young adult at-risk

students. Survey item 7 from the View of Math domain exhibited the second largest effect size for the treatment group stating, “Math problems usually have a specific way they must be solved.” The treatment group responses after the intervention indicated that they recognized the value of diverse ways to solve math problems. The impact of the intervention on math education and mindset for at-risk students in the treatment group was exciting and supported the findings of Clark (2004) and Paunesku et al.

An anecdote observed by the researcher is informative. One student who was reluctant to participate in the intervention and who was struggling in his math class changed dramatically; two months after the curricular intervention, he asked when he could participate in more sessions similar to the sessions he participated in during the treatment. Later that same day, he danced down the hallway with excitement. He had just learned that he scored 125 on the mathematics Postsecondary Education Readiness Test (PERT), well above the 97 required to illustrate algebra proficiency for graduation and above the mathematics college proficiency minimum score of 114. While it is impossible to generalize from just one student’s response, most educators would agree that the changes this student demonstrated are critically important and validate the curriculum’s ability to lead to a new way of thinking about himself, school, and mathematics.

Item 4 of the survey was the only test item that resulted in a significant change from pre- to post-test for the control group. The item, “Math problems usually involve specific procedures that must be followed,” was not significantly different among the treatment group. This finding was not surprising; the researcher hoped that the

experimental treatment would help students realize that math is best learned through exploration, problem-solving, and application of math concepts.

Curriculum Features

This study utilized a curriculum and measurement tool that has proven to be reliable and valid for improving math mindset, math anxiety, and view of math among at-risk 18-to-22-year-old students. These results support the need for sharing both the curriculum and measurement instrument with future and present mathematics educators who work with high school at-risk students.

Some key features of the experimental curriculum included videos and presentations of research demonstrating that even adult brains can grow and learn based on the research and theories of Dweck (2006) and Boaler (2016). The research on making mistakes and effects on the brain's growth was eye-opening for the students. In the treatment sessions, students earned high fives for growing their brains when they made a mistake. The sessions pointed out that if students were not making mistakes, they were not learning, but were simply regurgitating information they already knew. At-risk students have typically experienced numerous mistakes and unsuccessful attempts in their math classrooms; students found it refreshing that they were supposed to make mistakes and that mistakes were encouraged.

Another important feature of the experimental curriculum was the focus on choosing math concepts that contextualized the meaning and application of why students were learning some of the seemingly abstract algebra strategies and rules. In approximately four of the five hours of the training, students completed math activities that tied application and meaning to why they needed to learn factors, trinomial factoring,

graphing quadratic functions, and roots/zeros of quadratic functions. Through the design of real-world applications and engaging interwoven lessons and activities, the curriculum was able to engage all levels of students successfully in algebra concepts usually taught in weeks or months of math instruction. These activities reinforced the one-hour math mindset foundation on the importance of being willing to make mistakes and engage in learning, prompting the students to rise to the challenges. All experimental students completed the required activities, indicating a high level of engagement with the required material, unlike many math classes.

Assessments used in the experimental curriculum were formative and informal. Informal observation and screening by the teacher for understanding before giving groups the next step in a lesson were the main forms of assessment utilized. Students were allowed to keep all documents and notes for future reference. One female student returned several minutes after a session to find the paperwork that she had left by accident. She dug the papers out of the recycle box where they had been placed. The majority of the students placed the paperwork in their math binders for future use. This type of behavior is not typical in a traditional at-risk math classroom. If the curriculum techniques and format were replicated to sessions that could be used in all types of high school math courses, perhaps the impact on math mastery would lead to more students who are willing to consider math-related careers.

Recommendations for Future Research

With algebra's acting as the gatekeeper to graduation and higher education, educators should explore effective options for differentiating educational practices to support students who struggle to complete math graduation requirements. Keeping at-risk

students engaged in learning and ensuring that they understand and can apply the math content in the classroom, in real-world situations, and during standardized testing should be a part of every math course. In this manner, students can reach their graduation goal, explore careers requiring a strong mathematics background, and open the door for college and future career opportunities.

Based on the results of this study, the experimental curriculum and instructional intervention were highly effective. These significant results with at-risk young adults support further utilization of the experimental curriculum and instructional techniques in other classrooms. The principal of one of the experimental campuses noticed the changes in behaviors and attitudes of the students who completed the treatment sessions; he asked the researcher to conduct professional development training for faculty in all discipline areas to share the curriculum, instructional strategies, and the survey instrument. The principal also reported better attendance and work ethic among the experimental students after participation in the study. What would be the impact of requiring all students to go through an orientation process that included the experimental instruction when they enroll in school? Would just five hours of math mindset instruction change the course of their future and open more options for career and college?

If just five hours of instruction based on a positive math mindset can make a positive impact on a group of at-risk public charter school students who have struggled in the traditional school system, what might be the impact of math mindset pedagogy training for all K-12 math teachers? Future research could explore comparisons between the impact of math mindset instruction in typical or “average” students in traditional public schools and the at-risk student population addressed in this study. The evidence

from this study also points to the need for continued research on the impact of implementing growth mindset instruction in all secondary math classrooms. Further exploration of the impact of math mindset instruction at all grade levels and in various disciplines such as science, English, and social studies is needed to determine the generalizability of the curriculum's approach, the survey instrument, and the instructional techniques.

In this study, standardized math test data were unavailable to assess the long-term effects of the experimental study due to the nature of at-risk student populations and their movements in and out of school. Further research is needed to track math achievement and to compare scores on standardized tests before and after math mindset instruction.

Teacher strategies and praise utilized with students were key features of the experimental intervention in this research study. Teacher praise focused on effort, perseverance, and willingness to share recognition of errors was encouraged and implemented among the treatment group participants. Experimental teachers avoided direct instruction and utilized group-centered problem-solving activities in math. These activities were designed to build context for students with low prior knowledge and to provide high levels of learning opportunities. Future research should focus on the impact of teacher training in strategies that support a positive math mindset and math grades and standardized math scores.

A final recommendation is a call for replication of this research study with at-risk populations of students with controlled variations. If five hours of experimental math mindset instruction became a component of the orientation sessions of participating

schools, would more students complete high school rather than dropping out again? A well-controlled study would be able to address this question.

Summary

In summary, this study revealed powerful evidence that just five hours of experimental treatment instruction impacted significant differences in changes in the perceptions of math mindset, math anxiety, and view of math for at-risk young adult high school students. Based on this information, more research is warranted using the curriculum and survey tool with at-risk populations, traditional public school students, and students with special needs. Mindset may prove to be the key to unlocking learning for which educators have been searching for decades.

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Appendix A

Math Attitudes Post-Survey November 2016

Welcome to the Math Attitudes Survey

Thank you for participating in our survey. Your feedback is important.

Directions: Please select only one option for each statement below. Choose the option that most closely fits your situation right now. Please do not leave any responses blank.

Please note that by taking this survey you are certifying that you are 18 years-of-age or older.

* 1. Are you male or female?

Male

Female

* 2. Which of the following best reflects your current situation in math coursework?

I have not earned any high school math credits yet

33%

Next

Math Attitudes Post-Survey November 2016

I certify that by taking this survey I am 18 years of age or older.

- * 1. Directions: Please rate how well you agree or disagree with the following statements. Choose from strongly agree, agree, somewhat agree, somewhat disagree, disagree, or strongly disagree. Please select only one option for each statement below. Choose the option that most closely fits your situation right now. Please do not leave any responses blank.

By taking this survey, I certify that I am 18 years of age or older.

Please enter the specially assigned student ID number your math teacher gave you here. This number is very important to match the pre- and post-surveys. See your teacher if you are not sure of the number.

* 2. I often worry that my math assignments will be hard for me.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 3. My math intelligence can be changed.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 4. Math problems usually involve specific procedures that must be followed.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 5. I get tense when working on math assignments.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 6. Some people do well at math and others do not, no matter how hard they try.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 7. Math problems usually have a specific way they must be solved.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 8. I get nervous when performing math work.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 9. There is a limit to what I can learn in math.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 10. Math intelligence is based on knowing facts and procedures.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 11. I worry I will not get the grades I need in math.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 12. Some people just get math and others do not and never will.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 13. Reasoning and problem-solving skills are more important than getting the correct answer.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 14. I get very stressed about passing high-stakes mathematics tests.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 15. I can understand math concepts better if I keep exploring when I miss problems.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 16. Answers to mathematics problems are either correct or incorrect.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 17. I feel anxious when completing math homework.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

* 18. People can change how well they perform in math.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
<input type="radio"/>					

Math Attitudes Post-Survey November 2016

Thank you so much for your time and responses.



Prev Done

Appendix B

Math Mindset Domain Items

3. My math intelligence can be changed.
6. Some people do well at math and others do not, no matter how hard they try.
9. There is a limit to what I can learn in math.
12. Some people just get math and others do not and never will.
15. I can understand math concepts better if I keep exploring when I miss problems.
18. People can change how well they perform in math.

Math Anxiety Domain Items

2. I often worry that my math assignments will be hard for me.
5. I get tense when working on math assignments.
8. I get nervous when performing math work.
11. I worry I will not get the grades I need in math.
14. I get very stressed about passing high-stakes mathematics tests.
17. I feel anxious when completing math homework.

View of Math Items

4. Math problems usually involve specific procedures that must be followed.
7. Math problems usually have a specific way they must be solved.
10. Math intelligence is based on knowing facts and procedures.
13. Reasoning and problem-solving skills are more important than getting the correct answer.
16. Answers to mathematics problems are either correct or incorrect.