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Alleviating Mathematics Anxiety For Middle School Students Using A Combined Intervention Approach Versus Only Using The Cognitive Intervention Approach For Increasing Mathematical Achievement: A Comparative Study

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ALLEVIATING MATHEMATICS ANXIETY FOR MIDDLE SCHOOL STUDENTS USING A COMBINED INTERVENTION APPROACH VERSUS ONLY USING THE COGNITIVE INTERVENTION APPROACH FOR INCREASING MATHEMATICAL ACHIEVEMENT: A COMPARATIVE STUDY

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Dissertation Abstract

Alleviating Mathematics Anxiety For Middle School Students Using A Combined Intervention Approach Versus Only Using The Cognitive Intervention Approach For Increasing Mathematical Achievement: A Comparative Study

Current research has found evidence of effective interventions for mathematics anxiety, both motivational and cognitive interventions can affect learning through instructional design and increased student engagement. Thus, this study investigated whether a combined (cognitive and motivation) intervention approach was more effective than only using a cognitive intervention approach for alleviating mathematics anxiety in middle-school students in order to develop a positive mathematical self-concept.

The design used in this study was a comparison pretest-posttest study using the modified Abbreviated Math Anxiety Scale (mAMAS) to measure the participants' level of mathematics anxiety and the STAR Mathematics diagnostic assessment to measure gradual mathematics achievement. Approximately 68 students participated in the combined treatment, and 52 students participated in the cognitive treatment. Both the treatment and comparison groups participated in a 9-week intervention. The cognitive intervention used in this study was incorrect worked examples taught by the comparison group and the treatment group. In addition, a motivation intervention was integrated along with incorrect work examples with lessons to support the development of mathematical mindsets.

After the cognitive and combined interventions, the scores for the comparison group on the mathematics anxiety survey showed almost no change whereas the treatment group's score

decreased slightly. The difference in posttest means for the two groups was not statistically significant with an effect size close to zero, indicating no difference in posttest means between the two groups. On mathematics achievement, the scores for both groups showed a slight increase. The gain in scores from the pretest to the posttest was not found to be statistically significant. Nonetheless, both groups increased their mathematics grade level from fifth-grade to sixth-grade by the end of the 9-week intervention.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctoral of Education. The content and research methodologies presented in this work represents the work of the candidate alone.

Patricia Anna Garcia May 24, 2023
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CHAPTER I

STATEMENT OF PROBLEM

Traditionally, mathematics instruction has focused on content and not addressed the social-emotional needs of adolescents, such as the fear of mathematics. Students benefit when social-emotional learning is included in mathematics classrooms. According to Jones et al. (2009), students' attitudes, behaviors, and academic performance are positively affected when teachers foster a socially and emotionally supportive learning environment. Moreover, mathematics achievement and performance have also been demonstrated to improve with social-emotional learning interventions (DeLay et al., 2016). Mathematics teachers can create a supportive environment in their classrooms that both lowers students' fear of mathematics and supports cognitive abilities by addressing noncognitive components of learning such as persistence, motivation, self-discipline, focus, confidence, teamwork, organization, seeking help, and staying on task (DeLay et al., 2016). Furthermore, addressing noncognitive components in mathematics classrooms support students in developing a positive mathematics self-concept.

It is crucial to maintain students' interest in, attitudes toward, and confidence in mathematics as they move from elementary school into middle and high school (Wigfield et al., 2006). According to Wang and Pomerantz (2009), during adolescence, there is a decline in mathematics achievement and achievement motivation for mathematics that affects success in mathematics for students. The 2012 report from the Programme for International Student Assessment (PISA) ranked adolescents in the United States below average in mathematics performance compared to other countries. Moreover, the Programme for International Student Assessment (PISA) reported that 50% of students from the United States expressed a lack of enthusiasm for mathematics (Kelly et al., 2013). In the United States, mathematics, specifically Algebra, is seen as a gatekeeper for access to higher-level mathematics and science courses (Matthews & Farmer, 2008).

Middle-school students must develop an in-depth understanding of algebraic knowledge to succeed in Algebra and continue onto higher levels of mathematics. Unfortunately, Algebra is a difficult subject for many students, and as a result, it has a high failure rate across the United States (Kim et al., 2006). The ability for students to perform well in higher mathematics courses is essential for gaining access to college admissions (Schneider et al., 1998) and particularly for majoring in Science, Technology, Engineering, and Mathematics (STEM) fields (Chen, 2009).

One factor contributing to students' difficulty in mathematics is the anxiety many students have about mathematics. Mathematics anxiety has been defined as feelings of tension and of apprehension, and fear that individuals experience when engaging with mathematics (Ashcraft, 2002). Some individuals are debilitated due to their negative emotional reactions to mathematics. A mathematics-anxious student will experience more than worry or dislike for mathematics, and it can affect physiological results such as neural activation, cortisol, and increased heart rate (Faust, 1992). Some individuals show neural activation, much like those who experience physical pain when prompted with a mathematics task (Ramirez et al., 2018). Similar to Ramirez et al. (2018), in the proposed research study, the term mathematics anxiety will be defined as a continuous construct measured and identified through self-report questionnaires.

Most researchers use self-reporting questionnaires to ask individuals how they feel in mathematics situations to identify mathematics anxiety (Bieg et al., 2015). A consistent finding among researchers is that mathematics anxiety prevails across the globe, in the United States, and among 65 countries (Chang & Beilock, 2016). Additionally, mathematics anxiety has been linked to low mathematics achievement worldwide (Foley et al., 2017). According to Chang and Beilock (2016), in the United States, it is estimated that 25% of 4-year college students and approximately 80% of community college students suffer from moderate to high degrees of mathematics anxiety. In addition, students with high mathematics anxiety feelings demonstrated lower mathematics performance when compared to students who had low mathematics anxiety feelings (Ramirez et al., 2018).

Not only can mathematics anxiety affect day-to-day mathematics performance, but mathematics anxiety can also keep students away from career paths that require mathematics. In order to increase the number of students that pursue science, technology, engineering, and mathematics (STEM) careers and students' mathematics achievement, the fear of mathematics needs to be recognized and addressed by educators (Foley et al., 2017). Therefore, it is crucial to address students' social-emotional needs in every mathematics classroom with noncognitive and cognitive components of learning in order to increase mathematics performance and achievement and reduce mathematics anxiety during early adolescence.

Addressing Math Anxiety in the Classroom

When focusing on mathematics anxiety interventions, there are two main approaches that can be found in the literature: cognitive and motivational. Some effective approaches for reducing mathematics anxiety have been mathematics skill and exposure interventions (i.e., cognitive), interpretation interventions (i.e., motivation), and narrative and mindset interventions (i.e., motivational, Ramirez et al., 2018). Current research has found evidence of effective interventions for mathematics anxiety, both motivational and cognitive interventions can affect learning through instructional design and increased student engagement. Therefore, there is a need to investigate further the classroom implementation of these interventions.

Cognitive Interventions

Students can succeed in mathematics and increase their mathematics confidence with worked examples and incorrect worked examples serving as a cognitive intervention for improving student learning. Lange et al. (2021) defined a worked example as a problem that shows a completed problem to students and directs their attention to certain steps of the task as the focus of questioning. For example, students are asked to identify and explain the reasoning behind the steps that they saw carried out in a worked-out mathematics problem. Furthermore, a study by Booth et al. (2013) suggests that students' conceptual and procedural knowledge may be increased by using incorrect examples to assist them identify incorrect processes and consider how they vary from the proper methods.

Moreover, many at-risk students who have a history of failure in mathematics also have negative beliefs and feelings about their own abilities (Carroll, 1994). The use of worked examples coupled with self-explanation has been found to be an effective strategy to correct students’ own misconceptions (Carroll, 1994). Although at-risk students might have difficulty with using worked examples effectively, these examples can help them focus on important features of the problem and its solution, providing them with support for their learning (Carroll, 1994).

One should be deliberate about what is asked of the brain to perform because it can only do so many things at once. Further, when a learner has few schemas available to them, worked examples improve learning by reducing the available amount of information that working memory can handle at any given time (cognitive load) during skill acquisition because they provide instructions to reduce the difficulty of the material to be learned (intrinsic cognitive load). "Prompting students to self-explain the rationale behind worked out solution steps may also link new information with current information (germane cognitive load), provided that learners are capable of providing adequate explanations" (Paas & van Gog, 2006, p. 88). It is important to consider and build on the learners' prior knowledge to effectively influence learning when using worked examples. When students have more prior knowledge, it is easier for them to imagine the solution steps explained by the worked example, therefore, enhancing the understanding of the solution procedure. Research has shown that instruction for novice learners that relies heavily on worked examples is more effective for learning and transfer than instruction solely consisting of problem-solving (van Gog et al., 2011). Higher learning is reached with less investment of time or mental effort when using worked examples as an instructional practice.

Motivational Interventions

In order to create a positive mathematics self-concept among students, motivational interventions can be used to change students' fixed mindsets (believing that their intelligence is unchangeable) to a growth mindset (believing that their intelligence is malleable). In a study by Boaler et al. (2018), a free online course about how to learn mathematics was available to students nationwide. Students were taught the following key ideas: (a) everyone can learn mathematics to high levels; (b) mistakes, challenges, and struggles are the best times for brain growth; (c) depth of thinking is more important than speed; (d) mathematics is a creative and beautiful subject; (e) good strategies for learning mathematics including talking and drawing; and (f) mathematics is all around us in life and is important (Boaler et al., 2018). This course gave students opportunities to reflect on ideas, connect with other students in the course, and work on open-ended mathematics tasks that were strategically designed to shape students' perceptions of mathematics and develop a growth mindset. In fact, students who completed the course obtained a .33 standard deviation gain in SBAC (Smarter Balanced Assessment Consortium, 2013) mathematics overall scale score. Along with developing a positive mathematical mindset, the free online course from Standford University supports changing maladaptive beliefs and thoughts about mathematics during middle school through an appraisal process that can serve as interventions to shape affective reactions.

In sum, mathematics anxiety needs to be alleviated or reduced using both cognitive and motivational interventions during adolescence in order to increase mathematics achievement. As stated by Barbieri and Booth (2016),

> Researchers have traditionally set out to improve learning in one of two ways: cognitive interventions, which aim to design instruction that is more suitable for students' cognitive capabilities, or motivational interventions, which aim to increase student engagement or alter beliefs to increase the effectiveness of traditional instruction. (p.36)

If the focus is on only one intervention, cognition or motivation might not lead to increased mathematics achievement. A combined approach may be more beneficial and critical to student learning and mathematics achievement. Hence, this study will address mathematics anxiety in the seventh grade by using cognitive and motivational interventions.

Purpose of the Study

Past and current research has been focused on speed, accuracy, and solving fundamental mathematics problems (Ramirez et al., 2018). In addition, past research on mathematics anxiety primarily has focused on college students, leaving a gap in the literature as it relates to mathematics anxiety in younger students, especially in middle school. Therefore, the purpose of this study is to investigate: (a) to what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach, and (b) to what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach. The variables to be examined include mathematics anxiety levels, mathematics achievement, cognitive and motivational interventions.

The proposed study will investigate the effect of mathematics anxiety interventions that utilize a combined cognitive and motivational approach on seventh-grade adolescents. To accomplish this purpose, a pretest and posttest study will be conducted using seventh-grade mathematics classes from an urban middle school. The estimated number of students in this study will be 120 students. The modified Abbreviated Math Anxiety Scale that Carey and colleagues used with British children from ages 8 to 13 (see Appendix A for the mAMAS) will be used to measure mathematics anxiety (Carey et al., 2017). Finally, the impact of a combined intervention on students' mathematics achievement will be analyzed using data from the STAR Math assessment.

Significance of the Study

This study is important for the following reasons. First, providing students with skills and strategies to reduce or alleviate mathematics anxiety in order to perform well in mathematics is essential for helping students gain access to college admissions. In the United States, mathematics is a gatekeeper, specifically Algebra, for access to higher-level mathematics and science courses (Douglas & Attewell, 2017). Moreover, during adolescence, the decrease in success in mathematics is attributed to a decline in motivation and achievement (Wang & Pomerantz, 2009). This study investigated effective ways to alleviate mathematics anxiety and increase mathematics achievement in middle-school students by implementing a combined approach, both cognitive and motivational interventions, rather than solely implementing a cognitive or motivational intervention. If effective, the intervention can be used by educators who are facing similar issues in their classrooms.

Second, implementing the appraisal process to help middle-school students to reduce or regulate mathematics anxiety will contribute to filling in the gap in existing literature pertaining to alleviating mathematics anxiety among adolescents. In a study by Jamieson et al. (2016), they found cognitive reappraisal to be a promising strategy for enhancing mathematics performance and reducing mathematics anxiety among community-college individuals. The students who experienced the appraisal condition had greater improvement in their exams and experienced less mathematics anxiety than the control group. The development of mathematics anxiety is determined largely by how students interpret their early mathematics experiences. Therefore, this study will contribute to the literature on appraisal interventions by utilizing students' experiences with incorrect work examples to normalize mistakes and support experiences of making mistakes in mathematics as part of the learning process by changing maladaptive beliefs and thoughts about mathematics.

Third, the study is important because with further research conducted in these critical areas among middle-school students, mathematics anxiety can be better understood by teachers and combined interventions can be employed in the classroom to alleviate or eliminate mathematics anxiety before it begins to erode mathematics achievement. This argument in support of overcoming mathematics anxiety has been supported empirically by the literature, yet addressing mathematics anxiety in the classroom has not been a priority for teachers. Findings from this study would highlight the importance of teachers prioritizing and managing mathematics anxiety in their schools in furtherance of improving mathematics achievement school wide.

Theoretical Framework

There are a number of theoretical frameworks that can be used to develop interventions to support students with mathematics anxiety. This study uses both motivational and cognitive interventions, which are based on the following two theoretical frameworks: (a) the Interpretation Account framework, which describes how mathematics anxiety develops and how to resolve mathematics anxiety with a motivation intervention, and (b) a cognitive learning approach, grounded in research on mental schemata, knowledge, automaticity, that uses worked examples to normalize and understand mathematical mistakes.

First, the Interpretation Account (Ramirez et al., 2018) framework provides the theoretical foundation for motivation for this study. The evidence from the literature supports how students' interpretation of their mathematics-related experiences can lead to developing mathematical anxiety. The Interpretation Account derives both from the appraisal theory and the attitudes-constructions view, which claims that attitudes and emotional outcomes are constructed by interpretation of events, internal states, physiological cues, and personal behavior (Bem, 1972; Chaiken & Yates, 1985; Wilson et al., 2000). The application of the appraisal theory, however, mainly has been used to interpret stress and emotions, and until recently that the appraisal theory has been applied in the literature on mathematics anxiety.

The premise of the Interpretation Account from Ramirez et al. (2018) is that students actively participate in constructing meaning from their educational experiences by using their internal narratives. The Interpretation Account suggests that students develop mathematical anxiety by how they interpret past experiences or outcomes rather than the actual outcome itself. In addition, the development of mathematics anxiety is shaped not only by a student's avoidance tendencies, lower proficiency, or performance concerns but also by how individuals perceive their mathematics-related experiences. Research from Meece et al. (1990) supports the Interpretation Account with their study conducted with a sample of seventh-through ninth-grade students on how students' interpretation of skills in mathematics leads to the development of mathematics anxiety. Meece et al.'s results showed the strongest predictor of mathematics anxiety was attributed to the interpretation of the student's performance in mathematics rather than their actual past mathematics achievement. Moreover, students are more likely to develop mathematics anxiety if they use maladaptive appraisals and use their ability to account for their poor mathematics grades, as compared with students who attribute difficulty in mathematics to lack of effort and understand that making mistakes is part of the learning process. Therefore, if students can learn to redirect their appraisal in a positive way rather than a maladaptive manner, perhaps mathematics anxiety can be diminished or controlled during middle school (Meece et al., 1990).

A practice consistent with the interpretation account is called "storytelling self" (i.e., " My teacher tells us that our brain actually grows when we make math mistakes") (Baumeister & Newman, 1994; Wilson, 2011) or "narrative identity" (i.e., "I know that learning mathematics is a process and that there is no such thing as a math brain or math person!") (McAdams, 2001; McLean et al., 2007). Specifically, students who engage with positive internal narratives attain a sense of security, direction, and coherence (Ramirez et al., 2018). To facilitate a positive internal narrative, researchers have suggested students use continuous narratives to understand themselves and their prior educational experiences better rather than suppressing worries (Ramirez et al., 2018). For example, teachers can encourage and teach students how to re-appraise their mathematics-anxious reactions and embrace the view that mathematics can be a difficult subject to process during learning.

Another practice consistent with the interpretation account is the use of cognitive reappraisal in the classroom (i.e., “ I am a good student, but math is a subject that I have not understood yet”). Cognitive reappraisal is an adaptive method for promoting emotional control by reshaping our ideas about a circumstance perceived as intrinsically unpleasant (Ramirez et al., 2018). Students can learn how to overcome their affective reactions during a stressful mathematical situation by viewing the experience as a challenge instead of a threat to avoid. Blascovich and Mendes (2010) argued that situational demands could be evaluated as threatening when individuals appraise that they do not have the personal resources to address challenging situations adequately. Evidence suggests that the benefits of reappraisal show students with more improvement on mathematical exams and reported less mathematics anxiety than students who do not address stress (Jamieson et al., 2016).

The second theoretical framework used in this study is a cognitivist approach that uses worked examples to normalize and understand mathematical mistakes. Sweller's studies (1985, 1988, and 1989) of worked examples in teaching mathematics are grounded in research on mental schemata, knowledge, automaticity, and expert-novice comparisons of cognitive psychology. Sweller’s research suggests that extensive use of worked examples may be instrumental in developing such schemata. In addition, using worked examples “frees cognitive capacity for more rapid knowledge acquisition because this range of examples presents categories of problems in their initial state and illustrates correct steps for that problem type; the very information that should be encoded in schema” (Carroll, 1994, p. 360). Considered together, Sweller and Carroll suggest that using worked examples in mathematics frees cognitive capacity for more rapid knowledge of acquisition. The range of examples presents categories of problems and illustrates correct steps for that problem type in which educators are able to improve learning by reducing cognitive load during skill acquisition and alleviating mathematics anxiety.

A well-designed worked example requires two important features. First, color coding supports students in integrating information when there are several representations because their attention may be largely bound (Renkl, 2017). Second, when students are encouraged to explain the solution to themselves, then the potential for learning can be fully exploited (Sweller, 2006). Worked examples are designed as a scaffold to support student learning; eventually, a structured transition will be needed, such as fading worked steps. The fading procedure has been seen as more effective than using example problem pairs in studies by Sweller (2006). Fading worked steps allows for a smooth transition; students go from studying worked examples to solving problems on their own.

Since 2014, there has been a shift in the focus of mathematics curricula worldwide, and now students need to be able to generate or inquire about mathematical conjectures and have the ability to construct arguments for and against mathematical claims (Kollar et al., 2014). Therefore, learners with lower working-memory capacity can benefit from worked examples allowing them the capacity for knowledge acquisition (Schwaighofer et al., 2016). Learning from worked examples is an effective method for learning in a structured domain such as mathematics. But can the effectiveness of worked examples be further enhanced when errors are included? Große & Renkl (2007) defined “learning with incorrect solutions means that after providing some correct solutions, incorrect solution in worked examples is presented to learners in order to deepen the knowledge that has already been acquired” (p. 614).

Barbieri and Booth (2016) obtained results suggesting that students with low-prior knowledge benefited from incorrect worked examples. Exposure to solving incorrect worked examples provided learning benefits for students who needed the most support by allowing them to encode relevant features and misconceptions about a problem. These findings are consistent with previous research. Future studies need to be conducted, however, to further explore the use of standard worked example prompts, worked examples with self-explanation prompts, worked examples with instructional explanations, worked examples with a combination of instructional explanations and self-explanations, and faded worked examples for students with mathematics anxiety.

All of these findings can be applied to students struggling with mathematics anxiety in middle school. Innovative work is needed to improve student learning in mathematics during the critical time of adolescence. Students with mathematics anxiety report having low levels of interest in mathematics; therefore using worked examples can increase the germane load when prompts for self-explanations are used (Paas et al., 2003). Moreover, "the worked example effect is the best known and most widely studied of the cognitive load effects" (Sweller, 2006, p. 165).

In sum, the benefits of reappraisal interventions provide students with a method to make sense of their ongoing experience, as well as edit their ongoing narrative when facing challenges. From the interpretation account perspective, students should adopt a growth mindset rather than a fixed mindset to reduce mathematics anxiety (Ramirez et al., 2018). When interventions are designed to change the mindset of an individual and provide a distance perspective, students will have a more appropriate way to appraise stressful situations that can be long-standing (Blackwell et al., 2007). Moreover, middle-school teachers should use incorrect worked examples to reduce cognitive load and reinforce that mistakes are normal and optimal for learning mathematics. Therefore, this proposed study will investigate the effectiveness of a combined approach, using cognitive and motivational interventions in conjunction rather than implementing one intervention, a cognitive or a motivational intervention, to alleviate mathematical anxiety by using incorrect worked examples to normalize mistakes.

Background and Need

Current behavioral and psychological research reveals that mathematics anxiety and mathematics performance link is related to both individual (cognitive, affective or physiological, motivational) and environmental (social or contextual) factors (Ramirez et al., 2018). The research on low mathematics performance suggests that mathematics anxiety is a persistent and important theme of mathematics avoidance and low mathematics achievement (Ramirez et al., 2018). How students perceive themselves directly influences cognitive processes, decision making, strategies, and motivation. Therefore, understanding academic self-concept is crucial to the relationship between emotions and academic achievement (Van der Beek et al., 2017). In this study, if students view mathematical mistakes as a normal part of the learning process, then a positive academic self-concept will directly influence cognitive processes for academic achievement.

Previous research by Ashcraft et al. (1992) found correlations between mathematics anxiety and mathematics performance, suggesting that negative thoughts disrupted working memory and were far more critical for learning than having poor mathematics skills. Ashcraft (2002) defined mathematics anxiety as intense fear, dread, and nervousness related to the avoidance of mathematics activities that impede mathematics performance. According to Ashcraft (2002), “Math anxiety disrupts cognitive processing by compromising ongoing activity in working memory” (p. 181). Engle (2002) defined “working memory to be a short-term memory system that controls, regulates, and actively maintains a limited amount of information relevant to the task at hand." Worry generates distracting thoughts that reduce working memory capacity; therefore, working memory mediates the relationship between mathematics performance and mathematics anxiety (Ashcraft, 2002). Numerous studies (Ramirez et al., 2013, 2016; Vukovic et al., 2013) have shown that working memory renders an essential role in mathematics performance. Working memory is considered to be a limited capacity system that holds information for a brief period of time while simultaneously manipulating it (Justicia-Galiano et al., 2017). Learning mathematics tasks requires storage and simultaneous information processing; thus, students with mathematics anxiety have fewer resources available to accomplish mathematics tasks correctly; therefore, their mathematics performance is affected negatively (Ashcraft, 2002, p. 574).

Relative to addressing cognitive factors in teaching mathematics to students with mathematics anxiety, research also describes that anxious students with a more positive self-concept tend to compensate for their impaired efficiency by making an extra effort (Ramirez et al., 2018). Mathematics self-concept has been identified as an essential precursor for academic performance (Justicia-Galiano et al., 2017) because self-efficacy in mathematics determines how students see themselves learning and performing in mathematics. A study by Jamieson et al. (2016) found cognitive reappraisal to be a promising strategy for enhancing mathematics performance and reducing mathematics anxiety among community college students. The participants were selected from a remedial mathematics course and then placed in two groups; a control group and a treatment group. In the treatment group (the appraisal condition), students were educated about the adaptive benefits of stress arousal, whereas in the control group, students were advised to ignore stress during exams. The students who were in the appraisal condition had greater improvement in their exam scores and experienced less mathematics anxiety than the control group. Moreover, the control group had lower test scores and higher mathematics anxiety.

In particular, students with poor self-image in mathematics become less willing to carry out efforts to complete tasks, become less motivated to perform, and are more prone to avoid mathematics altogether; therefore, it is necessary to change students' ideas about mathematics and their own potential to improve their achievement in mathematics. Plausible explanations to better understand the development of mathematics anxiety and how to remedy mathematics anxiety include the following factors: (a) poor mathematics skills, (b) genetic predispositions, (c) socio-environmental factors, and (d) gender.

Poor mathematical skill

Before the longitudinal study conducted by Ma and Xu (2003), it was unclear if the relationship between feeling anxious and assessing one's performance effected arithmetic performance. Most of the previous studies investigating the association between mathematics anxiety and metacognition were primarily conducted with adults, therefore, resulting in the need for research with young primary students because mathematics anxiety can emerge between the ages of six to eight years old (Maloney et al., 2012; Ramirez et al., 2016). Ma and Xu set out to find concurrent and longitudinal intercorrelations between mathematics anxiety, metacognitive monitoring, and arithmetic achievement. Furthermore, this study was the first to use a longitudinal panel design to understand developmental dynamics through mediation analysis. The researchers assessed arithmetic skills with a computerized task and a standardized achievement test. Ma and Xu adapted a mathematics anxiety questionnaire by Suinn and Edwards (1982) to measure mathematics anxiety, which consisted of 15 daily life situations involving mathematics. The results of the study suggest poor mathematics skills and abilities contribute to mathematics anxiety. Additionally, Ma and Xu also found that students with lower mathematics anxiety in the early elementary years predicted higher mathematics achievement in later years. The researchers suggested that arithmetic achievement is an important predictor of mathematics anxiety and metacognitive monitoring; therefore, targeting interventions addressing arithmetic achievement may reduce mathematics anxiety and strengthen metacognitive monitoring (Ma & Xu, 2003).

A second study by Gunderson et al. (2017) also found similar findings between mathematics anxiety and achievement. Due to the theoretical and practical importance, this study focused on understanding how mathematics achievement, motivational frameworks, and mathematics anxiety relate to one another in the first 2 years of schooling (Gunderson et al., 2017). Furthermore, Gunderson et al. wanted to help intervention researchers target factors that would have the most significant effect on mathematics anxiety, mathematics achievement, and motivation among children because the data on young children was lacking. In this study, children completed motivation, mathematics achievement, and mathematics anxiety measures in a one-to-one session with a researcher who read the items to the student and recorded their responses. Students' motivational frameworks were assessed with an adapted six-item questionnaire, mathematics anxiety was assessed using a revised 16-item child mathematics anxiety questionnaire, mathematics achievement was assessed using the applied problems subtest of the Woodcock Johnson III Tests of Achievement, and reading achievement were assessed using the nationally-normed Woodcock-Johnson III Tests of Achievement Letter–Word Identification subtest (Gunderson et al., 2017).

Moreover, Gunderson et al. (2017) found that children who entered school with lower arithmetic achievement are more likely to develop mathematics anxiety, have less flexible motivational frameworks, and lack some core mathematics concepts that lay the basis for later mathematical development. This study was the first to demonstrate empirically that motivational frameworks predicted higher levels of mathematics anxiety over time. In addition, Gunderson et al.'s results suggest interventions that aim to promote both incremental theories of intelligence and learning goals have the potential to reduce mathematics anxiety while also enhancing mathematics achievement. A notable finding was the importance of implementing research-based techniques for improving mathematics achievement in preschool and kindergarten to help children establish a virtuous cycle of positive motivational frameworks, low mathematics anxiety, and high mathematics achievement (Gunderson et al., 2017).

Genetic predispositions

The first and only empirical research study on how genetics contributed to mathematics anxiety was published by Wang et al. (2014). Specifically, Wang et al.'s research investigated the genetic and environmental factors contributing to the reported variances in people's anxiety when faced with mathematical assignments. Mathematics anxiety was measured by using the Revised Mathematics Anxiety Rating Scale of Elementary Students (MARS-E), general anxiety was measured using the Spence Children's Anxiety Scale, mathematics problem solving was assessed using the Applied Problem subset from the Woodcock-Johnson III Tests of Achievement, and reading comprehension was assessed by using the Passage Comprehension subset from the Woodcock Reading Mastery Test-Revised (Wang et al., 2014). This longitudinal study examined 436 pairs of same-sex twins and found genetic factors accounted for roughly 40% of the variation for mathematics anxiety, with the remaining variation accounted for by environmental factors. Wang et al.'s results showed that both the development of mathematics anxiety and genetics were related to mathematics cognition and general anxiety. In addition, the researchers found that general anxiety was related to child-specific environmental risks. These findings indicate the equal importance of identifying social-environmental factors and the role that genes can play, either exacerbating or causing mathematics anxiety. Thus, these findings suggest to clinical practitioners and treatment programs to address simultaneously affective and cognitive components in order to reduce mathematics anxiety (Wang et al., 2014).

Socioenvironmental factors

Researchers have pieced together several theories based on extensive research on possible explanations of the causes of mathematics anxiety (Ramirez et al., 2018). Perhaps, examining both environmental and social factors of a student's experience may determine the cause of mathematics anxiety and how to alleviate it. The first experience to look at as a contributing factor to mathematics anxiety is outside the classroom, the home experiences around mathematics. One study looked into answering the question of whether parental involvement predicted mathematics achievement by reducing their child's mathematics anxiety (Vukovic et al., 2013). Vukovic et al. (2013) findings suggested that when parents provided strong support at home and maintained high expectations for their child, there was high mathematics achievement due to reducing mathematics anxiety in their child. Another study by Maloney et al. (2015) found children who received frequent mathematics help from high-mathematics-anxious parents had higher mathematics anxiety as compared with children who received less mathematics help in their homework from the same type of parents. Additionally, children who received help from parents who were not mathematics anxious did not increase their child's mathematics anxiety. The data indicate that homework interactions can reduce or increase mathematics anxiety according to their parents' disposition in helping with mathematics homework.

A second experience to investigate as a contributing factor to mathematics anxiety is the student experience inside the classroom. The majority of a student's mathematics knowledge is built in the classroom, where mathematics should flourish. Unfortunately, elementary-school teachers reported high levels of mathematics anxiety (Bryant, 2009; Hembree, 1990), consequently affecting how teachers and students perform and view mathematics. When mathematics-anxious adults participated in focus groups or were interviewed, they consistently linked their mathematics fear or dislike of mathematics to memories of their elementary-school teachers (Markovits, 2011). Other negative experiences in the classroom that lead to mathematics anxiety are hostile interactions with teachers who respond angrily when students ask for help (Jackson & Leffingwell, 1999). A notable amount of narrative evidence in research supports the premise that negative mathematics experiences at a young age with teachers will contribute to developing mathematics anxiety in later years.

Mathematics anxiety and gender

Current research has not found the answer to why women are likely to be more mathematics anxious than men, although some hypotheses have attempted to provide an answer. For example, Ashcraft's (2002) theory was that women are more comfortable reporting mathematics anxiety than men. Whereas Bieg et al. (2015) aimed to examine gender differences in students' traits versus mathematics anxiety. In addition, Bieg et al.'s study examined the effects of both students' self-concept and the endorsement of mathematics-related gender stereotypes as moderators of the trait-state discrepancy. Participants in the diary study completed a questionnaire that included trait measures of mathematics anxiety, self-concept, and demographic items. Findings from this study replicated the results from Goetz et al. (2013), who found that female students from 5th grade through 11th grade did self-report higher mathematics anxiety than male students, but when these female students were probed further about their real-time mathematics anxiety, the girls did not report more mathematics anxiety symptoms than the male students. Differing from Goetz et al.'s results, Bieg et al. found students' endorsement of mathematics-related gender stereotypes predicted the trait-state discrepancy for female students. Therefore, female students who believed mathematics was a male domain had a bigger gap between their trait and state anxiety levels. These findings showed a daunting number of stereotype endorsements of female students who have inaccurate beliefs about gender differences in mathematics ability. For this reason, schools, teachers, and parents need to address and prevent gender stereotypes in order to rectify the underrepresentation of females in STEM careers (Bieg et al., 2015).

Stoet et al. (2016) investigated whether the gender gap in mathematics anxiety had a role in the underrepresentation of females in STEM-related fields. The researchers measured mathematics anxiety for 761,655 high-school students from 68 different nations who participated in the PISA surveys that focused on mathematics performance and attitudes. PISA data were chosen because it is considered the largest international evaluation of the educational performance of 15-year-old students. The PISA survey took 2 hours for each student to complete and included questions measuring reading comprehension, math ability, and science literacy (Stoet et al., 2016). The findings from Stoet et al. confirmed that mathematics anxiety is higher for females than males.

Additionally, Stoet et al. (2016) found that economically developed and more gender-equal countries have a lower overall level of mathematics anxiety as opposed to less developed countries having larger national sex differences in mathematics anxiety (Stoet et al., 2016). The findings of this study prove to be important from an academic and policymakers' perspective. It is critical to ensure equal opportunities in STEM fields for females and provide support for females not to avoid mathematics due to mathematics anxiety (Stoet et al., 2016).

Thus, current research has not found the answer to why women are likely to be more mathematics anxious than men. Nonetheless, stereotype endorsements of female students who have inaccurate beliefs about gender differences in their mathematics ability must be addressed because external influences can shape negative appraisals in the mathematics classroom (i.e., “Girls are not good at math”). Girls having a positive interpretation of their mathematics abilities can prevent stereotypes from forming by using both cognitive and motivational interventions.

Research Questions

This study will investigate the following research questions with respect to using a combined intervention approach versus only using the cognitive intervention approach for increasing mathematical achievement and decreasing mathematics anxiety among middle-school students:

(1) To what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

(2) To what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

Definition of Terms

The terms provided here may have other definitions than those given; however, the definitions are the ones used in the proposed study.

Academic Self-Concept: An overall view across various aspects of oneself and the perception built on knowledge gained and assessed through experiences in a person's surroundings (Eccles, 2005).

Appraisal Process: When emotional outcomes and attitudes are based on the interpretation of events, physiological cues, personal behavior, and internal states (Wilson et al., 2000).

Cognitive Load Theory: A psychological theory and set of instructional principles based on knowledge of human cognitive architecture as an information processing system, in which the working memory is limited, and the long-term memory is essentially infinite (Moreno & Park, 2010; Paas & Sweller, 2014).

Cognitive Reappraisal: An adaptive method for promoting emotional control by reshaping one's ideas about a circumstance perceived as intrinsically unpleasant (Ramirez et al., 2018).

Disruption Account: Mathematics anxiety effects performance by triggering negative thoughts and ruminations that co-opt the working-memory resources necessary for solving mathematical problems. According to a Disruption Account, the reason that mathematics anxiety relates to lower achievement is that mathematics anxiety causes poor mathematics performance and abilities (Ramirez et al., 2018).

Fixed Mindset: In a fixed mindset, people believe their basic qualities, like their intelligence or talent, are simply fixed traits. They spend their time documenting their intelligence or talent instead of developing them. They also believe that talent alone creates success without effort (Dweck, 2016).

Germane Cognitive Load: The form of cognitive load that is dedicated to developing and automating schemas (Moreno & Park, 2010).

Growth Mindset: In a growth mindset, people believe that their most basic abilities can be developed through dedication and hard work, brains and talent are just the starting point. This view creates a love of learning and resilience that is essential for great accomplishment (Dweck, 2016).

Incorrect Worked Example: An instructional scaffold providing learners with examples of incorrect problem solutions, either in conjunction with or instead of correct examples. Incorrect worked examples are marked as such, and they demonstrate a common mistake that students make when learning to solve a particular type of problem (Booth et al., 2017).

Interpretation Account: Individuals develop mathematical anxiety by how they interpret past experiences or outcomes rather than the actual outcome itself (Ramirez et al., 2018).

Intrinsic Cognitive Load: The form of cognitive load that is imposed by the inherent difficulty of the information being learned (Sweller, 1994).

Mathematical Mindset: A mathematical mindset reflects an active approach to mathematics knowledge, in which students see their role as understanding and sense-making. For example, number sense reflects a deep understanding of mathematics, but it comes about through a mathematical mindset focused on making sense of numbers and quantities (Boaler, 2018).

Mathematics Anxiety: Is commonly defined as a feeling of tension, apprehension, or fear that interferes with mathematics performance (Ashcraft, 2002). In the current study, mathematics anxiety is defined as an emotional issue that involves self-doubt and fear of failing. Comments such as “I have never been good a math” and “I hate math” are used as defense mechanisms for stress. When students face difficulties or challenges, a student uses avoidance strategies or distractions to give up.

Mathematics Anxious: An individual will experience more than worry or dislike for mathematics, and can affect physiological results such as neural activation and cortisol and display observable measures such as increased heart rate or sweaty palms (Faust, 1992).

*Mathematics Self-Concept: "*how sure a person is of being able to learn new topics in mathematics, perform well in mathematics class, and do well on mathematics tests" (p. 560, Reyes, 1984).

Modified Abbreviated Math Anxiety Scale: A student questionnaire that is a valid and reliable scale for measuring mathematics anxiety in children and adolescents was used in the current study (Carey et al., 2017).

Motivational Strategies: Instructors emphasize growth and learning in mathematics and de-emphasize performance so that students stay motivated and encouraged about their learning (Boaler, 2018). For example, sharing and discussing students' mathematical mistakes through worked examples, so students know others are making them too and provide mathematical reasoning and understanding of misconceptions.

Reduced Competency Account: Interventions aimed to improve students' mathematical skills which may also be effective at reducing mathematics anxiety (Ramirez et al., 2018).

Social-Emotional Learning: Self-awareness and the ability to understand one's thoughts and feelings and how they influence behavior when learning, for example, self-efficacy, and having a growth mindset (DeLay et al., 2016).

STAR Math Assessment Test: An assessment to quickly gauge the mathematical knowledge of students that provides a grade level equivalency in mathematics. Students will answer questions for approximately 30 minutes that deal with: numbers and operations, algebra, geometry and measurement, data analysis, statistics, and probability (Renaissance, 2003).

Worked Example: Instructional scaffolds that depict an expert's detailed solution to a problem for students to study and emulate (Atkinson et al., 2000). Mathematics worked examples provide a step-by-step approach and explanation. Worked examples are effective interventions that improve learning when studying mathematics problems of solutions to issues rather than trying to solve the original mathematics problem.

Working Memory: The part of the brain responsible for consciously processing and assimilating new information. The working memory has a fixed capacity and can manage only a finite number of elements at once (Moreno & Park, 2010).

Summary

Practitioners have traditionally primarily addressed the mathematics content, overlooking the social-emotional needs of adolescents, such as their fear of mathematics. There is a gap in the literature addressing mathematics anxiety in middle school students, as previous studies have mostly focused on college students. Mathematics anxiety research in the past and present have concentrated on speed, precision, and solving basic mathematical problems (Ramirez et al., 2018). To improve mathematics performance and achievement and reduce mathematics anxiety throughout early adolescence in middle school, it is essential to meet students' social-emotional needs in every mathematics classroom with noncognitive and cognitive components of learning.

The purpose of this study is to investigate: (a) to what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach, and (b) to what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach.

Seventh-grade students from an urban middle school will be used in the pretest and posttest study to accomplish this purpose. The results of the proposed study will be beneficial to middle school mathematics instructors to provide students with skills and strategies to reduce or alleviate mathematics anxiety to perform well in mathematics.

Chapter II focuses on the literature review regarding background on ways to improve mathematics performance and achievement by understanding and alleviating mathematics anxiety in adolescence. The methodology is detailed in Chapter III.

CHAPTER II

REVIEW OF THE LITERATURE

Past research on mathematics anxiety has primarily focused on college students, leaving a gap in the literature as it relates to mathematics anxiety in younger students, especially in middle school. Moreover, in the past, mathematics anxiety interventions solely focused on using one intervention, either cognition or motivation. If the focus is on only one intervention, cognition or motivation, one focus might not lead to significant mathematics achievement (Barbieri & Booth, 2016). A combined approach may be more beneficial and critical to student learning and mathematics achievement. Hence, the proposed study will investigate the impact of mathematics anxiety interventions that utilize a combined cognitive and motivational approach on seventh-grade adolescents.

One of the primary goals of the educational system is to assist students in achieving high levels of achievement both in school and later in life when they enter the workforce (Maloney et al., 2015). Unfortunately, many students dread mathematics at an early age in school and continue to dislike mathematics as adults, and some even struggle with mathematics anxiety (Markovits, 2011). Consequently, students become discouraged from pursuing occupations that involve mathematics classes if they have mathematics anxiety (Ashcraft, 2002). Mathematics anxiety affects both the cognitive capacity to engage in mathematics problem solving and reduced motivation and involvement in mathematics-related activities (Wang et al., 2014). Notably, researchers found that students with high mathematics anxiety are associated with a decline in the performance of 34 points, equivalent to almost one year of school (Suárez-Pellicioni et al., 2016). Therefore, this literature review aims to provide background on ways to improve mathematics performance and achievement by understanding and alleviating mathematics anxiety in adolescence.

First, an overview of mathematics anxiety studies in children is provided; then, a review of valid instruments for measuring mathematics anxiety of children and adolescents follows. Last, research pertaining to cognitive, motivational, and combined interventions for addressing mathematics anxiety are presented.

Overview of Mathematics Anxiety in Children

In general, mathematics anxiety increases with age during childhood (Dowker et al., 2016). Although most studies imply that severe mathematics anxiety is uncommon in young children, some research has indicated considerable mathematics anxiety in children as young as primary school (Wu et al., 2012). Additionally, attitudes toward mathematics also correspond to age and deteriorate as children get older (Dowker, 2005). Therefore, a review of several studies investigating mathematics anxiety in children follows.

Brain Activity Related to Mathematics Anxiety

Park et al. (2014) found that first-grade students experienced mathematics anxiety, as well as that mathematics anxiety has a lifelong detrimental effect on mathematical development. Furthermore, Ma's (1999) meta-analysis found that mathematics anxiety had a negative impact on mathematical ability, resulting in poor career choices, employment, and professional achievement. Due to brain plasticity and these findings, it is critical to conduct research on mathematics anxiety in young students.

In a study by Young et al. (2012), the researchers found that mathematics anxiety was associated with hyperactivity of the right amygdala regions that are important for processing negative emotions. Moreover, they found that mathematics anxiety reduced activity of the posterior parietal and dorsolateral prefrontal cortex (DL-PFC) that is involved in mathematical reasoning (Young et al., 2012). Furthermore, Young et al. also found that effective connectivity between the amygdala and the ventromedial prefrontal cortex areas that control negative emotions was increased among children with high mathematics anxiety. In another functional MRI study conducted by Lyons and Beilock (2012), their findings suggest that mathematics anxiety causes a response in the brain similar to physical pain. This study also suggests that people with severe mathematics anxiety might experience pain merely thinking about solving a mathematics problem, even before they solve it.

Based on previous research that attempted to pinpoint the neurological mechanisms and causes of underlying mathematics anxiety, Yun and Shin (2015) aimed to examine the differences in brain wave activity shown between high-mathematics-anxiety and low-mathematics-anxiety individuals in students in the sixth grade. Due to the young ages of the students, a noninvasive electroencephalogram (EEG) was used to measure brain activity and analyze the difference between high-mathematics-anxiety and low-mathematics-anxiety students.

Yun and Shin (2015) used an adapted mathematics anxiety test (ANX-MAT Scale) on 112 sixth graders. A total of 22 students were selected to comprise a group of 11 students with high mathematics anxiety and a group of 11 students with low mathematics anxiety. The researchers found that when students experience mathematics anxiety, they feel emotional and mental uneasiness, including physical pain comparable to headaches (Yun & Shin, 2015). In addition, Yun and Shin (2015) found that when students performed arithmetic tasks, more delta wave was generated at the right frontal lobe in the high-mathematics-anxiety group compared with the low-mathematics-anxiety group. Hence, the delta wave is a brain wave that is produced in combination with pain.

Anxiety is not necessarily harmful; in fact, it can be beneficial when it prompts a person to react promptly to potential dangers (Yun & Shin, 2015). The major implication of this study was not to view mathematical tasks as fearful tasks that impede mathematical performance but rather to view them as a stimulus to overcome mathematics anxiety and achieve successful mathematics performance (Yun & Shin, 2015).

In summary, most important to the present study, empirical research found that mathematics anxiety had a negative impact on mathematical ability, and findings suggesting that mathematics anxiety causes a response in the brain similar to physical pain (Ma,1999; Young et al., 2012). Therefore, addressing mathematics anxiety with cognitive and motivational interventions are needed to reduce mathematics anxiety and reduce the negative impact of mathematics anxiety on achievement in middle school. Additionally, the study by Yun and Shin (2015) addresses the importance of helping students not to view mathematics with fear that impedes mathematical performance but rather to help students develop a mindset to overcome mathematics anxiety and achieve successful mathematics performance.

Mathematics Anxiety and Working Memory

The field's founding researchers of mathematics anxiety interpreted its effects within the framework of processing efficiency theory, which was considered a critical theory to explain the relationship between performance in cognitive tasks and anxiety (Eysenck & Calvo, 1992). According to processing efficiency theory, the anxiety reaction entails worried intrusive thoughts that consume the central executive's limited attentional resources of working memory, thus making it less available for current task processing (Suárez-Pellicioni et al., 2016). Results of Suárez-Pellicioni et al.'s (2016) study suggest that the negative effects of anxiety on performance should be larger on tasks that place a high demand on the central executive of working memory's processing capacity.

In 2001, Ashcraft and Kirk were the first to investigate the relationship between mathematics anxiety and working-memory capacity with two experiments. The first experiment assessed working-memory capacity by having participants store more numbers or words while processing arithmetic or verbal tasks (Ashcraft & Kirk, 2001). In the verbal task, Ashcraft and Kirk (2001) had the participants hear simple sentences, next answer a question (e.g., “When?”), then participants had to recall the final word of each sentence in a serial order. In the numeric task, the participants solved an arithmetic verification task (e.g., 6 + 2 =?; 7 - 3 = ?) and then were asked to recall the last addends of each operation in order (e.g., 2, 3). The first experiment found that mathematics anxiety was associated with a lower working-memory span only for the arithmetic verification task. The verbal task had almost no relationship between mathematics anxiety and language-based span (Ashcraft & Kirk, 2001). The researchers conducted a cognitive investigation that provided evidence that mathematics anxiety interferes with working memory capacity.

Moreover, participants were tested in a dual-task paradigm in the second experiment that Ashcraft and Kirk (2001) conducted. The participants were asked to hold a string of either two or six random letters in working memory while solving an addition problem. Next, participants had to recall the letters presented orally in the first place. Their results indicated that errors increased when memory load was heavy. This pattern was visible in all of the groups, but it was most pronounced in the one with the highest mathematics anxiety (Ashcraft & Kirk, 2001). Whereas, when the working-memory load was light, error rates were low and similar across the mathematics-anxiety groups. In sum, Ashcraft and Kirk (2001) found that mathematics anxiety works like a dual-task procedure, causing poor performance in any primary mathematical task that relies on working memory resources. This study is important because the researchers were able to conduct a cognitive investigation that undoubtedly provided evidence that mathematics anxiety interferes with working memory's ongoing, task-relevant operations, decreasing performance and lowering accuracy (Ashcraft & Kirk, 2001).

In 2013, Ramirez and colleagues were the first to examine if mathematics anxiety was present in first-grade and second-grade students. Investigating mathematics anxiety at the earliest possible age was important to the researchers because early mathematics anxiety may have a “snowball” effect leading to increased anxiety, dislike, and avoidance of mathematics (Wigfield & Meece, 1988). In addition, their findings may contribute to higher mathematics achievement among the population by identifying mathematics anxiety early on with the implementation of interventions to alleviate or diminish mathematics anxiety (Ramirez et al., 2013).

Ramirez et al. (2013) administered and measured four tasks to all 162 participants in the study. First, mathematics performance was measured using the Woodcock-Johnson III Applied Problems subtest is normed nationally (Woodcock et al., 2001). The Woodcock-Johnson III Applied Problems subtest and used to measure academic achievement skills in people ranging in age from 2 to 90 years (Ramirez et al., 2013). Second, reading performance was measured using the Letter–Word Identification subtest of the Woodcock-Johnson III Tests of Achievement. Third, mathematics anxiety was measured using the Child Math Anxiety Questionnaire (CMAQ), consisting of eight items adapted from the Mathematics Anxiety Rating Scale for Elementary children (Suinn et al., 1988). Finally, the Digit Span subtest was used to measure working memory because working memory is thought to be comprised of memory and executive attention processes (Engle, 2002).

Findings from Ramirez et al. (2013) were in line with findings from adult literature indicating that individuals who rely more heavily on working memory when solving difficult mathematics problems are most affected by anxiety because worries about the mathematics situation are likely to reduce cognitive resources needed for mathematics performance (Beilock, 2008). Moreover, this study showed that children with higher working memory have a pronounced negative relationship between mathematics anxiety and mathematics achievement (Ramirez et al., 2013). Notably, the Child Math Anxiety Questionnaire scores were related specifically to mathematics achievement and not general academic achievement.

In conclusion, Ramirez et al. (2013) show that mathematics anxiety negatively might affect children's mathematics achievement as early as first and second grade. The researchers also found that students with higher working memory may be the most susceptible to mathematics anxiety. These findings are alarming because children in first grade and second grade should have the most potential for high mathematics achievement. Thus, this study conducted by Ramirez et al. (2013) also highlighted the importance of developing interventions designed to increase mathematics achievement for young children to affect performance across the school years.

In regard to the current study, it is important to address students' worried intrusive thoughts that consume the central executive's limited attentional resources of working memory required for processing high-demand tasks in mathematics (Suárez-Pellicioni et al., 2016). Using appropriate interventions in mathematics can lower error rates by using incorrect examples to increase working memory. For example, Students can use incorrect work examples to teach others how to correct and view a mathematical mistake by organizing new information for long-term storage. Additionally, findings from Ashcraft & Kirk (2001) and Ramirez et al. (2013) support the importance of this study in developing interventions designed to increase mathematics achievement to alleviate or diminish mathematics anxiety.

Mathematics Anxiety and Mathematics Achievement

In order to understand the relationship between mathematics anxiety and mathematics achievement, theory and practice are essential for effective interventions. For example, if poor mathematics performance results in mathematics anxiety, the emphasis should be on improving mathematics skills (Namkung et al., 2019). If mathematics anxiety results in poor mathematics performance, intervention strategies should reduce mathematics anxiety to increase mathematics performance (Namkung et al., 2019).

Hembree's (1990) and Ma's (1999) meta-analyses provide a foundation for understanding the relationship between mathematics anxiety and mathematics performance. The results of both meta-analyses yielded a moderate, negative relationship between mathematics anxiety and mathematics performance (i.e., $r = -.34$ in Hembree, 1990; $r = -.27$ in Ma, 1999). Although providing a foundation to the existing literature, both studies left many unanswered questions.

First, Hembree (1990) and Ma (1999) only included a small number of studies with school-aged children. Understanding the relationship between mathematics anxiety and mathematics performance among school-aged students when mathematics learning actively is occurring is critical for remediation and early intervention purposes, given that mathematics anxiety is correlated negatively with mathematics performance (Namkung et al., 2019). Hembree’s (1990) meta-analysis included 17 studies across Grades 5 and 12 and 58 studies with college students, and Ma’s (1999) meta-analysis included 26 studies across Grades 4 and

12.

Second, both Hembree (1990) and Ma (1999) focused their meta-analyses primarily on secondary students. The problem in regard to a small number of studies in both meta-analyses may be attributed to a limited number of studies conducted on younger children prior to 1999 (Namkung et al., 2019). Additionally, due to the lack of research studies on young children, mathematics anxiety measures were still being developed and validated (Vukovic et al., 2013). Furthermore, studies conducted before 1999 mathematics anxiety measures were designed for older students relying on self-reports.

Third, potential moderating factors and mechanisms with respect to the relationship between mathematics anxiety and mathematics performance were not explored fully due to the insufficient number of studies reviewed (Namkung et al., 2019). Even with the lack of research, Ma's meta-analysis (1999) did examine some moderating factors such as grade level, race, and gender. Additionally, except for publication bias when all moderators were controlled simultaneously, Ma (1999) discovered no statistically significant results. Ma (1999) found that published articles reported weaker correlations than unpublished articles. Similarly, whereas Hembree (1990) analyzed the connections between mathematics and other aspects associated with mathematics performance, such as mathematics attitudes, the moderating functions of these components were never investigated (Namkung et al., 2019).

In sum, to address the limitations and unanswered questions that Hembree (1990) and Ma (1999) left unanswered, the meta-analysis conducted by Namkung et al. (2019) provides a much-needed updated synthesis of the relationship between mathematics anxiety and mathematics performance. The purpose of the meta-analysis conducted by Namkung et al. (2019) was to examine the relationship between mathematics anxiety and mathematics performance among school-aged students. Additionally, Namkung and colleagues focused on identifying potential moderators and underlying mechanisms of such relations, including grade level, temporal relations, the difficulty of mathematical tasks, dimensions of mathematics measures, effects on student grades, and working memory.

Namkung et al. (2019) identified 1,740 studies from their original literature search. After removing duplicates, record screening, and assessing full-text articles for eligibility, their meta-analysis included 131 studies. The researchers included two reports, 108 peer-reviewed articles, and 21 unpublished dissertations for the final meta-analysis. All of the studies included in the meta-analysis had to meet the following criteria: (a) at least have one measure of mathematics anxiety, (b) mathematics anxiety is defined explicitly as a measure of either negative affect or negative cognition that involves any situations that required mathematical tasks, (c) mathematics anxiety measures had to include one or both dimensions of mathematics anxiety, (d) studies had to include at least one assessment of mathematics, (e) studies had to report at least one direct bivariate correlation between any measures of mathematics anxiety and mathematics performance, and (f) or the percentage of variance in mathematics performance accounted for by mathematics anxiety only (Namkung et al., 2019).

The findings by Namkung and colleagues (2019)found that overall, there was a moderate but negative relationship between mathematics anxiety and mathematics performance ($r = -.34$). The findings from Namkung et al. were in line with previous meta-analysis studies; moreover, the correlation between mathematics anxiety and mathematic performance for secondary students ranged from −.27 to −.34, as found in meta-analyses conducted by Hembree (1990) and Ma (1999), respectively. Furthermore, Namkung et al.'s findings indicate that mathematics anxiety measures across cognitive and affective dimensions showed a more significant negative connection with mathematics performance than mathematics anxiety assessed across cognitive and affective dimensions. When compared with foundational mathematical tasks, advanced mathematical tasks that demand multistep processes revealed a greater negative correlation with mathematics anxiety (Namkung et al., 2019). Mathematics assessments that affected or reflected student grades exhibited a greater negative relationship with mathematics anxiety than other mathematics performance measures that did not affect student grades (Namkung et al., 2019). Overall, the findings from this meta-analysis indicate that for students in elementary school (K-12), mathematics anxiety may be linked to mathematics performance.

In conclusion, the Namkung et al. (2019) meta-analysis provided an updated synthesis of the relationship between mathematics anxiety and mathematics performance. Further the researchers' findings suggest that screening and treatment for mathematics should begin in lower elementary grades so that students with mathematics anxiety can be identified early on and receive interventions before suffering from the negative effects of mathematics anxiety (Namkung et al., 2019). The meta-analysis conducted by Namkung and colleagues is essential to the current study because its findings have important implications for interventions at a young age, perhaps even in the lower elementary years. This suggests that educators should address screenings and interventions for mathematics anxiety before young and adolescent students experience the detrimental effects of mathematics anxiety in later years.

Mathematics Anxiety Scale for Young Children and Middle School

In the last decade, research has begun to focus on younger children to understand the origins of how and when mathematics anxiety develops (Dowker et al., 2016; Ramirez et al., 2013; Wu et al., 2012). Primarily because studies have found that mathematics anxiety is reasonably consistent across time, current researchers must test mathematics anxiety theories on children that have already been tested on adults (Ganley & McGraw, 2016). For example, do relationships between mathematics anxiety hold between attitudes, performance, and working memory in younger children as they do in adults? To fully understand the development of mathematics anxiety, valid and reliable measures are needed to allow researchers to make accurate inferences about mathematics anxiety in young children (Ganley & McGraw, 2016). Even with newly developed mathematics measures for children between the ages of 7 and 10 years, there is a limited amount of work examining the reliability and validity of these measures.

Mathematics anxiety frequently has been theorized and measured as a multidimensional construct by researchers (Ganley & McGraw, 2016). One conceptualization has been the physiological aspect of anxiety (e.g., heart palpitations, sweating, or tightness in the stomach), and another aspect has been cognitive anxiety (e.g., worried and or racing thoughts; Wigfield & Meece, 1988). Moreover, in other research, mathematics anxiety has been conceptualized as two distinct components: learning mathematics in the classroom and solving mathematical problems in front of others or feeling anxious during taking a test (Ganley & McGraw, 2016; Hopko, 2003).

In current research, factor analyses have been used to examine if mathematics anxiety is a multidimensional construct in young children. Research by Wu et al. (2012), Harari et al. (2013), and Jameson (2013) found that multiple factors can be identified in young children. For example, Wu et al. (2012) found “numerical processing anxiety” and “situational and performance anxiety” factors in second-grade and third-grade students. Harari et al. (2013) found that their scale (Math Anxiety Scale for Young Children - MASYC) modeled the following factors: numerical confidence, negative reactions, and worry. Furthermore, Jameson (2013) found general mathematics anxiety, mathematics error anxiety, and mathematics performance anxiety among first-grade through fifth-grade students. Thus, these results suggest that mathematics anxiety at a young age may be a multidimensional construct and may parallel those identified in teenagers and adults, therefore, providing a map to understanding the development of mathematics anxiety.

Challenges for Measuring Math Anxiety in Young Children

Developing mathematics anxiety measures for young children has been challenging for researchers and to overcome the limitations of measuring mathematics anxiety, each of these researchers had to make different decisions for this age group (Ganley & McGraw, 2016). One challenge has been vocabulary and reading comprehension for this age group. Surveys used to measure mathematics anxiety in this age group must contain vocabulary that children understand and use simple sentence structure such that the items are at a reading level suited for children (Ganley & McGraw, 2016).

A second challenge to consider is not to overwhelm children when collecting data. Ganley and McGraw (2016) suggested a scale should be short from 8 to 20 items and be group administered for efficacy instead of one individual at a time. A second important suggestion by Ganley and McGraw is to balance a small number of items and good reliability. Other challenges that have arisen when measuring complex constructs in young children have been not presenting the concept of anxiety well enough for young children to understand; therefore, it is critical to explain the concept of anxiety in a manner that they can comprehend. Furthermore, the rating scale must match the construct of anxiety and make sense to students by age group (Ganley & McGraw, 2016).

A third challenge to consider is Pictorial and Likert scales used to measure mathematics anxiety have also presented challenges with children's accurate interpretations (Harari et al., 2013; Krinzinger et al., 2009). Word choices on a Likert scale did not make sense to specific age groups and pictorial scales did not accurately represent what exactly mathematics anxiety is and what it means not to have mathematics anxiety. In order to address these concerns, Wu et al. (2012) and Jameson (2013) used a combination of pictorial and simple answer choices; however, because students must maintain track of two representations, this may be more cognitively challenging for them (Ganley & McGraw, 2016).

The purpose of the study by Ganley and colleagues was to examine the reliability and validity of the Math Anxiety Scale for Young Children (MASYC; Harari et al., 2013) and to examine the reliability and validity of the revised Math Anxiety Scale for Young Children version that they developed (MASYC-R; Ganley & McGraw, 2016). The researchers removed items on the MASYC that were confusing to young children and examined how well the revised version could predict mathematics anxiety from its correlates (Ganley & McGraw, 2016). It is critical to have reliable and valid measures available to assess mathematics anxiety in young children therefore, this study is important to the current study because Ganley and McGraw (2016) support having mathematics anxiety measures that are age-appropriate for young children. Additionally, there is a need to have a mathematics anxiety measure that is age-appropriate for middle school students as well. These measures can help researchers and educators identify mathematics anxiety and provide interventions early to avoid detrimental consequences for later mathematical development.

Measuring Mathematics Anxiety in Middle-School Students

More recently, Anindyarini and Supahar (2019) designed an instrument to measure the level of students' anxiety toward mathematics, specifically for middle-school students, because one did not exist. In addition, the researchers set out to assess the validity of their instrument. During the teen years, students experience psychosocial changes that are divided into three stages (Hurlock, 1980). The three stages are named early, middle, and final adolescence. According to Hurlock (1980), in the early stage, due to psychological changes such as identity crisis, anxiety is strong from the ages of 12 to 15. Therefore, middle-school students (early stage) were chosen to be the subjects of this study (Anindyarini & Supahar, 2019).

To assess the level of mathematics anxiety in middle-school students, the researchers developed a questionnaire using a Likert scale without a neutral option (Anindyarini & Supahar, 2019). Thus, for this study, the researchers used the following scale: *always* (4), *often* (3), *rare* (2), *and never* (1). Additionally, the researchers used a nontest instrument development model consisting of 8 out of 10 steps. The following eight steps were used by Anindyarini and Supahar (2019): (a) determining the instrument specification, (b) writing the instrument, (c) determining the scale of the instrument, (d) determining the scoring system, (e) examining instruments,(f) trials, (g) instrument analysis, and (h) re-assembling instrument.

This study had 257 middle-school participants from Indonesia. Anxiety scales were used in the form of questionnaires and interviews to collect data, then the items were validated in terms of content by seven raters (Anindyarini & Supahar, 2019). The researchers developed a mathematical anxiety instrument framework based on the theory of anxiety symptoms by Stuard and Sunden (2009). Anindyarini & Supahar's (2019) mathematical anxiety instrument, of which 35 statement items were spread over four of the following aspects; physiological, behavioral, cognitive, and affective. Moreover, items on the instrument consisted of positive and negative statements.

The results of the study confirmed the 35 items on the instrument to have validity evidence. The mathematics anxiety scale questionnaire that was developed by Anindyarini and Supahar (2019) was tested theoretically and empirically that is considered a viable instrument based on the V Aiken validity test and Rasch model analysis (Anindyarini & Supahar, 2019). The V Aiken validity criteria from seven raters obtained a validation value ranging from .86 to 1.00. In addition, the reliability test results of the instrument obtained a value of .76. Therefore, the questionnaire developed and tested in this study can be considered to have validity and reliability.

Anindyarini and Supahar (2019) provide evidence of a reliable and valid instrument to be used specifically for middle-school students but did not provide the instrument itself. The mathematical anxiety instrument is a theory-based framework that refers to mathematics learning anxiety and mathematical evaluation anxiety, which are categorized into four aspects of anxiety. This instrument could provide critical insight for mathematics teachers to learn about their students' mathematics anxiety levels and characteristics if the questionnaire were to be published. With the student data collected by this instrument, mathematics teachers would be able to apply appropriate teaching strategies and interventions. Regrettably, this instrument specifically developed for middle school students could not be used in the present study or in any other middle school.

Taken together, Ganley and McGraw (2016) and Anindyarini and Supahar (2019), these two studies further support the need for additional research on creating and examining the reliability and validity of measures created for young children and adolescents. Moreover, because mathematics anxiety is consistent across time, age-appropriate valid and reliable measures are needed to make accurate inferences about mathematics anxiety in young students to provide promising interventions.

The Effect of Cognitive and Motivation Interventions

Research into interventions that reduce mathematics anxiety and reduce the negative effect of mathematics anxiety on achievement has been diverse in its approach. The ultimate goal of mathematics anxiety research should be intervention, with the goal of preventing the development of the disorder in children early on and reducing the negative consequences in those who already have mathematics anxiety (Suárez-Pellicioni et al., 2016). Given that the intensity of mathematics anxiety in 5th through 12th graders tends to rise with age (Ma, 1999), early interventions for mathematics anxiety are crucial.

What determines whether students give up or embrace an obstacle and work to overcome it when they struggle with their schoolwork? What skills can be developed in the classroom that effect academic success? Kautz and colleagues (2014) have found that noncognitive abilities are more malleable than cognitive abilities during the adolescent years. Noncognitive abilities examples are memory, attention, emotional maturity, empathy, interpersonal skills, and verbal and non-verbal communication. The predictive power of non-cognitive abilities seems to rival that of cognitive skills. Noncognitive skills predict educational achievement, labor market success, health, and criminality (Kautz et al., 2014). Moreover, a growing body of empirical research shows that noncognitive skills rival IQ. For students to succeed both inside and outside of the classroom, noncognitive abilities are crucial.

In achievement tests, both IQ and noncognitive skills predict scores, but noncognitive skills predict results above and beyond their effect in predicting scores on achievement tests (Kautz et al., 2014). Skills empower individuals. A greater level of skill encourages social integration and promotes personal and social growth, economic efficiency, and well-being. Skills provide people with the tools to shape their lives and thrive. Improving noncognitive skills early in life lays the foundation for meaningful and successful life outcomes (Duckworth et al., 2007). An array of positive personal attributes has emerged in the last ten years as important predictors of success in school and life. In particular, grit and the growth mindset have received attention from both researchers and practitioners (Duckworth & Gross, 2014; Yeager & Dweck, 2012). Grit is defined as perseverance toward a set goal, and it is related closely to conscientiousness (Duckworth et al., 2007). Grit has been shown to be correlated with grade point averages and educational achievement in college. Therefore, grittier students are more likely to graduate from high school. In response to failures, a student with grit will set high-performance goals and persevere if their perceived efficiency of effort is sufficiently high (Duckworth et al., 2007).

There are some components of Duckworth's work are important to the current study because building on students' noncognitive abilities such as perseverance, courage, passion, and resilience can serve as effective interventions for students with high mathematics anxiety. Even with research scholars' criticism of Duckworth's work around "grit", which emphasizes grit is a way of "blaming the victim" rather than taking up larger social, economic, and racial justice questions (Mehta, 2015), working on noncognitive abilities in the classroom may still be beneficial for students to strengthen their character if they are lacking noncognitive abilities.

The term "growth mindset" was proposed by Carol Dweck (2016) as the belief that you can cultivate your qualities through effort, whereas in a "fixed mindset," you believe your qualities cannot be changed through effort because they are permanent. Yeager and Dweck (2012) suggested that students in adolescence (middle school) need opportunities to build resilience through small failures that are just beyond their academic, social, or physical abilities. This fuels the willingness of students to want to try again as the goal remains within reach. This process develops, in essence, a growth mindset. In addition, during adolescence, they are more likely to take risks in a positive classroom environment and struggle in front of their peers (Yeager & Dweck, 2012). It is vital for teachers to foster the development of a growth mindset throughout multiple subjects and across the academic careers of students.

Academic Mindset Interventions

In a study by Paunesku et al. (2015), the researchers aimed to test if academic mindset interventions could effect academic outcomes when delivered to large samples. If so, their results could take theory into practice and serve as a model. This study also could serve to justify investments in psychological approaches to social and educational improvement. The researchers specifically addressed the following questions: Can psychological science provide scalable techniques to improve students' approach to learning and achievement in high school? Are academic mindset interventions a practical way to raise achievement in the United States, especially for under-performing students?

To investigate if mindset interventions could be effective on a large scale, the researchers converted current in-person interventions into short computer-based modules. Computerized interventions enabled the distribution of materials exactly as constructed without researcher involvement or preparation. The researchers removed geographic restrictions, opening up student access to many schools and locations farther from study centers, and they minimized logistical demands greatly, marginal expenses of additional participants, and the cost of gathering large-scale assessments of data (Marks et al., 2007). The researchers concentrated on interventions for a growth mindset and sense of purpose because they appeared more fitting for an initial attempt to scale these interventions to heterogeneous populations using standardized tools in an hour or less.

The study was conducted in 13 geographically diverse high schools located in the Eastern, Western, and Southwestern United States. One school was private, four were charter schools, and eight were public schools. The schools varied in socioeconomic status. The sample consisted of 1,594 students (800 males and 794 females). All four grade levels were represented, 82% freshmen, 4% sophomores, 10% juniors, and 4% seniors. Additionally, students were 33% Hispanic, 23% White, 17% Asian, 11% Black, and 15% classified as "other."

The students were administered two 45-minute sessions in the school computer lab about 2 weeks apart during the spring semester. The activities were described to the students as a Stanford University study about why and how students learn. The study website randomly assigned each student to a control condition or one of the three intervention conditions: growth mindset intervention, a sense of purpose intervention, or both interventions combined.

In the first condition, the growth mindset intervention used in this study drew directly from past research and was revised for an effective 45-minute single online session. In the first exercise, students read an article about the capacity of the brain to build and reorganize itself as a result of hard work and successful strategies. The article concentrated on the consequences of neuroscience results on the ability of students to become more intelligent with practice and study. In the second exercise, the students read about a hypothetical student who became frustrated and began to think of himself in school as not smart enough to do well. In order to advise this learner, participating students were asked to use what they had read.

In the second condition, the sense-of-purpose intervention was structured to help students explain how schoolwork will help them attain meaningful life goals. The students were first asked in the intervention to write briefly about how they wished the world could be a better place. It went on to explain that many students work hard in school because they want to grow up to make their families proud, or to be a good example for other people to make a positive effect on the world (Paunesku et al., 2015). Students were then asked to think about their own goals and to write about how they would help them reach these goals by studying and working hard in school.

The third condition was the control group, and students completed one of two modules that were similarly formatted and did not vary in their effect from each other. One treatment asked students to explain how in high school their lives varied from before high school. The other was somewhat close to the sense-of-purpose treatment, but as a justification to work hard in school, it suggested economic self-interest rather than voluntary actions. The researchers included a second condition of control to establish a focus beyond the self-goals, not just any potential personal future goal. This component was a theory backed by prior work, an integral component of the intervention (Yeager et al., 2014).

At the start of Session 1 and the end of Session 2, brief psychological measures were administered. In addition, this study examined students' interpretation of mundane academic tasks using the meaningfulness of schoolwork tasks that assessed whether students viewed schoolwork at a mechanical level or as germane to growth and learning. Three coding methods were used to measure academic performance providing comparable results. Lastly, students' end-of-semester GPAs in core academic courses were calculated both in the fall (preintervention) and the spring (postintervention). The focus was on core academic courses because they are the most challenging and crucial to student success.

The goal of Paunesku et al.'s (2015) study was to answer the following questions: First, are academic-mind-set interventions effective on a small scale only with carefully managed administration? Second, do they have the potential to scale up and thereby serve as a partial solution for pervasive underachievement in U.S. high schools? Based on the results, Paunesku et al. concluded that the two interventions delivered online, each lasting 45 minutes were successful in raising achievement in a large and diverse group of underperforming students over an academic period. For the bottom third of the student sample, the interventions raised their GPA in core academic classes. The results suggest the possibility of the methods tested in this study being applicable for dissemination and evaluation on a larger scale. Moreover, these effects were obtained from a sample of heterogeneous schools and scaled virtually to 1,594 students at a low marginal cost. Lastly, the interventions tested were drawn directly from intellectual psychology, theory, and laboratory experiments.

The researchers also concluded that a critical next step would be to examine how mindset interventions interact with diverse populations. Although the sample in this study was large and heterogeneous, nonetheless, they recognized it was a convenience sample. Additionally, they also suggest examining long-term effects among high-achieving students for whom the benefits of mindset interventions may not appear until courses become challenging either in high school or college.

This study was the first to test whether psychological interventions practically could be deployed to raise academic achievement on a wide scale. The results served as a model for research, taking theory into practice, and contributing to motivation literature. For practitioners, such as myself, these findings can be used in supporting a large number of diverse students who underperform in core academic courses by implementing mindset interventions at a large scale with a low marginal cost.

Grit and Growth Mindset During Adolescence

A number of beneficial personal characteristics have emerged in recent decades as predictors of achievement in school and life. More specifically, grit and a growth mindset have garnered attention from researchers and practitioners alike (Eskreis-Winkler et al., 2016). Little is understood, however, about how these traits impact the growth of each other. For 2 academic years, the researchers tracked more than 1,600 adolescents. They established four test points to measure grit with self-report questionnaires and instructor evaluations and, in parallel, measured growth mindset using self-report questionnaires. They defined grit to be the tendency to pursue long-term goals with steadfast dedication (Duckworth et al., 2007). Although orthogonal to intellect grit, the same achievement results can be predicted, including report card scores, lifetime academic achievement, work performance, and retention (Duckworth et al., 2007). Grit can be altered like other personality traits by environmental factors; for example, middle-school students who view their school cultures as promoting learning for the sake of learning exhibit rank-order increases in grit relative to their peers, which in turn forecast rank-order changes in report card grades (Park et al., 2018).

Several studies have shown that grit offers incremental predictive validity over and above conscientiousness for achievement performance, particularly for personal importance of goals, not only in U.S. samples but also cross-culturally. A growth mindset, similar to grit, also leads to adaptive cognitive and behavioral outcomes. For example, people with a growth mindset prefer to select difficult tasks that help them improve rather than simpler choices that eliminate errors (Hong et al., 1999). Students with a growth mindset associate their failure with a lack of effort or inefficient learning strategies after experiencing a setback, whereas those with a fixed mindset are more likely to blame their deficiency of ability (Park et al., 2018).

Several cross-sectional studies have shown a positive correlation between grit and growth mindset, but not at levels approaching unity. This understanding is also confirmed by brain imaging studies; whereas both grit and growth mindset are related to functional connectivity between cognitive-behavioral regulation regions, grit is related to connectivity between regions related to potential rewards, and growth mindset is related to connectivity between regions involving error monitoring (Myers et al., 2016). In addition, Duckworth (2016) proposed that a growth mindset might lead to grit. The growth of positive attributes such as grit and a growth mindset are important throughout life, but during adolescence, it is especially critical. Stress appears to increase during these formative years, whereas self-esteem, perceived ability, school commitment, and grades decline. Because normative development can have lifelong consequences, Park et al. (2018) found it essential to investigate personal attributes during this period when students can become resilient and flourish.

Park et al. (2020) conducted a longitudinal study of adolescents and repeatedly measured grit and growth mindset to test their hypothesis that the development of these personal attributes is mutually reinforcing. Data analyses were motivated by theory and specific research questions of interest. In addition, the researchers used autoregressive cross-lagged (ARCL) models because they were interested in whether grit measured at an earlier point in time predicts grit at a later point in time. This study adds to the current literature by revealing normative rank-order stability in grit and growth mindset over two academic years, commitment, and perspective effects between the two variables.

The study was conducted in eight middle schools from California, Idaho, Pennsylvania, and Texas. The sample consisted of 1,667 eighth graders (49% female and 51% male) with an average age of 13.75. Participants were recruited from a larger longitudinal study on character development during adolescence. Approximately 89% of the participants invited took part in the study, and during the second year of the current study, these students entered one of seven high schools. Participants in this study were 49% African American, 24% White, 15% Hispanic, 10% Asian, and 2% categorized as "other." Additionally, 66% of participants qualified for free-or-reduced-price meals. The sample was representative of the populations of schools from which it was taken. A total of 145 teachers participated in the study through four time points. Students were rated on grit, an average of 2.57 by teachers, and each teacher was rated on grit, an average of 69.74 by students. In order to maximize the available data, student data were retained for all individuals who provided information on at least one variable included in the analyses.

The researchers collected data during the fall of eighth grade (Time 1), spring of eighth grade (Time 2), fall of ninth grade (Time 3), and spring of ninth grade (Time 4), approximately spaced 6 months apart. Students who were not available during the fall of eighth grade were allowed to participate if parents and students gave their approval at each moment of data collection. Under the supervision of either an instructor or a researcher, all participants took the survey using school laptops.

Students completed five age-appropriate items adapted from Duckworth's (2007) original Grit Scale using a 5-point Likert response scale ranging from 1 = *never* to 5 = *always*. The researchers averaged the five items to create self-reports of grit for each time point. In parallel, teachers from four major classes, such as English, mathematics, social studies, and science, were asked to score each student on a single item using the same response scale. In addition, teachers saw the same five grit items that students filled out for themselves and provided each student with one global rating of grit. Due to the teacher ratings of the same students demonstrating high interclass correlation coefficients, the researchers decided to average teacher ratings for each student at each time point to create a composite teacher rating of grit. Following common practice, the researchers then averaged the composite teacher rating with mean self-reports from students to create composite grit scores. To measure growth mindset, the researchers used items from Dweck's scale (2016); the 6-point Likert scale ranged from 1 = *strongly disagree* to 6 = *strongly agree*. All items were reverse coded so that a higher growth mindset endorsement was represented by a higher score. Since beliefs are internal and cannot, therefore, be directly observed by teachers (Vazire, 2010), teachers were not asked to rate their students on their growth mindset.

For cognitive ability, the researchers included IQ scores as a covariate because prior studies indicated that grit and growth mindset have nonsignificant or negative correlations with cognitive ability (Duckworth et al., 2007). The Mill Hill Vocabulary Scale (1965) was used to measure IQ because it is highly correlated with other valid IQ tests. Additionally, the researchers included for each student, the following demographic covariates, gender, ethnicity, free-or-reduced-price meal status, and school affiliation. For all models, demographic covariates and cognitive ability were controlled.

The results indicated correlations of the main variables, Grit (r = .53 to .75) and growth mindset (r = .39 to.58) to have been moderate to large rank-order instability for over 2 years. Grit and growth mindset were moderately correlated at each wave and, in addition, across waves (r = .18 to .23). All autoregressive paths were statistically significant, suggesting that grit and growth mindset demonstrate substantial rank-order stability. Also statistically significant were, the cross-lagged paths from grit to growth mindset and the paths from growth mindset to grit. The results suggested that grit and growth mindset reciprocally predicted each other's developmental trajectories. Exploratory analyses revealed no reliable and systematic moderation effects by demographic covariates.

The present study was the first to investigate the longitudinal development of personal attributes that have been shown to predict academic achievement in separate research studies. In over four consecutive waves of data collection, the pattern of results was consistent and did not change by ethnicity, gender, or socioeconomic status. The predictive validity of grit for growth mindset (average $\beta = .07$) was double that of growth mindset for grit (average $\beta = .03$). The findings of this study are in line with clinical research indicating that cognitive changes can be affected by changes in behavior.

Park et al. (2020) found even with earlier beliefs, adolescents who believed that intellectual ability is malleable worked steadily toward demanding goals. Consequently, these adolescents worked steadfastly toward challenging goals. Moreover, higher measured grit predicted subsequent rank order increases in a growth mindset. These relationships of reciprocity suggest that interventions during adolescence can precipitate upward spirals for behavior and adaptive beliefs. As a practitioner, these findings provide evidence that indeed both grit and growth mindsets can be altered by environmental factors during adolescence. Therefore, the excuse from practitioners that there is not much they can do to motivate students has no merit.

Yet, Park et al. (2020) left the following remaining question unanswered: Is the observed effect driven more by the passion of the perseverance component of grit? Future research is needed to answer this question even with the authors' belief it is possible that the perseverance component of grit resulted in their findings. Moreover, future research also is needed to investigate how beliefs about the malleability of abilities other than intelligence relate to grit. Growth mindset interventions have shown to increase academic achievement; however, far less is known about how grit can be developed. Lastly, the researchers conclude that an intervention aimed at beliefs about passion therefore could be a promising path for a future grit intervention.

Worked Examples for Instructional Support

Carroll's (1994) study provides instructional support for high school students in an algebra classroom. The purpose of this study was to investigate if students could successfully use worked examples for self-instruction, support, and change beliefs about the students' ability to learn mathematics. This study examined the effects of having a greater range of examples to reduce the number of faulty inductions made among students with low achievement. Additionally, the study addressed the issue of students not having anyone to assist them with Algebra problems outside of the classroom; therefore, a homework format that included worked examples provided the scaffolding students needed at home.

Sweller's studies (Sweller, 1989; Sweller & Cooper, 1985) of worked examples in teaching mathematics are grounded in research on mental schemata, knowledge, automaticity, and expert-novice comparisons of cognitive psychology. According to Sweller and his colleagues, expertise in a domain is not the result of general problem-solving skills but rather a highly automated and interconnected knowledge base or schemata. Schemata are cognitive structures that assist a problem solver in classifying a situation in light of pertinent characteristics and then indicating the best solutions for that particular problem type (Brown & Borko, 1992). Several past studies also have suggested the importance of mental schemata in mathematical domains such as representing, categorizing, and solving mathematical word problems; constructing word problems; recalling relevant information from word problems; transferring knowledge across problem types; recalling algebraic equations.

What methods of instruction enhance schema acquisition? Sweller's studies (Sweller, 1989; Sweller & Cooper, 1985) suggested that extensive use of worked examples may be instrumental in developing such schemata. Because working examples show different issue types in their starting state and provide the appropriate actions for that problem type, they free up cognitive capacity for faster knowledge acquisition. This is because they provide the precise data that should be recorded in a schema (Sweller, 1989; Sweller & Cooper, 1985). Apart from cognitive load theory, the goal of Carroll's study was intended to extend the research on worked examples to an urban-school setting in which students began to study Algebra after 8 years or more of solely arithmetic.

Experiment one

Forty participants were students (19 female, 21 male, 15 to 17 years of age) enrolled in urban high schools where the dropout rate approached 50%, and standardized test scores were far below the national norms. Approximately one month before the experiment, all 71 students were in three levels (honors, regular, basic) of first-year algebra classes taught by the same instructor. The students were administered a 20-item test that assessed the students' knowledge of arithmetic and basic algebra. In each of the three classes, students were paired on the basis of their scores and randomly assigned to either a worked example or a conventional practice group. Due to attrition, only 20 pairs participated in this experiment. The scores from the placement test were used to define a second variable, achievement. Students who scored above the median were identified as high achievers, and students that scored below the median were identified as lower achievers. Although the term high achiever was used in this study, the term needs to be considered in light of the school population and standardized test scores far below the national norms.

All students in the study began with an instruction period with a worksheet on writing equations that included three examples and three practice problems then, after a discussion of the worksheet and the sample problems, the students were asked to complete the three practice problems. The practice problems were checked as a class. Additional questions were solicited from the students before proceeding. The questions asked by the students were all of a procedural nature regarding the three practice problems. After the students' questions had been answered and the instructional examples and problems collected, the students received a practice worksheet with 24 problems. The worked examples group had a worksheet that contained 12 worked examples, each followed by one similar practice problem. The conventional practice group received the same worksheet with 24 problems in the same order, but none of the problems had a worked example. The worked-example students had additional instruction in the form of the worked example and had fewer practice problems than the conventional-practice students. Target problems that were to be solved by both groups were used in an analysis of errors. A 20-minute acquisition time was given, the instructor was available to all students, and they were assisted in the order in which they requested help. The conventional practice students were first asked to think about the initial problems or about a similar problem they had completed, and additional guidance was provided as needed. Teacher support by group only differed in that the worked-example students were reminded to use the examples, and the conventional practice students were given more direct guidance from the teacher.

At the end of the 20-minute acquisition time, worksheets were collected, and an 8-item test was given to the students. After the test, a 20-item worksheet was assigned for homework. Mirroring the classroom worksheets, 10 of the problems were worked, and each problem was followed by one similar practice problem for the worked-example group. The conventional practice group had the same 20 problems without any worked examples. On the following day, all students were administered a 12-item test,10 of the items involved direct translation and the final two were transfer problems. No worked examples were available to students during the test.

For experiment 1, a 20 (block) x 2 (achievement level) x 2 (group) randomized block analysis of variance (ANOVA) was analyzed. ANOVAs also were carried out on the number of errors on the in class worksheet, on the homework, and on the two transfer problems on the delayed posttest. For the homework analysis, students who did not return the homework were paired, which removed 10 pairs from the homework analysis, and three pairs were deleted from the delayed posttest analysis because of absences. In these ANOVAs, with the group worked examples was statistical significant on the worksheet, F (1, 18) = 19.40, η^2=.52 on the posttest, F (l, 18) = 5.83, η^2=.24 on the homework, F (l, 8) = 5.45, η^2=.41 and on the delayed posttest, F (l, 15) = 5.02, η^2=.25 On all five measures, the worked-example group statistical significantly and practically importantly outperformed the conventional practice group. There was no statistical significant difference on the two delayed posttest transfer problems. The achievement was statistically significant only on the worksheet, F (l, 18) = 5.50, η^2=.23, with high achievers outperforming low achievers. No group x achievement level interactions were statistically significant (Carroll, 1994, p. 362). Although there were no Group x Achievement level interactions, results by class suggest that the worked examples were a very useful tool for students identified as low achieving. Similar results were found on the posttest, which were fully in line with the researcher's expectation that worked examples could be used successfully for self-instruction and support in learning mathematics.

The findings of experiment 1 suggest that for students in the conventional practice group, 30% of attempted target problems resulted in errors, whereas in the worked example group, 10% of attempted target problems resulted in errors. The students skipped 9% of the target problems, and the worked example students generally completed all items on the worksheets in which only 2% of the problems were not attempted. The worked example group required almost no assistance from the instructor, therefore successfully using worked examples as self-instruction. Additionally, both groups made nine reversals. The conventional-practice group, however, had three nonattempts on these problems, and 10 additional errors, whereas the worked-example group made only three other errors; these results were reflected in the posttest. Therefore, Carroll (1994) concluded that the worked examples were a very useful tool for students identified as low achieving and especially helpful for students who were deficient in mathematical language or for students in the process of learning English. The participants in experiment one are relevant to the current study because they are like the participants in this study—low achievers in mathematics and second-language learners. Worked examples can be used in the current study for successful self-instruction and support in learning mathematics in middle school. Using worked examples with similar participants provided the scaffolding students needed in the classroom and home.

Experiment two

The participants were 24 students (12 female, 12 male, ages 14 to 16 years) enrolled in Pre-Algebra in the same high school as in Experiment 1. All students were classified as low achievers with low mathematics scores on standardized tests and enrolled in a remedial mathematics course. One week prior to participating in the experiment, these students were administered a 12-item pretest on writing equations from written expressions. The pretest was identical to the delayed posttest in Experiment 1. According to these test scores, students were paired and assigned to either the worked-example or the conventional-practice learning condition.

After a 40-minute instruction period, explanation, and discussion, each student was given three practice problems with English expressions to translate into equations, and each student received individual instruction. During this time, the three worked examples were available, and the experimenter answered any questions and assisted the student as necessary. Problems were checked, and any errors made by students on the three practice problems were corrected and explained. Instruction was followed by a 10-minute acquisition period during which students received worksheets, and both groups completed the identical problems in the same order. Each of the three worksheets had 12 problems each. As students completed each worksheet, they were administered the next worksheet until they had completed all three or until the 10 min had elapsed. In the conventional-practice group, each worksheet contained 12 practice problems as in Experiment 1. The students in the worked-example group had half of the problems worked, and each worked-example was followed by one similar practice problem. Before starting the worked examples, students were instructed to study each example before doing the similar practice problem that followed. Students were instructed to refer to the examples when necessary. The conventional-practice students were informed that the problems they had received were like the ones they had studied and practiced before. The experimenter gave the students no assistance during this time, and the instructional sheet was not available. After the acquisition time, the worksheets were removed then students were administered a posttest identical to the pretest. Only the target problems that were to be solved by both groups were analyzed.

The results in experiment 2 suggested the worked-example group outperformed the conventional practice group on all four of the postinstruction measures (see table 1). The * means the difference is significant at the .05 level. Paired sample t tests showed that the learning condition was statistically significant on errors during acquisition time, statistically significant on practice problems undone, statistically significant on acquisition time, and statistically significant on posttest. Paired sample t tests by the group showed a statistically significant improvement between the pretest and the posttest for the worked-example group but not for the conventional-practice group.

Table 1

Experiment 2 (worked-example group)

	WE (n=12)		CD (n=12)		t	
Measures	*M*	*SD*	*M*	*SD*	df=22	η^2
Errors during Acquisition	2.25	1.36	13.50	3.00	12.09*	.52
Practice Problem Undone	0.33	0.65	4.92	2.64	5.58*	.34
Total Acquisition Time (Minutes)	8.11	1.65	9.36	0.82	2.65	.19
Posttest errors	5.08	2.47	6.42	2.11	2.40	.18

*Statistically significant at the .05 level.

It should be noted that the worked examples were not used by the students in the way they were intended. Students were directed to study the examples first for understanding and then attempt the accompanying problem. Nevertheless, the examples were successful in constraining errors and in motivating the students to stay on task. Based on the results, the worked examples were successful as in Experiment 1; the posttest showed gains, and the results indicated that no rote copying had taken place. Experiment 2 seemed in agreement with the analysis of Chi and her colleagues about how students with low academic achievement use worked-examples (Chi et al., 1989). Low academic students were more likely to use the examples as they solved the problems rather than studying the examples first. Additionally, experiment two is important to the current study because the researcher concluded that even a brief intervention consisting of worked examples in instruction could statistically significantly influence the mathematics performance of low-achieving students.

Carroll’s (1994) study both supported previous research and contributed to the existing research demonstrating: that students provided with worked examples required less acquisition time, needed less direct instruction, and made fewer types of errors during practice in mathematics. Additionally, this study included a placement test used to define a second variable, achievement. Furthermore, Carroll used a random assignment; students were paired on the basis of their scores and randomly assigned to either a worked example or a conventional practice group. Thus, the study was methodologically sound and gave the researcher credibility. Overall, Carroll's (1994) study is important to the current study because it offers evidence in support of the use of worked examples, that statistically significantly affected low-achieving students' mathematics performance. In the current study, worked-examples will be employed as an effective cognitive intervention.

A Combined Approach (Cognitive & Motivation)

In the past, researchers have looked at improving learning either cognitively or motivationally, but very few studies have looked at interventions that both address cognitive and motivational effects on students. Due to a decline in both mathematics achievement and achievement motivation during adolescence, research is needed to improve student learning in mathematics during this critical time, therefore the need for a combined approach particularly for middle school students learning Algebra. Because algebra is considered a gatekeeper course for higher-level mathematics and college admissions (Schneider et al., 1998).

Barbieri and Booth (2016) provided an intervention aimed at supporting struggling algebra students in middle school. The purpose of this study was to test whether reflecting on errors present in incorrect examples is both cognitively and motivationally relevant for middle-school students learning Algebra. Specifically, does having students reflect on and explain incorrect worked examples during problem-solving practice benefit algebra learning overall? Does studying and explaining incorrect worked-examples increase students' competence expectancy and sense of belonging to mathematics? Can studying incorrect worked examples normalize errors as part of the learning process?

The researchers tested four hypotheses. The first hypothesis was whether studying and explaining incorrect worked-examples would improve student learning overall. The second hypothesis was whether working with incorrect worked-examples would increase students' competence expectancy and sense of belonging to math. Competency expectancy in this study refers to students' confidence in their ability to accomplish a task, therefore, addressing student motivation. The third hypothesis was whether incorrect worked examples would be especially beneficial for students with low prior knowledge in refining algebraic problem-solving as measured by posttest scores. The fourth hypothesis was whether increases in students' competence expectancy or sense of belonging (motivation) to mathematics partially explained the moderation of the effect of incorrect worked-examples by prior knowledge.

The 125 participants in this study were middle-school students from five Algebra 1 classrooms. The participants were comprised of 57 males and 68 females, 97% were in 8th grade, 3% were in 7th grade, and 10.9% were considered low income. Students were classified by categories, according to members of ethnic and racial populations that are underrepresented in mathematics (Hispanic, African American, and biracial; 23%) and nonunderrepresented (White and Asian; 77%).

During the unit on solving systems of equations, students were assigned randomly to receive worksheets with correct worked examples (n=44), worksheets with incorrect worked examples (n=40), or control worksheets (n=41). In the control worksheet group, students were instructed to solve problems in which no worked examples were included. In Time 1, at the beginning of the study, students completed a motivation survey that was then followed by a pretest during the next school day. Students completed four worksheets individually over a period of 5 to 7 weeks. One of the five classes, an accelerated Algebra 1 course, completed the unit in two weeks. Without incentives for completion, teachers allowed students approximately 20 minutes to complete each worksheet. To coincide with each teacher's lesson plans the order of the worksheets given was varied. In Time 2, the motivation survey was re-administered after the completion of the four worksheets. At the completion of the study, a post-test was administered. A within-class assignment was used, and the only factor that varied systematically between the conditions were the types of worksheets received (correct example, incorrect example, and no example).

In both example conditions, students were given four example problem pairs that included examples of fictitious students' correct or incorrect work. Students were asked to study the examples and then respond to self-explanation prompts before solving the "Your Turn" problem paired with the example. In the correct worked examples condition, the correct procedure to the key concept was highlighted within the prompt. In the incorrect worked examples condition, the incorrect procedure was displayed and highlighted. The example groups were asked to explain 16 examples and solve 16 "Your Turn" problems, whereas the students in the control group were asked to solve a total of 32 problems.

Other measurements used by the researchers were the following: (a) students' competency expectancy using a Likert scale (Elliot & Church, 1997); (b) sense of belonging using five statements selected from the original sense of belonging scale; (c) a pre- and postcontent knowledge test with 25 items that assessed students' knowledge about solving systems of equations.

To answer question 1, the researchers conducted a 3(condition) × 2(time) repeated measures analysis of variance (ANOVA) on posttest scores to determine whether incorrect worked examples benefitted algebra learning. The participants demonstrated improvement from pretest to posttest but did not vary by condition; therefore, there was no supporting evidence for Hypothesis 1.

For question 2, the researchers conducted a parallel 3 × 2 ANOVA on competence expectancy and sense of belonging to examine the benefits of motivation. There was a slight but significant decline in competence expectancy from T1 ($M = 5.70$, $SD = 1.34$) to T2 ($M = 5.49$, $SD=1.43$). The proposed motivational benefits of incorrect examples were not supported. The participants maintained a high level of competency throughout the study.

To answer question 3, linear regressions predicting posttest scores were conducted with all of Time 1 and Time 2 scores grand mean. All scores were normally distributed. Results demonstrated that Although prior knowledge statistically significantly positively predicted posttest scores in both the control group ($\beta = 0.34$) and the correct examples group ($\beta=0.30$), it did not predict posttest scores for the incorrect examples group ($\beta=0.04$). The results suggested that students with low-prior knowledge benefited more from the incorrect worked examples condition than the correct worked examples condition or the control group; therefore, Hypothesis 3 was supported.

The final research question posed that incorrect examples may be beneficial for students with low-prior knowledge due to fostering the idea that errors are part of the learning process. Both the increased competence expectancy and sense of belonging to mathematics were expected to increase. Because there were no increases in motivation found in the proposed mediated moderation model, however, Hypothesis 4 was not supported.

Barbieri and Booth's (2016) findings suggest that error reflection was equally beneficial for students across levels of prior knowledge, but incorrect examples were more effective than correct worked examples or problem-solving alone for those who began the study with little knowledge of systems of equations. Using incorrect worked-examples fostered the idea that errors are part of the learning process and provided the motivation for students to solve complete mathematical problems. This finding has great value to both practitioners and researchers who are in the quest of improving learning for students who struggle with Algebra 1. For successful problem solving, prior knowledge has an effect on the students' ability to encode relevant features of algebraic equations (Booth & Davenport, 2013). The researchers attributed their findings to the following explanations: (a) highlighting common errors in incorrect examples provides the support students need to fully benefit from worked examples on procedural knowledge and (b) highlighting errors that represent an underlying algebraic misconception may reduce the prevalence of that misconception and allow students more benefits from the instruction. Students in the correct or incorrect example group were inconsistent with previous worked examples studies conducted in laboratory settings (Booth & Davenport, 2013; Sweller & Cooper, 1985). The students in this study did not have an overall influence on learning by correct or incorrect worked examples.

Barbieri and Booth's (2016) results suggest that students with low-prior knowledge benefited from incorrect worked examples. Exposure to solving incorrect worked examples provided learning benefits for students who needed the most support by allowing them to encode relevant features and misconceptions about a problem. These findings are consistent with previous research. Future studies, however, need to be conducted to further explore the use of standard worked examples prompts, worked examples with self-explanation prompts, worked examples with instructional explanations, worked examples with a combination of instructional explanations, incorrect worked examples and self-explanations, and faded worked examples for students with low mathematics achievement along with classroom implementation.

Barbieri and Booth's (2016) study contributed to the literature on the use of incorrect worked examples for students with low-prior knowledge of algebra. Experiencing student errors or incorrect methods of solving a problem does not interfere with learning algebra. Incorrect worked examples may provide learning benefits for the students who need the most support in mathematics. Algebra is a course considered to be a gatekeeper for higher mathematics courses and college requirements; therefore, using incorrect worked examples for students with low-prior knowledge is beneficial to foster the idea that errors are a normal part of the learning process.

Taken together, Paunesku et al. (2015), Park et al. (2020), Carroll (1994), with Barbieri and Booth (2016) highlighted the importance of the proposed dissertation study, which (a) expands on the body of research around applying cognitive and motivation interventions for alleviating mathematics anxiety in middle school when anxiety is strongest from the ages of 12 to 15, and (b) application of the use of worked examples and incorrect worked examples to free cognitive capacity for more rapid knowledge acquisition. These studies suggest that cognitive and motivational interventions may statistically significantly increase students' comprehension of mathematical concepts. Using a combined approach (cognitive & motivation), Barbieri and Booth (2016) provided students with the support they needed by using worked examples to support procedural knowledge, and incorrect worked examples to highlight common errors in order to reduce the prevalence of misconceptions.

Summary of the Literature

Mathematics anxiety can start as early as first grade and increase during middle school and high school. Wang et al. (2014) found that mathematics anxiety affects both the cognitive capacity to engage in mathematics problem solving and reduced motivation and involvement in mathematics-related activities. Additionally, research has found that mathematics anxiety has a negative effect on mathematical ability, resulting in poor career choices, employment, and professional achievement (Ma, 1999; Scarpello, 2007). Research for improving mathematics performance and mathematics achievement by understanding and alleviating mathematics anxiety in early adolescence has not been robust. In the past, researchers have attempted to increase learning in one of two ways, either using a cognitive intervention or a motivational intervention (Barbieri & Booth, 2016). Using a cognitive or a motivational intervention for addressing mathematics anxiety have proven to be successful interventions on their own merit. Still, what is lacking in research today is using a combined intervention approach to address mathematics anxiety among middle school students. Therefore, the proposed dissertation study will address the need for research on the combined intervention approach (cognitive and motivational) and the influence of a combined intervention both on mathematics anxiety and mathematics achievement versus solely using one intervention (cognitive intervention).

CHAPTER III

METHODOLOGY

The purpose of this study is to investigate: (a) to what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach, and (b) to what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach. The variables that were examined included mathematics anxiety levels, mathematics achievement, and cognitive and motivational interventions. This chapter contains a description of the following sections: research design, setting and participants, instructors, protection of human subjects, treatment, procedures for data collection, data analysis, and position of the researcher of the study.

Research Questions

1. To what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?
2. To what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

Research Design

The purpose of this quantitative study was to learn whether a combined (cognitive and motivation) intervention approach was more effective than only using a cognitive intervention approach for alleviating mathematics anxiety in middle-school students. The design used was a comparison pretest-posttest study using the modified Abbreviated Math Anxiety Scale (mAMAS) to measure the participants' level of mathematics anxiety and the STAR Mathematics diagnostic assessment to measure gradual mathematics achievement. The independent variable of this study was the instructional intervention, in which one group received the cognitive intervention approach and the second group received the combined (cognitive and motivation) intervention approach. This study took place during the first 9-weeks of the semester in August 2022. For a schematic overview of the research design, see Figure 1.

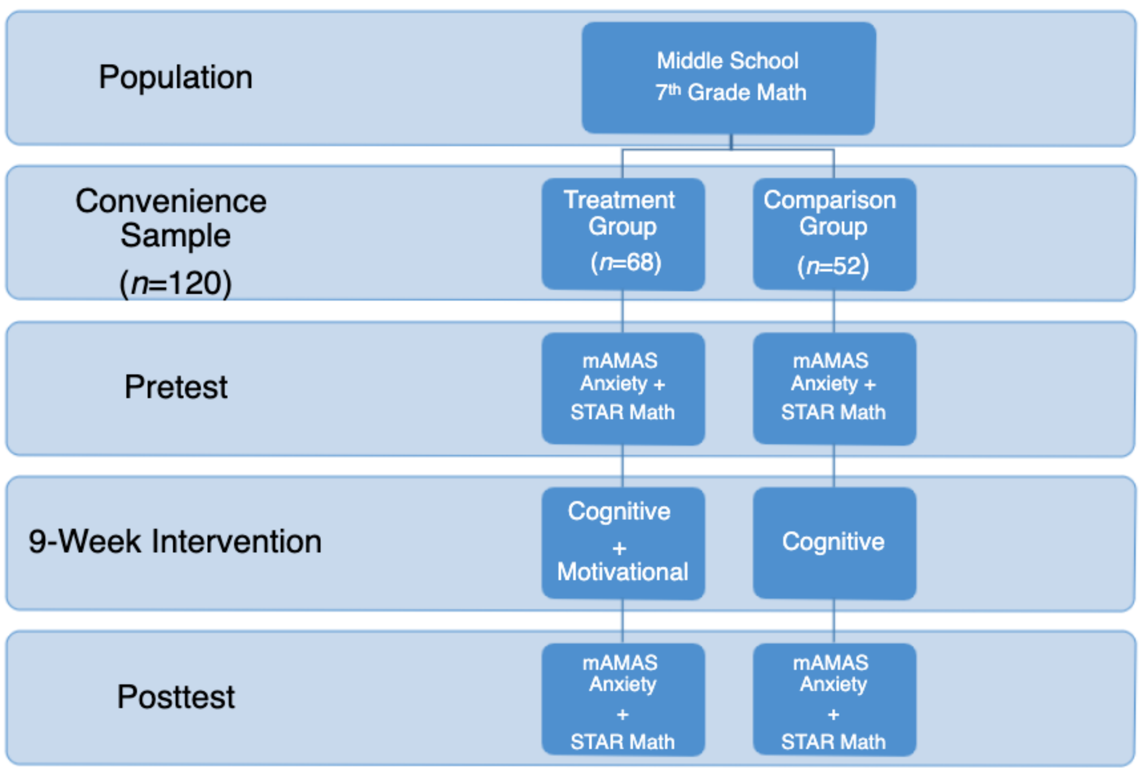

Figure 1. Research design schematic overview

In the cognitive intervention, participants learned from error reflection by using an incorrect example to (a) find the error, (b) explain why an incorrect response is incorrect, and (c) fix the incorrect response and complete the work. In the combined intervention (cognitive and motivation), participants developed a growth mindset by learning how to (a) normalize errors, (b) view mistakes positively, (c) increase confidence in their ability to learn mathematics, and (d) learn from error reflection by using an incorrect example. Dependent variables for this study were the mathematics anxiety levels perceived by the participants and the mathematics achievement as measured by scores on the Standardized Testing and Reporting (STAR) Mathematics diagnostic assessment.

Setting and Participants

The participants are from a middle school on the Central Coast of California. The total enrollment of the middle school is approximately 1,194 students, of which 611 students are in seventh grade and 583 are in eighth grade. The student population was identified as 46.4% Female, 53.6% Male, 91.9% Hispanic or Latino, 3.0% White, 3.6 % Filipino, 2.1% Asian, 0.3% African American, 1.6 % American Indian or Alaska Native, 0.2% Native Hawaiian or Pacific Islander, and 0.2% two or more races. The student body was 90.1% socioeconomically disadvantaged, 30.3% English learners, and 12.4% students with disabilities. This middle school was of interest because of the low percentage of students not meeting or exceeding the state mathematics standards since 2019. The middle school in this study has met or exceeded the state standards in mathematics with only 19% of its population. Additionally, their district average of 22% is below the state average of 40% in California. Data were taken from the School Accountability Report Card 2020-2021. Middle-school students in this sample who are behind grade level in middle school may absorb negative stereotypes and have self-doubt.

The participants for the study were a convenience sample that came from 8 seventh-grade mathematics classes (n =120). Although by definition the student participants in this study were from a convenient sample, these students are from a title one low-performing school. The STAR Mathematics diagnostic assessment was given to all seventh-grade students in order to measure the grade level of each student. From the results of the STAR Math assessment, the participants from both groups ranged in mathematics grade-level skills from second grade to tenth grade. The sample makes up approximately 20% of the seventh-grade class, providing an adequate representation of the academic and demographic diversity of the middle school. Although the student population was identified as 46.4% female and 53.6% male the participants in this study were comprised of more females than males. Demographic information for the participants in this study is provided in Table 2. The choice of using seventh-grade classes for the study was based on the students' first-time experience with a content-specific instructor in mathematics. Both the treatment and comparison groups participated in the 9-week intervention. Students in this study had a rotating schedule; the schedules changed the order of classes every day. One of the benefits of a rotating schedule is that students do not attend the same class at the same time each day because the end of the day is not optimal for learning mathematics when students are tired and eager to go home. Another benefit of a rotating schedule is achieving more homework balance and ensuring that students and teachers are exposed to their best teaching and learning times throughout the day.

Instructors

The teacher for the comparison group (cognitive intervention) in this study was a Latina female from the community. The teacher had 9 years of teaching experience in mathematics, and all of her teaching assignments have been in a middle-school setting. It should be noted that she also was an alumna of the middle school where the study took place. The teacher for the treatment group (cognitive and motivation intervention) was also a Latina female from the community. The teacher for the treatment group was the primary researcher of this study with

28 years of teaching experience. Her teaching experience in teaching mathematics includes an elementary school, middle school, high school, and community college. The teaching assignments for the teacher-researcher have been primarily with second-language learners and students with extremely low mathematics skills. The teacher-researcher has also had 5 years of implementing researched growth mindset interventions in mathematics.

Table 2

Demographic Data for the Participants

		Cognitive Intervention (n=52)		Cognitive & Motivation Intervention (n=68)	
Demographic		f	%	f	%
Gender	Male	21	40.38	30	44.12
	Female	31	59.62	38	55.88
Ethnicity					
	African American	1	1.92	1	1.47
	Filipino	4	7.69	4	5.88
	Latino	45	86.54	60	88.23
	Chinese	1	1.92	1	1.47
	White	1	1.92	2	2.94
Subgroups					
	Mainstream	29	55.77	45	66.18
	English Learner	19	36.54	19	27.94
	Students with Disabilities	4	7.69	4	5.88

Protection of Human Subjects

Prior to conducting this study, the researcher submitted an application and observed all ethical standards and policies of the University of San Francisco Institutional Review Board for the Protection of Human Subjects. The process of receiving approval at the research site proceeded in four parts: (a) Associate Superintendent of Instructional Services, (b) Middle School Principal, (c) Parents, and (d) Participating Students in the Study. The researcher completed the mandated training for the protection of human subjects on July 4, 2022. The supporting and approval emails from the associate superintendent of instructional services and the site principal were both received in July 2022. The process for final site leadership permission took two weeks. The University of San Francisco IRB approved all essential documents that were submitted in July 2022 on August 15, 2022. Due to an expedited request the total duration for the approvals from the research site and USF was approximately one month, from July to August 2022.

Consent from parents and students took approximately 2 weeks to complete. A 5-minute video was created for parents and students to explain the process, the anonymity of student data, and the rationale for the study. The video provided all students (from both the treatment and comparison group) with key information about the study. In addition, teachers from both the comparison and treatment groups answered parent and student questions about the study when they arose.

Data were gathered in compliance with American Psychological Association (2020) guidelines for research. Students' names were coded as ID numbers so no one could identify a particular student. The ID numbers of students were used to match pretests and posttests. Documents with student data were password-protected. All identifiable information through email and data collection was coded using participant ID numbers to ensure participant anonymity. Participant data were stored separately from any other raw or recorded data. Given the use of informed consent and confidentiality protocols, there were no anticipated risks to participants in the present dissertation study. Participants were not paid for their participation, were not given gift cards, they did not receive special course credits. By participating in the study, students had the opportunity to learn cognitive or cognitive and motivation strategies to alleviate mathematics anxiety.

Treatment Description

The independent variable for this study is the instructional intervention, which had two levels: (a) cognitive intervention and (b) cognitive and motivational intervention. Approximately 68 students participated in the combined treatment, and 52 students participated in the cognitive treatment, which was based on the unit for integers, fractions, similar figures, and percentages.

Cognitive Intervention

The cognitive intervention used in this study was incorrect worked examples taught by the co-teacher to the comparison group and by the researcher to the treatment group. Additionally, common lesson plans were used, and common assessments were used to measure student mastery of mathematical content. First, a mathematics topic or concept was taught for 2 to 3 days. Second, students were given an activity to check for mathematical comprehension and misconceptions. Third, an incorrect worked example was deployed after the midway checkpoint. Fourth, the researcher and the coteacher worked together to analyze student work to find student mistakes and constructed a worksheet with two to four common mistakes from the checking for understanding activity. Pseudonyms were used to share examples of student mistakes. Finally, students were asked to complete the following on the worksheet: (a) find the error, (b) explain why an incorrect response is incorrect, and (c) fix the incorrect response and complete the work. The cognitive intervention was systematic for 9 weeks giving students 9 worksheets of incorrect worked examples to reflect on errors (see Appendix B).

Combined Intervention

The combined cognitive and motivation intervention was taught by the teacher-researcher. The cognitive intervention used the same treatment as the comparison group. In addition, a motivation intervention was integrated along with incorrect worked examples with lessons to support the development of a growth mindset. Students learned to normalize errors and view mistakes positively to help internalize that mistakes are learning experiences and are part of the learning process. Assisting students in learning from their mathematical mistakes can provide insight into their misconceptions and assist them in building a deeper understanding of the mathematics they are learning.

The language around student mistakes during the 9-week combined intervention was delivered in a supportive and constructive manner, for example: “Mistakes are proof that you are trying,” “I’m glad you made that mistake; it means you’re thinking about the problem, and you can learn from it,” and “Mistakes help your brain grow.” To help students develop a growth mindset about learning mathematics and embrace mistakes as opportunities for deeper learning, they completed a curriculum from an online student course offered by Stanford University featuring Professor Jo Boaler. This online course was chosen to be used in this study because the course was designed to change students' ideas about mathematics, change their potential and improve students' mathematics achievement (Boaler et al.,2018)

The massive open online course from Boaler and colleagues (2018) was implemented as an intervention immersed with growth mindset messages into mathematics, especially targeting the beliefs students hold about learning mathematics. The results of Boaler et al's study found the treatment group (online participants) obtained higher scores on the following: Smarter Balanced Assessment Consortium; mindset change; mathematics creative change; fear of mathematics change; and change in student engagement reaching statistical significance in all categories.

The online course consists of a total of six sessions, with the first three lessons lasting roughly 10 minutes, each and the final three lessons lasting approximately 20 minutes each. The Stanford free student course taught students about their own ability to succeed and the strategies required to approach mathematics effectively. The following are the titles of the six sessions presented in this course: (a) Knocking Down the Myths about Math; (b) Math and Mindset; (c) Mistakes and Speed; (d) Number Flexibility, Mathematical Reasoning, and Connections; (e) Number Patterns and Representations; (f) Math in Life, Nature, and Work. This course supported students to develop a growth mindset and helped the researcher to create a mistakes-friendly environment for students to use the power of the word "yet." The word "yet" provided the confidence to continue learning regardless of mistakes made when learning mathematics. See Appendix B for a detailed outline of the motivational lessons and the curriculum for both groups.

Procedures For Data Collection

After receiving approval from the district, the middle school-principal, parents, and the University of San Francisco Institutional Review Board for the Protection of Human Subjects, the researcher obtained access to data from the STAR Math test. All the seventh-grade students took the STAR Math test during the first week of school in order to identify grade equivalency. The data were used to identify the grade levels of the treatment and comparison groups. Using the STAR Math test as a pretest provided data for both groups of participants in order to classify and compare mathematical skills. This pretest helped assess the similarities and differences between the groups. Then the teacher-researcher selected four classes for the comparison group with similar grade equivalency to the treatment group. In addition, a second pretest (mAMAS) was administered during the third week of school when students were settled into their seventh-grade mathematics class, and their anxiety is not above normal due to the first week's worries of a new school and having six different teachers. Each group was composed of four classes, with 68 students participating in the combined treatment and 52 students participating in the cognitive treatment.

During the third week of school, both the cognitive only intervention and combined intervention were implemented for the duration of 9 weeks. For each of the 9 weeks, both teachers met every Monday for 2 hours to plan lessons and select a checking for understanding strategy for the learning objective. Additionally, they met each Wednesday to review student work to construct an error analysis worksheet with incorrect worked examples of actual student mistakes using Pseudonyms to protect anonymity. At the end of the 9-week intervention, the researcher collected the posttests: both the mathematics anxiety survey (mAMAS) data and Math Star data.

Data Analysis

The following research questions were investigated in this study:

1. To what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?
2. To what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

To address the first research question, an independent-samples *t* test was conducted to investigate the difference between the combined intervention approach and cognitive intervention approach for pretest, posttest, and the change from pretest to posttest for the mAMAS questionnaire. Subsequently, there were no statistically significant differences found on the pretest, therefore an analysis of covariance (ANCOVA) was not conducted on the mAMAS questionnaire posttest scores with pretest mAMAS scores as the covariate. Levene's test of equality of variances was conducted to verify the assumption of homogeneity of variance. The significance value (*Levene's* $F = 1.05$, $p = .30 > .05$) was not significant, which confirmed that the treatment and comparison group variances were equal. When conducting the statistical analyses, the significance level was set at .05 for each two-tailed test.

To address the second research question, an independent-samples *t* test was conducted to investigate the difference between the combined intervention approach and cognitive intervention approach for pretest, posttest, and the change from pretest to posttest for the STAR Math test. There were no statistically significant differences on the pretest, therefore, an ANCOVA was not conducted on the STAR Math posttest scores with pretest STAR Math scores as the covariate. Levene's test of equality of variances was conducted to verify the assumption of homogeneity of variance. The significance value (*Levene's* $F = 1.05, p = .30 > .05$) was not significant, which confirmed that the treatment and comparison group variances were equal. When conducting the statistical analyses, the significance level was set at .05 for each two-tailed test.

Effect sizes

Cohen's *d* is a measure of practical importance that describes the standard deviation difference between group means. Based on independent samples from each group, the effect size is used to determine whether the unknown means of the two populations are different from one another. The sample size in this study was relatively large for each group (treatment $n=68$, comparison $n=52$), and including effect size provides an understanding of the magnitude of differences found in the data. Effect sizes were calculated for research questions one and two. Eight-tenths of a standard deviation difference, or an effect size of $d >.80$, is regarded as having a large effect. A difference of half a standard deviation, or $d >.50$, is regarded as having a moderate effect. A difference of two-tenths of a standard deviation, or $d >.20$, is regarded as having a small effect.

Position of the Researcher

I strongly believe that becoming an educator and leader in education is my life's purpose; therefore, obtaining the knowledge behind a doctoral degree will add to my professional credibility both as a practitioner and a researcher. During my 28 of teaching experience, I have taught in elementary school, middle school, high school, and community college that has provided me with a wide perspective of the educational system. In each grade level, I have chosen to work with at-risk students and implement both academic and behavioral interventions that are researched based. Additionally, I have served as Department Chair, Mathematics Lead, Instructional Coach, Administrator, and `Intervention Specialist working with academics and behavior systems. I am a firm advocate of Professional Learning Communities.

My educational philosophy is a child's education goes far beyond a classroom, a textbook, and homework. A child's education is an opportunity to accept knowledge, share experiences, discover new relationships, and ultimately build a strong and independent mind. Educators must be prepared to adapt continually to meet the needs of the ever-changing populations of children flowing through schools, so those children can, in turn, actualize their full potential as adult citizens in a productive global community regardless of ethnic background and socioeconomic status or language.

My educational philosophy is due to my personal experiences as a student in the K-12 system. I was a migrant student who attended at least three schools a year from California to Arizona. My parents followed the seasonal crops moving several times throughout the school year. I fell behind in reading, writing, and mathematics by two to three grade levels. Although I struggled to learn, I loved school. When I struggled in school, my parents were not able to help me with my homework. My father had a third-grade education, and my mother had a sixth-grade education. Although both of my parents were born in the United States, they were under schooled and could only encourage me to try my best like many Latino parents.

After high school, I wanted to attend UC Santa Cruz because that was my dream college. I failed Algebra in 9th and 10th grade; therefore, I had to take basic mathematics classes to graduate high school. Then I had to attend a community college because I did not meet the UC admission requirements for mathematics. When I attended Hartnell Community College, I was nervous about mathematics because I had failed Algebra twice in high school and had lost the opportunity to attend UC Santa Cruz. Once again, I failed my Algebra courses for 2 more years.

It was then that I learned that I had dyslexia, attention deficit disorder, and mathematics anxiety. Now, I knew why learning was so difficult for me, yet during my K-12 years, no one had identified my learning difficulties or taught me learning strategies to be successful.

I believe that the true "gatekeeper" are teachers and not Algebra. Why do I believe that? I believe that teachers hold on to myths that shape students' minds. Teachers believe that speed is important for mathematicians to do mathematics in their heads quickly. They believe some students have a mathematical mind and some do not, which is simply not true! At community college, I met an instructor who changed my life, Mr. Rand. Instead of putting myself down, he helped me look at things from a positive perspective. I understood his teaching style, and I felt confident and loved learning mathematics. Looking back, I realize that he used both cognitive and motivational interventions to help me be successful in mathematics. I became a mathematics teacher because I, too, want to inspire students to love mathematics as Mr. Rand inspired me. Failing algebra was one of many obstacles I had to overcome in the educational system. Mistakes are learning opportunities, and mathematics teachers must explain to students that mistakes are part of the learning process. Our brain actually grows when we make mistakes. When we make a mistake, an electrical signal moves between parts of the brain that is, when learning occurs. I never knew this as a young student, and students today must understand that learning is a process at an early age in order to avoid mathematics anxiety.

CHAPTER IV
RESULTS

This quantitative study aimed to learn whether a combined (cognitive and motivation) intervention approach is more effective than only using a cognitive intervention approach for alleviating mathematics anxiety in middle-school students. A classic treatment-comparison repeated measures pretest-posttest design was used for research questions one and two. All quantitative data were analyzed using a series of independent-samples *t* tests between treatment and comparison groups for each variable. In this chapter, the findings are reported by research questions. Descriptive statistics about the sample, including means and standard deviations are presented. The results from the *t* test and effect sizes are presented for research questions one and two. Lastly, the chapter will close with a summary addressing each research question.

Research Question 1: Mathematics Anxiety Results

To what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

The first research question investigated the difference in mean scores between the treatment group and the comparison group on the mathematics anxiety survey before and after the intervention. Independent-samples *t* tests were conducted on a convenient sample of 120 middle-school participants to investigate whether there was a mean difference in scores between participants who underwent the 9-week combined (cognitive and motivational) intervention and solely a cognitive intervention. There were 68 participants in the combined intervention (treatment) group and 52 participants in the cognitive intervention (comparison) group. Levene's test of equality of variances was conducted to verify the assumption of homogeneity of variance.

Levene's test for homogeneity of population variances was not statistically significant (F = 1.05, p = .30), which confirmed that the treatment and comparison group variances were equal. Additionally, the first research question examined the change between pretest and posttest scores on the mathematics anxiety survey. The difference in mean scores between the treatment and comparison groups was calculated by subtracting each student's pretest score from their posttest score. Descriptive statistics, mean scores, standard deviations, independent-samples *t* test results, and effect sizes (Cohen's *d*) for comparing the pretest and posttest between treatment and comparison groups are presented in Table 4.

Table 3

Descriptive Statistics, Independent-Samples t-Test Results, Effect Sizes for Comparing Pretest and Posttest Mathematics Anxiety Scores for Treatment and Comparison Groups

	Treatment (n=68)		Comparison (n=52)			
Test	*M*	*SD*	*M*	*SD*	*t*(118)	Cohen's *d*
Pretest	22.71	6.98	20.63	7.78	.13	.28
Posttest	20.24	5.59	20.00	6.93	.84	.03

The scores on the mathematics anxiety survey showed that the comparison group began the study with slightly lower mathematics anxiety levels than the treatment group. The difference in the pretest means for the two groups was not statistically significant, with a small effect size of .28. After the cognitive and combined interventions, the scores for the comparison group on the mathematics anxiety survey showed almost no change whereas the treatment group's score decreased slightly. The difference in posttest means for the two groups was not statistically significant with an effect size close to zero, indicating no difference in posttest means between the two groups.

To investigate whether there was a difference between the change from pretest to posttest scores for mathematics anxiety, a second independent-samples *t*-test was conducted (see Table 5). In terms of reducing mathematics anxiety between the pretest and the posttest, the mean average of the treatment group decreased by 2.47, and the mean of the comparison group decreased by 0.63. Although the change in scores from the pretest to the posttest was not found to be statistically significant, both the treatment group and the comparison group had a slight decrease in mathematics anxiety.

Table 4

Descriptive Statistics, Independent-Samples t-Test Results, for Change from Pretest and Posttest Mathematics Anxiety Scores for Treatment and Comparison Groups

	Treatment (n=68)		Comparison (n=52)			
	M	*SD*	*M*	*SD*	$t(118)$	Cohen's *d*
Change	-2.47	5.49	-0.63	4.93	1.90	.35

Overall, at the end of the 9-week intervention, the results showed that the change in mathematics anxiety scores from the pretest to posttest for the treatment (combined intervention) group decreased more than the scores for the comparison (cognitive) group. The *t*-test result was close to being statistically significant and had a small effect size of .35, which may indicate a Type II error.

Research Question 2: Mathematics Achievement Results

To what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

The second research question investigated the difference in means between the treatment group and the comparison group on a mathematics achievement measure (STAR Math) before and after the intervention. Independent-samples *t* tests were conducted to determine whether there was a mean difference in scores between participants who underwent the 9-week combined (cognitive and motivational) intervention and solely a cognitive intervention. Additionally, the second research question examined the change between pretest and posttest scores on mathematics achievement. The difference in means between the treatment and comparison groups was calculated by subtracting each student's pretest score from their posttest score. Descriptive statistics, means, standard deviations, independent-samples *t*-test results, and effect sizes (Cohen's *d*) for comparing the pretest and posttest between treatment and comparison groups(Table 6).

Table 5

Descriptive Statistics, Independent-Samples t-Test Results, Effect Sizes for Comparing Pretest and Posttest STAR Math Assessment Scores for Treatment and Comparison Groups

	Treatment (n=68)		Comparison (n=52)			
	M	*SD*	*M*	*SD*	$t(118)$	Cohen's *d*
Pretest	5.96	1.99	5.71	1.72	.47	.13
Posttest	6.17	1.99	6.10	1.83	.86	.03

The means on the STAR Math assessment (mathematics achievement) showed that the comparison group began the study with relatively similar scores as the treatment group. These scores indicate that both groups started with a fifth-grade mathematics level. The difference in the pretest means for the two groups was not statistically significant. After the cognitive and combined interventions, the scores for the comparison group on mathematics achievement showed a slight increase, whereas the treatment group's scores also showed a slight increase. The difference in posttest means for the two groups was not statistically significant indicating no difference in posttest means between the two groups and the effect size is close to zero.

To investigate whether there was a difference between the change from pretest to posttest scores for mathematics achievement, a second independent-samples *t* test was conducted (see Table 6). In terms of improving mathematics achievement between the pretest and the posttest, the mean of the treatment group increased by .21, and the mean of the comparison group increased by .39. Although the gain in scores from the pretest to the posttest was not found to be statistically significant, both the treatment group and the comparison group had a slight increase in mathematics achievement.

Table 6

Descriptive Statistics, Independent-Samples t-Test Results for Change from Pretest and Posttest STAR Math Assessment Scores for Treatment and Comparison Groups

	Treatment (n=68)		Comparison (n=52)			
	M	*SD*	*M*	*SD*	t(118)	Cohen's d
Change	.21	1.11	.40	0.89	-.32	-.19

Overall, at the end of the 9-week intervention, the results showed that the change in mathematics achievement scores from the pretest to posttest for the treatment (combined intervention) group and for the comparison (cognitive) group both slightly increased. The *t*-test result was not statistically significant, $t(118) = .32$, and had an effect size close to small ($d = .19$). At the end of the study, both groups had abilities equivalent to those of at a sixth-grade mathematics level. It is important to emphasize that students from the treatment and control group both moved from one grade level to the next within a 9-week period with the use of the targeted interventions. Although the data did not show a statistically significant increase in mathematics achievement (grade level) the growth in grade level was significant to the students in this study.

Summary of Results

The purpose of this study was to learn whether a combined (cognitive and motivation) intervention approach is more effective than only using a cognitive intervention approach for alleviating mathematics anxiety in middle-school students. The study considered the effect of incorrect worked examples (cognitive intervention) on mathematics anxiety and on mathematics achievement for the comparison and treatment groups. The study also considered the effect of learning how to have a growth mindset (motivational intervention) by normalizing errors and viewing mistakes positively to increase confidence in their ability to learn mathematics for the treatment group. For research questions one and two, no statistically significant differences were found between the treatment (cognitive and motivation) and the comparison (cognitive) group for the two dependent variables: (a) mathematics anxiety perceived by the participants and (b) the STAR Mathematics achievement assessment.

CHAPTER V

SUMMARY, LIMITATIONS, DISCUSSION, AND IMPLICATIONS

An overview of the research that led to the study's research questions opens this chapter. Next, a summary of the findings is given, followed by a discussion of the limitations which lead to conclusions of the study. Subsequently, this chapter concludes with implications for future research, and educational practice.

Summary of the Study

Past research on mathematics anxiety primarily has focused on college students, leaving a gap in the literature as it relates to mathematics anxiety in younger students, especially in middle school. It is crucial to maintain students' interest in, attitudes toward, and confidence in mathematics as they move from elementary school into middle and high school (Wigfield et al., 2006). According to Wang and Pomerantz (2009), during adolescence, there is a decline in mathematics achievement and achievement motivation for mathematics that affects success in mathematics for students. The 2012 report from the Programme for International Student Assessment (PISA) ranked adolescents in the United States below average in mathematics performance compared to with other countries. Moreover, the Programme for International Student Assessment (PISA) reported that 50% of students from the United States expressed a lack of enthusiasm for mathematics (Kelly et al., 2013). One factor contributing to students' difficulty in mathematics is the anxiety many students have about mathematics. Mathematics anxiety has been defined as feelings of tension and apprehension, and fear that individuals experience when engaging with mathematics (Ashcraft, 2002). According to Chang and Beilock (2016), in the United States, it is estimated that 25% of 4-year college students and approximately 80% of community college-students suffer from moderate to high degrees of mathematics anxiety. In addition, students with high mathematics anxiety feelings demonstrated lower mathematics performance when compared to students who had low mathematics anxiety feelings (Ramirez et al., 2018).

Not only can mathematics anxiety affect day-to-day mathematics performance, but mathematics anxiety can also keep students away from career paths that require mathematics. In order to increase the number of students to who pursue science, technology, engineering, and mathematics (STEM) careers and students' mathematics achievement, the fear of mathematics needs to be recognized and addressed by educators (Foley et al., 2017). Therefore, it is crucial to address students' social-emotional needs in every mathematics classroom with noncognitive and cognitive components of learning in order to increase mathematics performance and achievement and reduce mathematics anxiety during early adolescence.

Traditionally teaching mathematics has been only about focusing on the content and not addressing the social-emotional needs of adolescents, such as the fear of mathematics. Every mathematics classroom needs to include social-emotional learning. According to Jones et al. (2009), students' attitudes, behaviors, and academic performance are positively affected when teachers foster a socially and emotionally supportive learning environment. Moreover, mathematics achievement and performance have also been demonstrated to improve with social-emotional learning interventions (DeLay et al., 2016). Mathematics teachers can create a supportive environment in their classrooms that both lowers students' fear of mathematics and supports cognitive abilities by addressing noncognitive components of learning such as persistence, motivation, self-discipline, focus, confidence, teamwork, organization, seeking help, and staying on task (DeLay et al., 2016).

When focusing on mathematics anxiety interventions, there are a variety of diverse approaches. Some effective approaches for reducing mathematics anxiety have been mathematics skill and exposure interventions (i.e., cognitive), interpretation interventions (i.e., motivation), and narrative and mindset interventions (i.e., motivational, Ramirez et al., 2018). Current research (Ramirez et al., 2018)has found evidence of effective interventions for mathematics anxiety, both motivational and cognitive interventions can affect learning through instructional design and increased student engagement. Therefore, there is a need to investigate further the classroom implementation of these interventions.

The theoretical framework for this study had two pillars. The first was Ramirez et al.'s (2018) Interpretation Account that provided the theoretical foundation for the motivation component of this study. The evidence from the literature supports how students' interpretation of their mathematics-related experiences can lead to developing mathematical anxiety and how to resolve mathematics anxiety with a motivation intervention. The second pillar for this study was Sweller's (1985, 1988, and 1989) cognitive approach of worked examples in teaching mathematics that used worked examples to normalize and understand mathematical mistakes.

This study addressed the essential quandary if the focus is on only one intervention for mathematics anxiety, cognitive or motivation, then either might not lead to increased mathematics achievement. A combined approach using cognitive and motivation may be more beneficial and critical to student learning and mathematics achievement. Therefore, this quantitative study aimed to learn whether a combined (cognitive and motivation) intervention approach was more effective than only using a cognitive intervention approach for (a) alleviating mathematics anxiety in middle-school students and (b) increasing mathematics achievement. In the cognitive intervention, participants learned from error reflection by using an incorrect example to (a) find the error, (b) explain why an incorrect response is incorrect, and (c) fix the incorrect response and complete the work. In the combined intervention (cognitive and motivation), in addition to learning from error reflection using incorrect worked examples, participants developed a growth mindset by learning how to (a) normalize errors, (b) view mistakes positively, and (c) increase confidence in their ability to learn mathematics.

The design used was a comparison pretest-posttest study using the modified Abbreviated Math Anxiety Scale (mAMAS) to measure the participants' level of mathematics anxiety and the STAR Mathematics diagnostic assessment to measure gradual growth in mathematics achievement. To accomplish the purpose of the study, the following two research questions were addressed.

1. To what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?
2. To what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?

Summary of Findings

The first research question investigated the difference in means between the treatment group and the comparison group on the mathematics anxiety survey before and after the intervention. After the cognitive and combined interventions, the differences for the comparison group on the mathematics anxiety survey showed almost no change while the treatment group's anxiety means decreased slightly. Independent-samples *t* tests indicated that there was no statistically significant mean difference between participants who underwent the 9-week combined (cognitive and motivational) intervention and a solely cognitive intervention. Additionally, the first research question examined the change between pretest and posttest scores on the mathematics anxiety survey. The difference in posttest means for the two groups was not statistically significant with an effect size close to zero (*d*= .03), indicating no difference in posttest means between the two groups. Overall, the results showed that the change in mathematics anxiety from the pretest to posttest for the treatment (combined intervention) group decreased more than the comparison (cognitive) group, although the results were not statistically significant.

The second research question investigated the difference in means between the treatment group and the comparison group on the mathematics achievement measure (STAR Math) before and after the intervention. The scores on the STAR Math assessment (mathematics achievement) showed that the comparison group began the study with relatively similar grade level scores as the treatment group, indicating that both groups started with a 5th-grade mathematics level. The difference in the pretest means for the two groups was not statistically significant. After the cognitive and combined interventions, the means for the comparison group and the treatment group on mathematics achievement both showed a slight increase in scores. The difference in posttest means for the two groups was not statistically significant indicating no difference in posttest means between the two groups. Additionally, the second research question examined the change between pretest and posttest scores on mathematics achievement. In terms of improving mathematics achievement between the pretest and the posttest, the means of the treatment group increased by .21, and the means of the comparison group increased by .39. Although the gain in grade level scores from the pretest to the posttest was not found to be statistically significant, both the treatment group and the comparison group had a slight increase in mathematics achievement. At the end of the 9-week study, both groups of students had scores equivalent to a 6-grade mathematics level. There is a discrepancy with the STAR Math test results of the students in both groups and what the statistical analyses of the study indicated. The students in both groups had slightly higher scores moving them to the next grade level.

Limitations

This study broke away from the traditional approach to improving learning by using cognitive interventions, which try to design instruction that is more suited to the cognitive ability of students (Sweller, 2006), or motivational interventions, which try to improve the effectiveness of traditional education by increasing student involvement or changing belief (Barbieri & Booth, 2016). Although this study set out to add to the void of research that uses a combined approach intervention (cognitive and motivational) for alleviating mathematics anxiety and increasing mathematics achievement, there were limitations to the present study. This section will examine six limitations of the present study: convenience sample, teacher-researcher bias, coteacher bias, participant bias, survey bias, and time constraints.

First, the sample from this study was not chosen through random selection, it was a convenience sample; the sample of this study comes from a title one low-level performing school therefore, the results of convenience sampling cannot be generalized to the larger population because of the potential bias of the sampling technique. Participants in this study were selected by the researcher and the coteacher of this study because they were easily accessible from each teacher's own classes. A total of 120 students were willing to participate out of 280 available students. Additionally, because only specific groups of individuals are given the chance to become willing participants as opposed to addressing the problem randomly, researcher bias can enter into the convenience sample.

Second, teacher-researcher bias may have been present in this study. The teacher-researcher had 10 years of experience incorporating a combined intervention approach (cognitive and motivation) with regular instruction. Furthermore, it is possible that there was an internal conflict between the roles of a researcher and the roles of a teacher. A researcher must be able to understand as many facets as possible, to constantly doubt, and to conscientiously preserve the study, and the teacher has a primary responsibility to use the best teaching methods available for their students and possibly add instruction to the agreed upon intervention design for the current study.

Third, the coteacher in the comparison group had no experience with either cognitive or motivational interventions in mathematics. It is possible that they may not have implemented the cognitive approach with fidelity. The coteacher may have not implemented the cognitive intervention the way the teacher-reacher intended or designed it to be implemented therefore, the infidelity to the intervention may have influenced the results.

Fourth, participants in both groups of this study may have altered their behavior because they knew they were part of a study, specifically in the treatment group due to the teacher being the researcher of the study. Participants may have consciously or unconsciously changed their behavior or answers to what they believed their teachers in both classes wanted. Moreover, participant bias may have occurred if the teacher-researcher used targeted interventions for alleviating mathematics anxiety before the 9-week intervention that was a part of the teacher-researcher innate instructional strategies.

Fifth, survey bias often occurs when participants are asked to self-report on their behaviors. Students might have answered untruthfully or inaccurately in their responses. Four participants selected one (low anxiety) as a response to all nine questions on the mathematics anxiety survey (mAMAS). It could have been possible that those participants' answers deviated from how they actually felt and did not reflect their actual viewpoint. If survey bias was present in this study those responses could have negatively affected the research results.

Sixth, the time constraints of the study may have contributed to not being able to demonstrate a significant change in mathematics achievement or mathematics anxiety when interventions were only implemented for 9 weeks. It may have been possible that students needed additional time to internalize that mistakes are part of the learning process for both the comparison and treatment groups. In addition there may also be a latent effect, changes of self concept and mathematical self-concept happen over time that might not be seen until a later time in 7th grade, 8th grade or 9th grade for these changes in self-concept to manifest. A followup of this study could yield statistically significant findings.

Discussion of Findings

This section presents the discussion of findings for the research questions. With regard to research question one: "To what extent is there a difference in the mathematics anxiety for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?" one of the key findings from this study was that the results from the combined intervention scores on mathematics anxiety decreased slightly whereas the cognitive only intervention on the mathematics anxiety survey showed almost no change the findings in this study both confirm and conflict with prior research. In alignment with the study of Yun and Shin (2015), students in the treatment group (combined intervention) were instructed to view anxiety as not to be necessarily harmful; in fact, it could be beneficial when it prompts a person to react promptly to potential dangers. In addition, with targeted motivational lessons the treatment group did not view mathematical tasks as fearful tasks that impede mathematical performance but rather to help them develop a mindset to overcome mathematics anxiety and achieve successful mathematics performance. In contrast with the study of Meece and colleagues (1990), their findings suggest mathematics anxiety can be diminished or controlled during middle school if students learn to redirect their appraisal in a positive way rather than a maladaptive manner. In terms of reducing mathematics anxiety between the pretest and the posttest, the average of the treatment group decreased by 2.47, and the mean of the comparison group decreased by 0.63. Although this was not a statistically significant result, there was still a larger decrease in mathematics anxiety for the students in the combined intervention (motivation + cognitive) group than for the students in the cognitive only intervention group.

There are two possible explanations for this finding. First, addressing mathematics anxiety early on in seventh-grade is important because early mathematics anxiety may have a "snowball" effect leading to increased anxiety, dislike, and avoidance of mathematics in later school years (Wigfield & Meece, 1988). Lessons from Jo Boaler and Stanford used in the study were designed to cultivate a growth mindset when learning mathematics. The students in the treatment group learned to associate their failure with a lack of effort or inefficient learning strategies after experiencing setbacks, whereas students with a fixed mindset are more likely to blame their deficiency on their ability. Additionally, students in the treatment group who believed that intellectual ability was malleable and worked steadily toward demanding goals could account for the result. Using both motivational and cognitive interventions may have affected learning through instructional design and increased student engagement. When conducting the study, 9-weeks of developing a growth mindset may have provided students with skills and strategies to begin reducing or alleviating their mathematics anxiety in small increments.

Second, in the treatment group, it was important to address students' worried intrusive thoughts that consume the central executive's limited attentional resources of working memory required for processing high-demand tasks in mathematics (Suárez-Pellicioni et al., 2016). The combined intervention attempted to lower error rates by using incorrect examples for increasing working memory. How students perceive their early mathematics experiences has a big effect on how mathematics anxiety develops. Therefore, the study utilized students' experiences with incorrect worked examples to normalize mistakes and support experiences of making mistakes in mathematics as part of their learning process. The students in the treatment group used incorrect worked examples to teach others how to correct and view mathematical mistakes by organizing new information for long-term storage. Moreover, the use of incorrect worked examples helped the students to interpret their mathematics-related experiences in a positive way to avoid further development of mathematics anxiety. For instance, by focusing on normalizing mathematical mistakes students learned to redirect their appraisal in a positive way rather than a maladaptive manner. Students are more likely to develop mathematics anxiety if they use maladaptive appraisals and use their ability to account for their poor mathematics grades, as compared with students who attribute difficulty in mathematics to a lack of effort and understand that making mistakes is part of the learning process (Meece et al., 1990). Alongside normalizing mistakes with incorrect worked examples students experienced how to overcome their affective reactions during a stressful mathematical situation by viewing the experience as a challenge instead of a threat to avoid. How students perceive themselves directly influences cognitive processes, decision making, strategies, and motivation.

According to Ma (1999), mathematics anxiety levels tend to increase with age among students in grades 5 through 12, therefore, providing appropriate interventions is essential for student learning and achievement. A motivation intervention can assess whether students give up or embrace an obstacle and a cognitive intervention can provide students with skills to work to overcome a problem when they struggle. Participants needed to receive the most beneficial intervention, hence taken together, applying cognitive and motivational interventions for alleviating mathematics anxiety in middle school when anxiety tends to be the strongest from the ages of 12 to 15. Because interventions for mathematics anxiety is not part of the curriculum for middle school, it is not addressed by educators in the classroom. In the treatment group, time was allocated to foster perseverance as the noncognitive ability because the predictive power of noncognitive abilities seems to rival that of cognitive skills. To answer the second research question "To what extent is there a difference in mathematics achievement for middle-school students in the combined intervention approach versus those using the cognitive intervention approach on the pretest, posttest, and change from pretest to posttest?" the results showed that the comparison group began the study with relatively similar scores (M = 5.71, SD = 1.72) as the treatment group (M = 5.96, SD = 1.99), indicating both groups started with a 5th-grade mathematics level. The posttest scores for the comparison group on mathematics achievement showed a slight increase (M = 6.17, SD = 1.99), whereas the treatment group's scores also showed a slight increase (M = 6.10, SD = 1.83). The difference in posttest means for the two groups was not statistically significant indicating no difference in posttest means between the two groups and the effect size was close to zero. In terms of the result between the change from pretest to posttest scores for mathematics achievement the mean of the treatment group increased by .21, and the mean of the comparison group increased by .39. The gain in scores from pretest to posttest was not found to be statistically significant for either group.

The current study results are inconsistent with previous studies (Boaler et al., 2018; Barbieri & Booth, 2016). Barbieri and Booth (2016) carried out a study among 125 middle-school students from five Algebra 1 classrooms. Their findings are inconsistent with this study because they suggested that error reflection was equally beneficial for students across levels of prior knowledge, incorrect examples were more effective than correct worked examples or problem-solving alone for those who began the study with little knowledge of systems of equations. Using incorrect worked examples fostered the idea that errors are part of the learning process and provided the motivation for students to solve complete mathematical problems. Barbieri and Booth (2016) attributed their findings to highlighting common errors in incorrect examples to provide the support students need to fully benefit from worked examples on procedural knowledge and to highlighting errors that represent an underlying algebraic misconception to reduce the prevalence of that misconception and allow students more benefits from the instruction. Aligned with Barbieri and Booth's study (2016), Boaler et al. (2018) found significant effects on changing minds and achievement in mathematics for students who took the online course lessons (i.e., Mistakes and Speed, Knocking Down the Myths about Math, Math and Mindset). The results of the current study are not consistent with either Barbieri and Booth (2016) or Boaler et al. (2018), as these studies suggest that cognitive and motivational interventions may statistically significantly increase students' comprehension of mathematical concepts.

Possible reasons for the inconsistency with the current study could be that this study used a unit where students were reviewing material, rather than a unit that covered new material. Compared to a unit containing material they were already familiar with, an unfamiliar unit (with greater fear) might have demonstrated greater growth. Also, this study took place at the beginning of the seventh- grade, therefore, the teacher-researcher had to follow the district-mandated curriculum calendar. In Barbieri & Booth's (2016) study, 97% of the students involved were in eighth grade and 3% were in seventh grade, in the incorrect worked examples condition, the incorrect procedure was displayed and highlighted, and finally, the participants were asked to explain 16 examples and solve 16 "Your Turn" problems). In contrast, the mathematics unit in this study was based on integers, fractions, similar figures, and percentages and not Algebra 1. One hundred percent of the participants were seventh-grade students. In both the comparison and treatment groups, the incorrect procedure was displayed but not highlighted. The participants were asked to explain 9 examples and solve 9 "Error Analysis" problems. Moreover, students were asked to complete the following on the worksheet: (a) find the error, (b) explain why an incorrect response is incorrect, and (c) fix the incorrect response and complete the work.

Furthermore, Barbieri and Booth's (2016) findings suggested that incorrect examples were more effective than correct worked examples or problem-solving alone for those who began the study with little knowledge of systems of equations. Using incorrect worked examples fostered the idea that errors are part of the learning process and provided the motivation for students to solve complete mathematical problems. Hence, the current study focused on incorrect examples to support students with little prior knowledge, motivate students to complete mathematical problems, and attempted to normalize mathematical mistakes as part of the learning process. Although not statistically significant, small gains were found for both the comparison and treatment groups for mathematical achievement.

The current study results are not consistent with the findings from Boaler et al.'s (2018) delayed-treatment research design. The motivation intervention they used was designed to change students' minds about mathematics and their own potential and improve their mathematics achievement. Participants in the treatment group that took the massive open online course obtained 63% higher Smarter Balanced Assessment Consortium (SBAC) scores than the control group. Participants in the current study took the exact same online course because the intervention connected mindset messages to learning mathematics and focused on student's beliefs about mathematics. With respect to a plausible explanation for the small gains in mathematics achievement, perhaps because of the negative effects of COVID on students, they had a stronger hold on damaging fixed mindsets, believing that their intelligence could not be changed. Additionally, it could be possible that the students in this study needed longer lessons from the online course than those Boaler et al.'s (2018) study used and for a longer period of time. Additionally, the participants in the treatment group had less time to practice and learn the mathematics content compared with the comparison group in which the cognitive intervention was embedded into the curriculum.

Conclusions

This study investigated the combined intervention approach (cognitive and motivational) and the influence of a combined intervention both on mathematics anxiety and mathematics achievement versus solely using one intervention (cognitive intervention) for alleviating mathematics anxiety in middle-school students. The 68 participants in the combined intervention (treatment) group and 52 participants in the cognitive intervention (comparison) group responded to the mathematics anxiety survey before and after the intervention. Based on the participants' STAR Mathematics diagnostic assessment, the participants from both groups ranged in mathematics grade-level skills from second grade to tenth grade.

The study did not find statistical significance on the mathematics anxiety survey after the cognitive and combined interventions, and the scores for the comparison group on the mathematics anxiety survey showed almost no change, whereas the treatment group's score decreased slightly. The mean average of the treatment group decreased by 2.47 in terms of lowering math anxiety between the pretest and the posttest, whereas the mean of the comparison group decreased by .63. At the end of the 9-week intervention, the results showed that the change in mathematics anxiety scores from the pretest to posttest for the treatment (combined intervention) group decreased more than the scores for the comparison (cognitive) group.

In addition, the study did not find statistical significance in the STAR Math assessment (mathematics achievement) for both groups. However, after the cognitive and combined interventions, both groups showed a slight increase in mathematics achievement on the posttest and in the difference between the change from the pretest to posttest scores for mathematics achievement. Students in both groups moved from a fifth-grade mathematics level to sixth-grade mathematics level. Overall the study did not provide statistical evidence that the combined intervention is more beneficial than solely using the cognitive intervention for alleviating mathematics anxiety or increasing mathematics achievement among middle-school students. There is a gap in the literature addressing mathematics anxiety in middle-school students therefore, further studies need to continue to explore if a combined intervention approach may be more beneficial and critical to alleviating mathematics anxiety and increasing mathematics achievement. Along with the need for further research, practitioners who have traditionally primarily addressed the content need to stop overlooking the social-emotional needs of adolescents, such as their fear of mathematics. After the COVID pandemic, it is now even more essential to meet students' social-emotional needs in every mathematics classroom with noncognitive and cognitive components of learning that promote a positive mathematics self-concept.

Implications for Research

This section outlines five suggestions for future research: (a) exploring the effects of cognitive and combined interventions over a longer period of time, (b) using worked examples with students before instructing on how to use incorrect worked examples, (c) expanding students internalization of both cognitive and motivation interventions, (d) exploring the implementation of motivation interventions in seventh grade and adding the cognitive intervention in eight grade, and (e) using qualitative interviews or a focus group to learn more about the impact of motivational and cognitive interventions from the students perspective.

First, this study investigated whether a combined (cognitive and motivation) intervention approach is more effective than only using a cognitive intervention approach for alleviating mathematics anxiety and increasing mathematics achievement among middle-school students within a short time frame of 9 weeks. Future studies could implement cognitive and motivation interventions for a longer period of time, for example perhaps a full semester or a year. It is possible that students need more time to become adept at the skills the interventions provide for alleviating mathematics anxiety and increasing mathematical achievement. The current study is limited to representing a snapshot of a short point in time, perhaps the time constraints did not yield enough time for the effective implementation of interventions. Further research using a longitudinal study is recommended to allow for an understanding of the degree and direction of mathematics anxiety and mathematics achievement changes which over time may provide different findings.

Second, future studies should start with the use of worked examples before instructing students with incorrect worked examples. Students could have benefited more if they first practiced with completed problems that direct their attention to certain steps of a task as they focused on questioning coupled with self-explanations, this strategy has been found to be an effective strategy for correcting students' own misconceptions (Carroll, 1994). By employing worked examples first, students would build upon their prior knowledge to effectively influence learning and improve their understanding of the solution process. When students have more prior knowledge, it is easier for them to imagine the solution steps explained by the worked example, therefore, enhancing the understanding of the solution procedure. Moreover, higher learning is reached with less investment of time or mental effort when using worked examples as an instructional practice (van Gog et al., 2011). Thus, future studies should focus on student practice with worked examples before the use of incorrect worked examples as a cognitive intervention because both are needed.

Third, it is recommended that future studies expand on students' internalization of both cognitive and motivation interventions. The teachers in this study followed a strict curriculum plan that did not allow students to space out learning of cognitive/motivation interventions over time. The fast pace of the curriculum calendar did not allow students enough time to make personal connections or reflections. Cognitive and motivational strategies were taught to students however there was little or no time for them to summarize or synthesize their new knowledge that is required for the interventions to be retained and retrieved when needed. Perhaps future studies should consider providing students with enough time to internalize cognitive and motivational interventions.

Fourth, future studies using a combined intervention approach for alleviating mathematics anxiety and increasing mathematical achievement might consider the implementation of motivation interventions in seventh grade and adding cognitive intervention in eighth grade with the purpose of having a combined approach by the second year in middle school. Past research suggests it is crucial to maintain students' interest in, attitudes toward, and confidence in mathematics as they move from elementary school into middle and high school (Wigfield et al., 2006). Moreover, mathematics anxiety needs to be alleviated or reduced using both cognitive and motivational interventions during adolescence in order to increase mathematics achievement (Barbieri & Booth, 2016). Historically, researchers have focused on improving learning in mathematics in one of two ways, either using cognitive or motivational interventions.

Fifth, future studies should use qualitative interviews or a focus group to learn more about the impact of motivational and cognitive interventions from the student's perspective. Qualitative interviews could provide an in-depth insight into what was going on with the individuals in the study. Students can provide specific details about how their mathematical mindset changed or was changing during the 9 week intervention. Soley using quantitative data alone may not be able to provide the human experience that is difficult to quantify in order to comprehend. Although this study came close to finding statistical significance that a combined intervention approach was more effective than a singular intervention for alleviating mathematics anxiety, it is merely a small study with a convenient sample. Further research in this field is warranted.

Implications for Practice

This section presents four implications for educational practices based on the results of this study: (a) providing training for teachers on worked and incorrect worked examples, (b) incorporating cognitive and motivational interventions as part of the mathematics curriculum, (c) sharing with students the importance of learning from mistakes as part of their learning process, and (d) and providing classroom teachers with concrete suggestions for supporting students to develop a positive mathematics self-concept.

First providing training for middle-school mathematics teachers on both worked and incorrect worked examples would be beneficial for the following reasons. The first is that teachers need to internalize the benefits of the use of worked examples in their instruction. According to research, problem-solving-only training is less effective for learning and transfer than instruction that strongly emphasizes worked examples for beginning learners (Paas & van Gog, 2006). When worked examples are used as a teaching strategy, students learn more with less time or effort expended. Second, worked-example training would provide teachers with two important skills required for a well-designed worked example. First, color coding supports students in integrating information when there are several representations because their attention may be largely bound (Renkl, 2017). Additionally, by encouraging students to explain the solution for themselves then the potential for learning can be fully exploited. Worked examples are designed as a scaffold to support student learning; eventually, a structured transition will be needed such as fading worked steps. The fading procedure has been seen as more effective than using example problem pairs in studies by Sweller and colleagues (1985, 2006). Fading worked steps allows for a smooth transition, students go from studying worked examples to solving problems independently. Moreover, after providing correct worked examples to students, teachers can learn when to present incorrect worked examples to learners in order to deepen the knowledge that has already been acquired (Große & Renkl, 2007). Integrating, the use of incorrect worked examples for students can be beneficial to foster the idea that errors are a normal part of the learning process. Therefore, it is essential for teachers to have training on how to use worked and incorrect worked examples with middle school students to support learning in mathematics and alleviate mathematics anxiety.

Second, middle-school teachers must incorporate fully for 2 years both cognitive and motivational interventions as part of the mathematics curriculum. Historically in the United States, mathematics, specifically Algebra, is seen as a gatekeeper for access to higher-level math and science courses (Douglas & Attewell, 2017). The ability of students to perform well in school mathematics is important for gaining access to college admissions. Unfortunately, during adolescence, there is a decline in both mathematical achievement and achievement motivation for mathematics, which both impact student success in mathematics (Barbieri & Booth, 2016). The findings of this study came close to finding statistical significance for alleviating mathematics anxiety among middle-school students using a combined intervention (cognitive and motivation) approach. There were small increases in mathematics achievement and small changes in lowering mathematics anxiety in this 9-week study therefore, providing sufficient time for implementing both interventions in middle school would give students time to (a) internalize and execute their metacognitive knowledge, and (b) sustain positive feelings about their mathematics learning experiences.

Additionally, mathematics education has traditionally primarily addressed the content, overlooking the social-emotional needs of adolescents, such as their fear of mathematics. Social and emotional development is a necessary component of every mathematics classroom. Jones et al. (2009) claim that when teachers provide a socially and emotionally supportive learning environment, students' attitudes, behaviors, and academic performance increase. Moreover, social-emotional learning interventions have been shown to enhance mathematical proficiency and achievement. Mathematics teachers addressing noncognitive components of learning like perseverance, motivation, confidence, and staying on task after a mistake is made can create a supportive environment in their classrooms that both reduces students' fear of mathematics and supports cognitive abilities. Especially in the age of post-COVID pandemic, students are struggling with their socioemotional development. This study offers an approach to supporting students' interest in, attitudes toward, confidence, and perseverance in mathematics as they move from middle school to high school.

Third, the importance of learning from mistakes as part of their learning process is crucial to incorporate in the classroom. Middle-school students tend to worry about what their peers think of them, therefore, they are unwilling to share their mistakes or discuss them. Students learning from mathematical mistakes can be used to change students' fixed mindsets (believing that their intelligence is unchangeable) to a growth mindset (believing that their intelligence is malleable). Teachers must normalize that mistakes are part of the learning process so that students can internalize and comprehend that mistakes, challenges, and struggles are the best times for brain growth. Providing students with the skill and strategy of using mistakes as both a cognitive and motivational intervention to reduce or alleviate mathematics anxiety in order to perform well in mathematics is essential for helping students gain access to higher mathematics that is required for college admissions.

Fourth, as a practitioner-researcher I present the following concrete suggestions for supporting students to develop a positive mathematics self-concept. During the first week of school teacher should introduce, explain, and utilize lessons that support developing a growth mindset. Teachers should continue integrating a growth mindset perspective into their daily mathematics lessons throughout the school year keeping in mind that developing a positive mathematics self-concept takes time because changing negative self-beliefs can be deeply ingrained in students. In addition, teachers can enroll their students in the free Stanford online course developed by Dr. Jo Boaler that is designed to teach students how to learn math. Boaler's (2018) research has shown that students who take this course, report more positive beliefs about math, engage more deeply in math in class and perform significantly better on standardized tests. After students complete the online course, teachers can continue to have class discussions about the lessons they completed with an emphasis on learning from mistakes. Teachers can use correct worked examples first until the students understand how to use them as a learning tool, and then teachers can incorporate incorrect worked examples into their curriculum so that students are able to learn how mistakes in mathematics are a normal part of the learning process. Teachers can continue to use both correct and incorrect worked examples for the entire school year. All of these suggestions are ways to create and encourage a mistakes-friendly environment.

This study attempted to emphasize using a combined approach (cognitive and motivation) intervention to be more beneficial and critical for increasing mathematics achievement and diminishing mathematics anxiety with supporting data. Teachers are expected to teach all grade-level common core mathematics standards in one school year, that alone is a daunting task. Teachers may be reluctant to incorporate cognitive and motivational intervention strategies when they already feel that they do not have enough time to teach all the mathematics standards; however, providing students with researched interventions has proven to increase mathematics achievement and reduce mathematics anxiety. Teachers must step away from saying

"I think that this strategy might work for student learning, besides it looks fun" and "There is no way to motivate these students to learn" because there is research that can guide teachers to indeed raise academic achievement and motivate students to learn. Educators need to stop guessing and using how they personally feel to determine what interventions to use with their at-risk students, it is their obligation to use relevant researched strategies in middle school to prevent the decline in mathematics achievement and motivation among adolescents. Teachers have the key to unlocking a student's potential by providing both cognitive and motivational support when learning mathematics to prepare students for success, assisting in facilitating rich learning experiences that incorporate growth mindset development.

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APPENDICES

APPENDIX A

Modified Abbreviated Math Anxiety Scale (mAMAS)

Instructions:
Please give each sentence a score in terms of how anxious you would feel during each situation. Use the scale on the right side and circle the number which you think best describes how you feel.

	☺				☹
	Low anxiety	Some anxiety	Moderate anxiety	Quite a bit of anxiety	High anxiety
1. Having to complete a worksheet by yourself.	1	2	3	4	5
2. Thinking about a math test the day before you take it.	1	2	3	4	5
3. Watching the teacher work out a math problem on the document camera.	1	2	3	4	5
4. Taking a math test.	1	2	3	4	5
5. Being given math homework with lots of difficult questions that you have to hand in the next day.	1	2	3	4	5
6. Listening to the teacher talk for a long time in math.	1	2	3	4	5
7. Listening to another student in your class explain a math problem.	1	2	3	4	5
8. Finding out you are going to have a surprise math quiz when you start your math lesson.	1	2	3	4	5
9. Starting a new topic in math.	1	2	3	4	5

Note: Adapted from "The Modified Abbreviated Math Anxiety Scale: A Valid and Reliable Instrument for Use with Children," by E. Carey, F. Hill, A. Devine, D. Szűcs, 2017, *Frontiers in Psychology, 8.* (https://doi.org/10.3389/fpsyg.2017.00011) Copyright 2017 by Carey, Hill, Devine, and Szűcs.

APPENDIX B

Intervention Activities by Intervention Group

Intervention Activites by Intervention Group

Week 1	Topics	8/22 Monday	8/23 Tuesday	8/24 Wednesday	8/25 Thursday	8/26 Friday
Cognitive Intervention Valencia	Zero Pairs Modeling Adding Integers Number Lines	Instruction	Parent Consent Student Video Instruction	Instruction Check for understanding	Model Error Analysis Worksheet	Student Survey Review of the topic(s)
Combined Intervention Garcia	Zero Pairs Modeling Adding Integers Number Lines	Instruction	Parent Consent Student Video Instruction	Instruction Check for understanding	Model Error Analysis Worksheet	Student Survey Review of the topic(s)

Week 2	Topics	8/29 Monday	8/30 Tuesday	8/31 Wednesday	9/1 Thursday	9/2 Friday
Cognitive Intervention Valencia	Integer Rules Word Problems Subtract Integers	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Integer Rules Word Problems Subtract Integers	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 1: Knocking Down Myths About Learning Math Review of the topic(s)

Week 3	Topics	9/5 Monday	9/6 Tuesday	9/7 Wednesday	9/8 Thursday	9/9 Friday
Cognitive Intervention Valencia	Subtract Integers with Double Negatives Integer Real Word Problems ($)	No School Labor Day	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Subtract Integers with Double Negatives Integer Real Word Problems ($)	No School Labor Day	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 2: Math and Mindset Review of the topic(s)

Week 4	Topics	9/12 Monday	9/13 Tuesday	9/14 Wednesday	9/15 Thursday	9/16 Friday
Cognitive Intervention Valencia	Absolute Value and word problems	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Absolute Value and word problems	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 3: Mistakes and Speed Review of the topic(s)

Week 5	Topics	9/19 Monday	9/20 Tuesday	9/21 Wednesday	9/22 Thursday	9/23 Friday
Cognitive Intervention Valencia	Multiply and Divide Integers	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Multiply and Divide Integers	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 4: Number Flexibility, Mathematical Reasoning, and Connections Review of the topic(s)

Week 6	Topics	9/26 Monday	9/27 Tuesday	9/28 Wednesday	9/29 Thursday	9/30 Friday
Cognitive Intervention Valencia	Multiply Fractions Real Word Problems	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Multiply Fractions Real Word Problems	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 5: Number Patterns and Representati-ons Review of the topic(s)

Week 7	Topics	10/3 Monday	10/4 Tuesday	10/5 Wednesday	10/6 Thursday	10/7 Friday
Cognitive Intervention Valencia	All Integer Mixed Review	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	All Integer Mixed Review	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 6: Math in Life, Nature and Work Review of the topic(s)

Week 8	Topics	10/11 Monday	10/12 Tuesday	10/13 Wednesday	10/14 Thursday	10/15 Friday
Cognitive Intervention Valencia	Similar Figures	Instruction	Instruction	Instruction Exit Ticket to check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Similar Figures	Instruction	Instruction	Instruction Exit Ticket to check for understanding	Error Analysis Worksheet	Lesson 7: Growth Mindset Vs. Fixed Mindset Review of the topic(s)

Week 9	Topics	10/17 Monday	10/18 Tuesday	10/19 Wednesday	10/20 Thursday	10/21 Friday
Cognitive Intervention Valencia	Percents	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Review of the topic(s)
Combined Intervention Garcia	Percents	Instruction	Instruction	Instruction Check for understanding	Error Analysis Worksheet	Lesson 8: Believe in Yourself Review of the topic(s)