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Interventions and Supports to Ameliorate Math Anxiety in K-12 Schools: A Meta-Analysis of Experimental Group Design Research

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of Experimental Group Design Research

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ABSTRACT

Interventions and Supports to Ameliorate Math Anxiety in K-12 Schools: A Meta-Analysis of Experimental Group Design Research

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"Math anxiety is commonly defined as a feeling of tension, apprehension, or fear that interferes with math performance" (Ashcraft, 2002, p. 181). Symptoms of math anxiety are reported by 33% of students by the time they reach the age of 15, possibly contributing to this workforce dilemma (Organisation for Economic Co-operation and Development, 2013). Many models and perspectives of math anxiety have been established including conceptualizing math anxiety as a function of working memory deficits, sociocultural conditioning, lack of reappraisal, and anxiety as a precursor to escape-maintained behavior. Math anxiety is more common in individuals with certain disabilities, such as developmental dyscalculia and deaf and hard of hearing. Hembree (1990) conducted a meta-analysis of research evaluating intervention effects on math anxiety and its moderators. They reported that cognitive-behavioral interventions were most effective at reducing math anxiety. While definitions of, models examining, and causes and co-occurrences of math anxiety are well examined in current literature, Hembree's (1990) meta-analysis remains the only such investigation for the past 30 years.

The purpose of the present study is to conduct an updated meta-analysis based on previous research (Hembree, 1990) but focused on interventions in K-12 school settings. We identified 11 articles between the years of 1990-2020 that met our inclusion criteria. From those articles, we calculated an omnibus effect size, tested homogeneity, evaluated publication bias, explored moderating variables, and assessed methodological rigor. Our Q statistic indicated homogeneity; however, the forest plot and I^2 indicated a small amount of heterogeneity. The asymmetric shape of the funnel plot may be indicative of publication bias. The omnibus effect size was $g = 0.316$. The results of our moderator analysis indicated that math anxiety interventions produce the best results when conducted in targeted small groups. Additionally, three studies were considered methodologically sound. Our findings support the use of school-based interventions to reduce math anxiety, especially when those interventions are implemented as a targeted, small group intervention.

Keywords: math anxiety, math achievement, elementary education, secondary education, systematic reviews

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CHAPTER 1

Background

Mathematics is a tool to make sense of, to explain, and to navigate the world around us, as Descartes insisted, “mathematics is a more powerful instrument of knowledge than any other that has been bequeathed to us by human agency” (Code, 2005, p. 36). As our modern world becomes more and more complex, it is increasingly critical for people to possess mathematical competencies and apply those competencies in an array of everyday decision making.

Learning mathematics is not just an academic curiosity, it is essential to our quality of life. For example, mathematical capability is directly related to our ability to make meaningful personal health decisions. Reyna et al. (2009) wrote, “Low numeracy distorts perceptions of risks and benefits of screening, reduces medication compliance, impedes access to treatments, and impairs risk communication” (p. 943). Additionally, the ability to calculate and comprehend numerical values is integral to financial literacy. Individuals with poor financial literacy are more likely to make poor monetary decisions, less likely to invest in stocks, and are at greater risk for increased high-cost borrowing (Lusardi & Mitchell, 2014). A longitudinal study reported that lower math performing students later had lower SES in adulthood as compared to higher performing peers (Ritchie & Bates, 2013).

Additionally, as digital information systems, from social and news media to online purchasing, become increasingly reliant on algorithms, consumers are engaging with massive amounts of data online, and often doing so without understanding the ways this information is manipulated by those algorithms (Rainie & Anderson, 2017). Rainie and Anderson (2017) also explain that because these mathematical processes are hidden and not well understood, we become disconnected from that critical thinking process and begin to rely too heavily on the results of what may be a biased, overgeneralized, or simply inaccurate calculation. These algorithms push content that gets clicks over prioritizing content that is truthful. This can encourage a shift of our ideologies into the extremes. We become "quarantined into distinct ideological areas" (Rainie & Anderson, 2017, Theme 5 section), where in that echo chamber, we no longer face contrasting views that help us maintain nuance. In the end, these divisive algorithms target the poor and uneducated, and as such, it is imperative that we booster our math curricula to prepare citizens to step back and do the math and critical thinking for themselves (Rainie & Anderson, 2017).

Statement of the Problem

Unfortunately, only 40% of fourth grade students are proficient in math; and competency continues to decline throughout the upper grades (e.g., 33% of eighth grade students and 25% of high school seniors, U.S. Department of Education (2017). To compound this, students are less likely to sign up for advance placement classes in high school when they do not begin the 7th grade with high math achievement. Additionally, students not enrolled in algebra 1 or above by the 8th grade were less likely to report wanting to attend a 4-year college or pursue an advanced degree (Walston & McCaroll, 2010). Perception of aptitude and self-appraisal in a given subject are linked to pursuing that subject further, through taking classes and being more likely to consider a career related to that topic (Wang & Degol, 2013). Interestingly, self-appraisal is highly linked to math anxiety (Meece et al., 1990).

Math Anxiety

One contributor to poor math achievement is math anxiety. A frequently circulated definition states that "math anxiety is commonly defined as a feeling of tension, apprehension, or fear that interferes with math performance" (Ashcraft, 2002, p. 181). Math anxiety has an identity independent of both general anxiety and test anxiety. Ho et al. (2000) describes two dimensions found in any type of anxiety: affective and cognitive. Affective symptoms are feelings or states of being: sadness, discomfort, or irritability. Cognitive symptoms are thoughts: “I’m nervous. I don’t like this.” Affective symptoms are a stronger moderating factor between math anxiety and math performance, whereas cognitive symptoms are the stronger moderating factor between test anxiety and math performance. Meaning, math anxious students’ performance is primarily impacted by affective barriers; while test anxious students’ performance is primarily impacted by cognitive barriers (Ho et al., 2000). Additionally, Dowker et al. (2016) found that test anxiety and general anxiety highly correlated with each other, while math anxiety correlated very little with either. Ho et al. (2000) and Dowker et al. (2016) provide captivating evidence to demonstrate that math anxiety is a separate entity from generalized anxiety and test anxiety.

In addition to studies investigating definitions of math anxiety, data exists describing its prevalence and its effect on math performance. One measure indicated that math anxiety is present in 33% of 15 year olds (Organisation for Economic Co-operation and Development, 2013). Gunderson et al. (2018) explained that math anxiety is reciprocally associated with achievement and motivation. The latest meta-analysis reviewing the influence of math anxiety on math performance in K-12 students reported a significant correlation coefficient (-0.34) across 131 studies (Namkung & Lin, 2019). This is comparable to Ma (1999), who reported significant common population correlation (-0.27) in 26 studies. Hembree (1990) reported significance (g = -0.61) covering 13 studies.

Hembree (1990)

Hembree (1990) published the last meta-analysis that reviewed intervention for math anxiety. They also studied moderators that explain why certain individuals have more anxiety than others. They reported that females exhibited higher levels of anxiety, although that gap has narrowed since the time of their analysis (Ganley et al., 2013). They also found that Hispanic students exhibited higher rates of math anxiety as compared to other ethnicities. IQ, low math performance, and negative perceptions of math also correlated with higher anxiety levels. Hembree (1990) organized their reviewed interventions into four categories: classroom, cognitive, behavioral, and behavioral cognitive. They reported that behavioral-cognitive interventions produced the highest effect. These types of interventions included elements of mindset training or reappraisal and paired them with cognitive approaches such as systematic desensitization or relaxation training.

Hembree (1990) assessed design quality, but did not define what elements were measured. They reported a median score of two, out of three possible points. We believe it is important to expand this measure of methodological rigor by utilizing commonly accepted assessments, and to explicitly outline strengthens and weakness of methodological rigor. Methodological quality is the basis by which a field can determine if a practice is evidence-based (Council for Exceptional Children Standards for Evidence-based Practices in Special Education, 2014). Utilizing these practices is especially important in context of Response to Intervention (RTI) frameworks, where practitioners rely on such practices to provide universal, small group, and individualized supports (Jimerson et al., 2016).

Statement of the Purpose

The purpose of this study is to conduct the first meta-analysis for math anxiety interventions exclusively in K-12 settings, and to update the field on the availability of evidence-based practices. We, defined as the graduate student author supported by an assistant professor in special education, conducted moderating analyses to determine what factors make interventions more efficacious. Lastly, we assessed the methodological quality of this literature.

Research Questions

1. To what extent are school-based interventions targeting math anxiety effective at reducing anxiety and/or increasing math performance for K-12 students?
2. Are these effects moderated by other intervention factors (e.g., intervention intensity, duration, disability status)?
3. To what extent is the current literature on this topic methodologically rigorous?

CHAPTER 2

Review of Literature

Math illiteracy restricts future options for impacted students and limits opportunities for society to progress in STEM-related fields. The demand for STEM careers is expanding twice as fast as other markets, yet the number of students pursuing STEM majors is growing 23.1% slower than other fields (National Governors Association, NGA Center for Best Practices, 2011). It is clear that student educational outputs are not meeting workforce demands in an economy that increasingly relies on competencies grounded in mathematical thinking. Carl Sagan declared, “We live in a society absolutely dependent on science and technology and yet have cleverly arranged things so that almost no one understands science and technology. That's a clear prescription for disaster" (Head, 2006, p. 100). Given that by 8th grade, less than half of students are proficient in math (U.S. Department of Education, 2017), and that math anxiety is highly correlated with low math performance (Gunderson et al., 2018), it is imperative to address math anxiety in school settings. This chapter will cover models of math anxiety and explore research in math anxiety interventions.

Models of Math Anxiety

The causes and catalysts for math anxiety are complex, nuanced, and not mutually exclusive. As such, diagnosing the anxiety’s origin is challenging. It is valuable to understand how teacher, community, and cultural actions may contribute to this problem. It is also important to develop and implement evidence-based practices that can remediate the anxiety regardless of its ultimate origin. Models discussed include direction of influence, sociocultural, neurobiological, reappraisal, and behavioral.

Direction of Influence Models

The literature suggests three discrete models that attempt to explain directionality of math performance and math anxiety. First, the disruption model suggests that low math performance is the result of math anxiety. Second, the reduced competency model states that poor math performance creates future math anxiety (Ramirez et al., 2018). Finally, the bidirectional model declares that establishing directionality is not possible because math anxiety and math performance influence each other through a dialectal relationship (Namkung & Lin, 2019).

Sociocultural Models

Also explored in the literature are sociocultural models explaining the genesis and impacts of math anxiety. One perspective proposes that math anxiety is transferred from parents and teachers to students. Hembree (1990) reported that the college students with the most math anxiety were majoring in elementary education. This suggests an alarming trend that those introducing a child's first math experiences may also be inadvertently introducing math anxiety. Mixed results slightly favor that transference was more common for girls (Hembree, 1990). This may be a result of cultural expectations that insinuate girls are worse at math compared to boys. It could also be linked to cultural ideas that girls are more allowed to freely express emotions, meaning boys under-report anxiety (Ramirez et al., 2018). However, gender gaps have narrowed in recent studies, such as reported by Ganley et al. (2013), suggesting there is flux in gender-based sociocultural models.

Neurobiological Model

Research conducted through a neurobiological lens has provided new understanding about the region of and processes in the brain that are involved with mathematical processing and math anxiety. For example, Mammarella et al. (2019) reported that the amygdala is more active in students with higher math anxiety. The amygdala is part of the central executive system that sustains working memory. This activation of the amygdala in anxious students shows that working memory is impaired as a result of the attention demands on anxiety.

Working Memory. Dowker et al. (2016) reports that math anxiety is correlated most often with multi-step problems. This finding supports the notion that working memory is a key mediator between math anxiety and performance. Working memory is the cognitive component serving as a “scratch-pad” to hold and manipulate temporary information (Skagerlund et al., 2019). The more steps in a problem, the more working memory is required. Using electrophysiological scans, Klados et al. (2015) found that working memory, anxiety, and mathematical problem solving place demands on the same areas of the brain. Skagerlund et al. (2019) suggested that anxiety consumes available working memory, leaving insufficient capacity to attend to mathematical thinking.

Cognitive Preparation. A second implication found in neurobiological research is cognitive preparation. When presented math stimuli, students with low math anxiety demonstrate brain patterns suggestive of cognitive preparation for completing that task. In contrast, students with high levels of math anxiety do not show that cognitive planning. This discrepancy suggests that anxiety is connected to a lack of cognitive preparation (Mammarella et al., 2019).

Reappraisal Model

A model attracting attention in recent literature is reappraisal. This model suggests that math anxiety is more about the interpretation that past math experiences were negative, regardless if they were truly net negative or positive encounters. These “Math efficacy-related judgments significantly predict math anxiety in students” (Meece et al., 1990, p. 68). Those who perceive low performance as an outcome of low ability will perform worse in the future than those who perceive low performance to be a consequence of low effort (Mammarella et al., 2019). Students with poor reappraisal will view feelings of physiological arousal before a math task as a threat, rather than as cognitive preparation for a task, which contributes to the cycle of negative perceptions.

Behavioral Model

Behavioral models examine math anxiety through visible, and therefore more observable, behaviors to qualify and quantify the effects of math anxiety on individuals. Much like a phobia (Ramirez et al., 2018), the function of math anxiety is usually avoidance (Ashcraft, 2002). Individuals with math anxiety are negatively reinforced by the removal of the math stimulus when engaging in avoidant behavior. For example, students may display behaviors in the classroom such as leaving their desks, disrupting instruction with inappropriate behavior, or engaging peers to escape math tasks by being removed from the classroom or delaying the start of their work until the period is over. Math anxiety predicts the avoidance of signing up for math classes suggesting that students avoid even signing up for math classes due to previous negative experiences (Meece et al., 1990).

To increase a school community's ability to recognize math anxiety, it is imperative to make risk factors observable and measurable. The following proposed definition bridges neurological approaches of math anxiety with a behavior analytic view of math anxiety: the presence of math stimuli elicits physiological arousal (heart racing, tension, and nervousness (Ashcraft, 2002) which evoke other escape-related responses (e.g., expressing frustration, leaving homework unfinished, seeking peer attention or other more highly preferred activities) which have been reinforced in the past by the removal of the math stimuli. In this case, the removal of the math stimuli reinforces the escape-related behaviors and simultaneously strengthens the respondent conditioning associated with the physiological experience of anxiety. This vicious cycle maintains escape-related responding over time and can result in decreased math engagement and performance if ignored or ineffectively addressed by school staff.

Math Anxiety and Disability

When seeking to understand phenomena such as math anxiety, it is important to consider how it may present differently in those with disabilities. Unfortunately, very little research exists on the intersection of math anxiety and disability in K-12 settings.

Developmental Dyscalculia

Developmental Dyscalculia (DD) is a condition that makes it difficult to process numerical and spatial information (Mammarella et al., 2015). Devine et al. (2018), in study of nearly 2,000 K-12 students, found that those with DD are twice as likely experience math anxiety. The author explains that although this comorbidity is common, math anxiety as compared to cognitive blocks inherent to DD affect math performance in distinctly different ways (Devine et al., 2018). In fact, Mammarella et al. (2015) conducted a study on the cognitive profiles of students with isolated DD and students with isolated math anxiety. Students with DD scored lower on visuospatial working memory, while students with math anxiety scored lower on verbal working memory, implying that math anxiety and DD impact performance oppositely. Thus, while overlap with DD and math anxiety commonly exists, these issues must be treated with interventions that accommodate and treat their respective working memory deficits.

Autism

Georgiou et al. (2018) compared the prevalence of math anxiety between teens students with autism and typically developing peers. Interestingly, the researcher found that those with autism reported lower levels of anxiety. It has been a concern in the past that students with autism have a decreased ability to self-report feelings, but authors cited more recent research, as well as cited high reliability within their own study, to indicate this is not true. Unfortunately, math anxiety in autism research is scarce, and as academic and cognitive needs differ across the autism spectrum, these results should be considered but not widely generalized.

Deaf and Hard of Hearing

Students who are deaf and hard of hearing were also found to have higher levels of math anxiety as compared to typical peers (Ariapooran, 2017). They typically perform two standard deviations below their grade mean and are 3.5 years delayed in math competency as compared to same age peers. To compound these statistics, students with deafness also display lower levels of self-determination and intrinsic motivation. Ariapooran (2017) found that students who are deaf and hard of hearing exhibit higher levels of extrinsic goal orientation as compared to hearing peers. The combination of poor performance, lack of intrinsic motivation, and high levels of math anxiety all compound to further solidify barriers to math success.

Meta-Analysis Exploring Correlations and Interventions for Math Anxiety

Hembree (1990) conducted a meta-analysis on math anxiety to identify correlates and differentials, as well as reviewed interventions for math anxiety. Across all included studies, 29 (19%) included participants in K-12 settings, but an unreported number of these studies were not exclusively K-12, including post-secondary participants. Hembree (1990) did not specify age groups within the 70 experimental studies. They provided a simple metric of methodological quality, reporting a median of two out of three possible points. They did not report which factors were measured, which practices or studies exhibited high levels of rigor, or explain what improvements would benefit this field of research.

Correlates and Differentials

Their findings indicated that factors relating to high anxiety include lower IQ, low math performance, feeling negatively towards math, and not feeling confident in math ability. Hembree (1990) also found that math anxiety increases as school grade increases. Females were linked to higher anxiety than males, but this gap narrowed by college. Lastly, Hispanic students experience higher levels of math anxiety as compared to students of other ethnicities.

Interventions

Hembree (1990) reviewed 115 studies that conducted interventions in K-12 and postsecondary settings. He organized intervention types into four categories: classroom, cognitive, behavioral, and cognitive-behavioral.

Classroom Interventions. This category included all interventions that occurred in a classroom. Hembree (1990) differentiated two types of interventions: curricular changes and psychological interventions. Curricular changes included calculator accommodations, whole group versus small group instruction, and self-paced learning. They did not provide examples of psychological interventions in the classroom. The effect size for both curricular changes (Δ = -0.04) and psychological interventions (Δ = -0.10) were not significant.

Cognitive Interventions. Cognitive modifications included group counseling and restructuring. The practice of restructuring is also called reappraisal. As discussed previously, reappraisal is the idea that perception of an experience is more impactful than reality. When reconstructing is used as an intervention, the individual attempts to deconstruct their negative perceptions (Mamarella et al., 2019). Hembree (1990) reported group counseling as not effective (Δ = -0.03), and reconstructing as a medium effect (Δ = -0.51).

Behavioral Interventions. Behavioral treatments addressed observable signs of anxiety. The interventionist manipulated variables in the environment to shape the individual's behavior, with the goal to elicit less anxiety when confronted with the anxiety-inducing stimuli in the future. Interventions include systematic desensitization and relaxation training. Systematic desensitization is a form of classical conditioning where the individual is gradually introduced to their phobia trigger in more invasive ways, but only when anxiety is diminished in the current stage (McLeod, 2015). Relaxation training encompasses intentional tensing and relaxing of the muscles. It also can include guided imagery, of both imagining scenarios that are peaceful and those that are anxious. The interventionist walks the individual through anxious scenarios to teach them to identify, monitor, and understand their body's reaction to stress (Bernstein et al., 2000). Systematic desensitization had a large effect ($\Delta = -1.04$), and relaxation training had a medium effect ($\Delta = -0.48$).

Cognitive-Behavioral Interventions. Cognitive-behavioral interventions combined cognitive strategies as mentioned previously, with behavioral strategies as mentioned previously. Integrating these two practices together produced the highest effect ($\Delta = -1.15$).

Research Not Synthesized in Related Meta-Analysis

Researchers tended to remediate math anxiety from two angles. Some studies attempted to reduce anxiety by academic strategies, while other studies used therapeutic tools.

Academic Interventions

Pedagogical Strategies. Batton (2010) conducted a quasi-experimental study to test the impact of a nine-week cooperative learning intervention on math anxiety and achievement for 64 fifth graders. Cooperative learning is an instructional strategy that encourages students to solve problems together. Per Batton (2010), this design allows students to learn new strategies from each other, develop social skills, and improve academic achievement. Mixed ability and mix gender groups worked for 70 minutes' total weekly, split into two sessions a week. The teacher did not provide help until the groups tried all alternatives, and only provided positive feedback when assignments were turned in. Following the intervention, female participants in the experimental group demonstrated greater improvement in math anxiety symptoms as compared to the control group [$F(1, 30) = 4.75$, $p = .037$]. Interestingly, males did not demonstrate statistically significant differences across control and treatment phases. This result suggests that gender is likely a moderating factor for the effectiveness of certain treatments.

One-on-One Tutoring. Supekar et al. (2015) reported that one-on-one math tutoring improved math anxiety symptoms, increased math performance, and decreased observed amygdala reactivity. The amygdala is one location in the brain where anxiety is processed, and higher levels of anxiety produce increased activation on brain scans (Supekar et al., 2015). Forty-six third graders were divided into 2 groups by levels of math anxiety: low math anxiety (LMA) and high math anxiety (HMA). Both groups received tutoring on single and double digit problems for addition and subtraction, as well as instruction on associative, commutative, and identity properties. The authors reported that the HMA group had significantly lower anxiety levels post tutoring and equalized to similar levels as the LMA group. Interestingly, LMA math anxiety levels were the same before and after the intervention. Supekar et al. (2015) observed less amygdala activation in the HMA group after the intervention. Their hyperactivity equalized to the same activation levels as the students with LMA after the treatment. Meaning, after the tutoring intervention, the brains of students with HMA did not activate any more anxiety than did the brains of students with LMA. The authors surmised that the intervention was successful due to the math skill remediation functioning similar to desensitization and exposure-therapy treatments. Desensitization occurs with focused exposure to the anxiety inducing stimuli (Bernstein et al., 2000), which is exactly what happened as students were provided focused exposure to the anxiety inducing math stimuli. Students may be able to escape and disengage in classroom settings but working individually with a tutor can help them stay engaged and reconcile math anxiety in a structured environment.

Therapeutic Interventions

Expressive Writing Therapies. Hines et al. (2016) studied the effect of an expressive writing intervention with 93 low performing secondary students in their geometry class. This intervention may fit under Hembree's (1990) behavioral intervention category. The experimental group was directed to write down their feelings about math class, math tests, and school for an average of twenty minutes a day for three classes. The control group was tasked to write about school, but on themes unrelated to emotions, and other emotionally neutral themes like favorite time of year. After the intervention, authors reported that, compared to the control, the experimental group produced more organized writing and more effectively analyzed their thought patterns. Hines et al. (2016) surmised this is because being directed to write about emotions made students better at processing those emotions. The experimental group was also better at identifying their anger and negative emotional responses. Both mathematical and general anxiety symptoms were improved in the experimental group, and the control group exhibited improved math anxiety symptoms. Both the experimental and control experienced improvement in math anxiety symptoms in response to the treatment, and there was no significant variance between the groups [$F(l, 93) = 2.3$, $p>.05$]. Although this was not the anticipated result, the authors learned that even just writing about school or life in general while in math class may reduce levels of math anxiety. Lastly, the experimental group's increased ability to identify and process emotions as compared to the control, is an additional strategy that students could use if they were to experience future instances of math anxiety.

Reappraisal Therapies. Ramirez et al. (2018) defined reappraisal as cognitive strategies that improve math anxiety symptoms by teaching the individual to question perceived level of a threat. This is beneficial for math anxiety because those with anxiety tend to overestimate the consequences of a given situation. Reappraisal consists of addressing physiological symptoms associated with a threat, such as increased heart rate, faster breathing, increased body temperature, and fidgeting. Individuals who are good at reappraisal, activate certain parts of their brain that aid precurrent problem solving better than those who are not good at reappraisal. Meaning, they are more efficient at gearing up to face a task that may elicit anxiety, as better at mentally collecting relevant information that may assist in problem solving that task.

Hocker (2017) conducted an experimental design study at five public charter high schools for at risk-students. Math anxiety, mindset, and view of math were measured before and after treatment. The five-hour curriculum taught and practiced growth mindset, problem solving, and math exploration. Teachers praised students who shared mistakes, reinforcing the value of productive struggle. The intervention produced a medium effect ($d = 0.38$). Reframing mistakes as an integral part of learning and viewing effort as more important than the right answer may be an effective treatment to improve math anxiety symptoms.

Cognitive-Behavioral Therapies. Mindfulness-Based Cognitive Therapy (MBCT) is an approach to regulating emotional responses using mindfulness (LaGue et al., 2019). Mindfulness is a practice of observing emotions, feelings, and the surrounding setting without judgment. LaGue et al. (2019) tested MBCT's impact on math anxiety through a nonconcurrent multiple-baseline single-case design, with three students in secondary education. The authors' visual analysis of graphed results reported that math anxiety symptoms improved in all three participants. However, for one student, the data did not demonstrate a stable baseline before intervention. As such, the authors should have considered confounding variables that may have contaminated the data. For another student, the data did not seem to demonstrate an effect until the last two data points, thus not establishing a strong treatment effect in the given time frame.

Research Gaps

Need for Methodological Quality

One of the greatest gaps in math anxiety intervention analysis is the lack of methodological quality measurement. According to the Council for Exceptional Children Standards for Evidence-based Practices in Special Education (CEC), a study must meet all of its respective quality indicators to be considered methodologically sound. Quality assessment measures, like the CEC Standards, require a clearly established independent and dependent variable with data analysis proving a functional relationship. Inter-rater and inter-observer reliability is assessed to ensure the statistical analysis is based on accurate data. For a treatment to be considered a best practice, it must be supported by at least two methodologically sound studies of that treatment (CEC, 2014). It is crucial that the current literature is assessed for methodological quality so effective interventions can be disseminated to teachers and practitioners as evidence-based practices.

Teacher-Led Interventions

Additionally, Hembree (1990) reported that interventions that occur in the classroom are not significantly impactful on math anxiety. However, recent research challenges Hembree's (1990) claim. Given the availability of contemporary research on classroom interventions, it is imperative to seek out and synthesize data from new interventions to inform practitioners if this is a viable and effective pathway to treat math anxiety.

K-12 Focus

Hembree (1990) did not provide a clear context for what interventions benefit K-12 students specifically. As bad math experiences accumulate over time, and in different developmental stages, anxiety may get worse or require different types of interventions.

Moderating Variables

There is no existing review on disability as a moderating factor in the success of math anxiety interventions. Just as age may impact what interventions are effective, so might disability. Additionally, frameworks such as response to intervention (RTI), organize decision-making for when a student needs more intensive supports. In an RTI framework, all students receive the first universal tier, small groups of students receive second tier services, and in the last tier, students are provided highly individualized interventions. Knowing in which tier an intervention would be most effective is valuable information for practitioners (Jimerson et al., 2016). Providing an analysis of moderating factors such as these would be indispensable in guiding practical and effective application of math anxiety treatments.

Statement of the Purpose

The purpose of this study is to conduct the first meta-analysis for math anxiety interventions exclusively in K-12 settings, and to update the field on the availability of evidence-based practices. We conducted moderating analyses to determine what factors make interventions more efficacious. Lastly, we assessed the methodological quality of this literature.

Research Questions

1. To what extent are school-based interventions targeting math anxiety effective at reducing anxiety and/or increasing math performance for K-12 students?
2. Are these effects moderated by other intervention factors (e.g., intervention intensity, duration, disability status)?
3. To what extent is the current literature on this topic methodologically rigorous?

CHAPTER 3

Method

After searching the literature on models of math anxiety, as well as studies on interventions to reduce anxiety, we created research questions that we felt would extend the current dialogue:

1. To what extent are school-based interventions targeting math anxiety effective at reducing anxiety and/or increasing math performance for K-12 students?
2. Are these effects moderated by other intervention factors (e.g., intervention intensity, duration, disability status)?
3. To what extent is the current literature on this topic methodologically rigorous?

Following the establishment of these questions, we developed a process for selecting articles, decided on inclusion criteria, and created a data analysis procedure we felt would provide informative outcomes.

Article Selection Process

Study Identification

First, we performed a systematic electronic search in several databases: ERIC EBSCO, Academic Search Premier, Psychology and Behavioral Sciences Collection, and Education Full Text. We queried these databases using the search string: *("math anxiety" OR "mathematic anxiety" OR "mathematics anxiety") AND ("intervention" OR "training" OR "therapy" OR "reappraisal training" OR "guided imagery" OR "treatment") AND ("student*" OR "high school students" OR "middle school students" OR "secondary school students" OR "primary school students" OR "elementary school students")*. This search resulted in 318 articles. Later in the process, we conducted an index search by investigating the reference sections of selected articles and obtained three additional studies. These 3 studies likely did not appear in database searches because they were theses/dissertations published to a university website rather than in a journal. To ensure reliability in this selection process, a first research assistant, who was an undergraduate student majoring in Special Education, repeated the initial search string and evaluated titles and abstracts as in the original search. She identified 375 possible articles in the database search. The additional 57 articles may be due to new journals being added to the databases or articles added during the four-month interval between the first and second searches. In the end, this reliability check did not produce any additional articles. Finally, the first research assistant also conducted a 10-year ancestral search in four journals: School Science and Mathematics, Educational Technology Research and Development, Journal of Education, and Journal of Humanities and Social Sciences Studies. The research assistant found no additional studies.

Inclusion Criteria

We screened articles for research design, publication language, date, intervention location, and dependent variables. To be included, studies must have been experimental or quasi-experimental group designs. The publication language had to be English, with a publication date after 1990. We selected after the year 1990 as the inclusion criteria because this timeline is after the publication of the last meta-analysis, Hembree 1990. We selection 1991 at the beginning year in the database filter. Next, we followed the population, intervention, comparison, and outcomes model (PICO; University of Illinois Library, 2020). We selected articles that studied K-12 students (i.e., ages 5-21). The inclusion criteria also required interventions to be situated on a private, public, charter, or residential school campuses, and to be delivered by a teacher, researcher, or clinician. We defined clinician as a therapist, school counselor, or school psychologist. We required that interventions be either therapeutic or academic. We defined therapeutic interventions as cognitive strategies taught to the participant that (a) identify the existence of the math anxiety, (b) explain why math anxiety is present, and (c) create a plan to cope with that anxiety. If the intervention implemented at least one of those three strategies, it met our criteria. We defined academic interventions as any math instruction specifically targeting math anxiety. To simplify the coding process, if a study used both therapeutic and academic strategies, we coded the study as an academic intervention. Additionally, we required studies to identify what occurred in the control group in place of the intervention, and that the control group activity consist of the regular math instruction present before the study began. Finally, we required that studies measure math anxiety as a dependent variable. While we welcomed any data on math performance, we did not exclude studies measuring only math anxiety. The desired outcome of these interventions was an improvement in math anxiety symptoms, which would ideally lead to an increase in math engagement and performance.

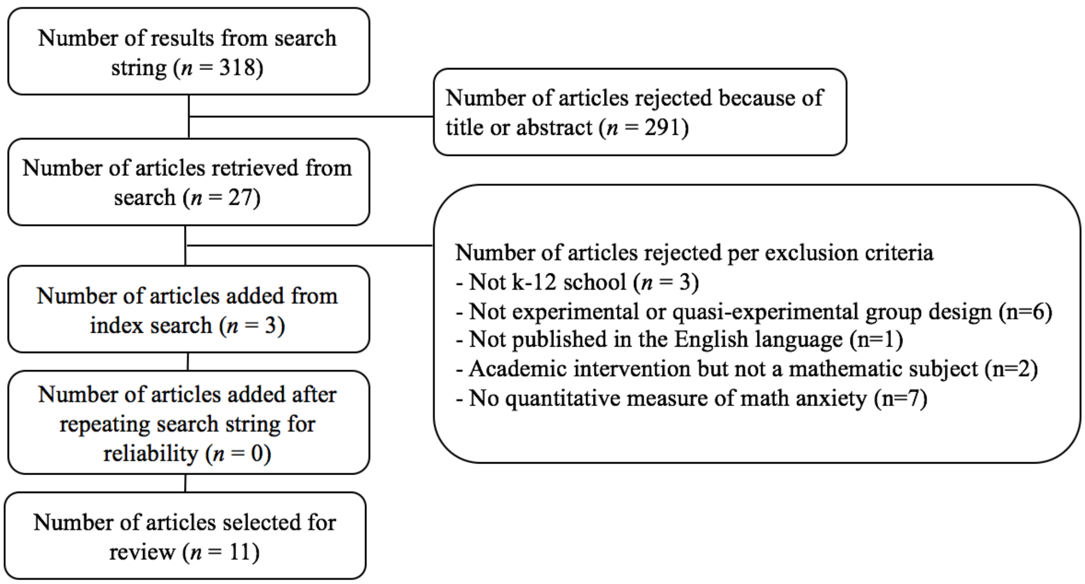
Screening

We present the results of our screening process in Figure 1, modeling the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram (Moher et al., 2009). We briefly evaluated each title and abstract of the 318 results from the initial search. If the study obviously contradicted one of our inclusion criteria, we rejected it. We discarded 291 of the initial results because of title or abstract, which resulted in 27 remaining studies. To this point in the screening process, we had accepted both single-case and group design; however, we only identified three quantitative single-case designs that measured math anxiety. Thus, we made the decision to include only group-design studies in the present review. As summarized in Figure 1, we rejected additional studies from this list of 27 for not being conducted on a K-12 campus, not reporting quantitative math anxiety data, not reporting a control, not being published in

English, not including a mathematic or therapeutic intervention in the design, or not utilizing a quasi-experimental group design. This step reduced our qualified articles to eight. After this point was when we conducted the index search and added three more articles. In total, we identified 11 articles for inclusion in this systematic review.

Figure 1

Article Selection Process



Note. The top left bubble is indicative of the beginning of the article selection process. All left bubbles contain information on where articles were found and how many were found in that location. The bubbles on the right contain the reasons for article rejection.

Coding Procedures

We coded all articles that met our inclusion criteria using a survey in Qualtrics, an online survey tool (Qualtrics, Provo, UT). Members of the research team utilized a code sheet to review each study. We organized the code sheet into eight sections: identification information, research design, participant information, setting, intervention procedures, dependent variable, results, and methodological quality. The survey in its entirety can be found in Appendix B.

Identification Information

We noted who coded the article, article name, location of study, journal name, and date of publication.

Research Design

We included coding to identify the independent and dependent variables, research question(s), and research design.

Participant Information

We gathered data on participant characteristics, including the number of participants, participant age, gender identity, race/ethnicity, disability status, and socioeconomic status.

Setting

We identified the type of school, where in the school the intervention occurred, and whether the intervention was presented to an individual, small group, or an entire class setting.

Intervention Procedures

We entered information regarding the interventionist qualifications, duration of intervention, treatment type (e.g., therapeutic or academic), and the specific activities employed during the intervention. If the study included both therapeutic and academic elements, it was coded as academic to simplify coding procedures.

Dependent Variables

We noted if authors measured math anxiety, math performance, or both. For Additionally, we documented how authors measured anxiety and/or math performance.

Results

We gathered all information available regarding social validity, implementation fidelity, data analysis, means with corresponding standard deviations, and effect sizes.

Methodological Quality

We assessed articles using the Council for Exceptional Children Standards for Evidence-based Practices in Special Education [CEC Quality Indicators] (CEC, 2014) to evaluate the methodological quality of each article. We selected these indicators with the rationale that a high number of students with math anxiety also have a disability. For example, in students with developmental dyscalculia, the incident rate of math anxiety can be 50% higher than those of their typical peers (Mammarella et al., 2015).

When coding each article, the coders responded *yes* or *no* to each indicator. We used this information to illuminate our understanding of the quality of research available for math anxiety interventions. Per CEC (2014), an article must meet all respective indicators to be considered methodologically rigorous. The CEC Quality Indicators organize standards into eight sections. We only utilized certain components, as some were specifically targeted for single-case designs and were not relevant to our review.

QI 1.0 Context and Setting. (1.1) The study had to include relevant information regarding the school and classroom setting.

QI 2.0 Participants. (1.1) Authors were required to provide demographic information about the participants, and (2.1) give details about participants with disabilities or with at risk status.

QI 3.0 Intervention Agent. (3.1) They had to describe the interventionist's background and role in the study. (3.2) They also needed to indicate the training given to the interventionist about their role in the study, as well as credentials required to be an interventionist.

QI 4.0 Description of Practice. (4.1) The study had to describe essential components of the intervention, and (4.2) explain what materials were used as a part of the intervention.

QI 5.0 Implementation Fidelity. (5.1) Authors needed to assess implementation fidelity and report the results. (5.2) They had to assess implementation fidelity about the length of the study and/or the duration of intervention sessions with direct and reliable measures. (5.3) It must be reported that implementation fidelity occurred for all interventionists and during the entire intervention process.

QI 6.0 Internal Validity. (6.1) Authors needed to prove that they had control over manipulating the independent variable. This cannot be met if indicator 5.1 is not met. (6.2) Authors had to indicate the differences between control and treatment setting. (6.3) The study needed to reference how they prevented the control group from accessing the intervention. (6.4) Authors had to explain how participants were assigned to control or treatment groups. (6.8) They needed to report that overall attrition was lower than 30% during their study and (6.9) indicate that differential attrition was less than 10%.

QI 7.0 Outcome Measures. (7.1) Authors needed to explain that outcomes were socially important, and (7.2) how they measured dependent variables. (7.3) They had to report all results, not just those with the desired outcomes, (7.4) and disclose that data collection occurred with appropriate frequency and timing. (7.5) Authors had to reveal that their measure of reliability was at least 80% or higher, and (7.6) report adequate validity.

QI 8.0 Data Analysis. (8.1) Authors had to employ and report relevant data analysis techniques, (8.3) and report effect sizes or data that an effect size could be calculated from.

Training Coders

A primary and secondary coder completed the Qualtrics (Provo, UT) survey to record relevant article information. The primary coder was the researcher, and the secondary coder was an unpaid volunteer who has an M.Ed. in Curriculum and Instruction. This coder was not the same individual who conducted reliability in the article selection process. Before initiating this process, the secondary coder participated in a training session. The primary coder led the training over a Zoom conference call using Google Slides and modeled coding an example article. After the completion of this training presentation, the primary coder assessed the secondary coder via a practice article, which had been previously coded by the primary coder. Answers were compared to generate a proficiency score for the secondary coder. To qualify as proficient, the inter-rater agreement was required to be at least 80%. If agreement had been less than 80%, the secondary coder would have been required to discuss inter-rater disagreements, review the original presentation, and code a second practice article. However, this was not necessary because the first attempt resulted in an inter-rater agreement of 80.6%. The primary and secondary coders discussed and resolved discrepancies before the termination of the training. After this portion of the training was complete, the secondary coder had access to the Google Slide presentation at any time. The presentation was also uploaded to Nearpod (Nearpod, n.d.) with recorded commentary by the primary researcher. Additionally, the secondary coder had access to a vocabulary guide that defined relevant terminology, such as dependent/independent variable, various research designs, and statistical terms. This document, found in Appendix C, was allowed during both the practice and official coding.

Inter-Rater Agreement

The secondary coder completed four out of 11 articles. The primary coder completed all eleven articles. We used a random number generator function in Microsoft Excel to select the double-coded articles (Savitsky, n.d.). In one column, each first authors' last name was listed in alphabetical order. In a second column, the randbetween function was used to associate a random number with each authors' name. We selected the four smallest numbers as our inter-rater reliability articles.

We calculated percent agreement by adding up the number of agreements and dividing that total by the number of opportunities to agree. If the percent of agreement did not meet the criteria of at least 80%, the coders would have been required to review the initial training and demonstrate at least 80% practice accuracy on an additional practice article before returning and re-coding in the official process. Additionally, coders were to discuss all inconsistencies until a consensus was made.

The articles selected by random generation included Kim et al. (2016), Ruark (2018), Walter (2018), and Wei (2010). The respective percentages of inter-rater agreements were 85.48%, 85.48%, 91.94%, and 85.48%. The most consistent question marked as a disagreement was CEC component 1.1. This component states, "The study describes critical features of the context or setting relevant to the review; for example, type of program or classroom, type of school (e.g., public, private, charter, preschool), curriculum, geographic location, community setting, socioeconomic status, physical layout" (CEC, 2014). Of the inter-rater reliability articles, 50% were scored as a mismatch on this question. Inconsistency could be attributed to the additional question description, where it was clarified that it was allowable to select "met" if type of school could be inferred. Coders likely exhibited a discrepancy on what qualified a description as sufficient to extrapolate an inference.

Data Analysis

Dependent Variable: Math Anxiety

To calculate a common metric in Cohen's d, we used Campbell's Collaboration (Wilson, n.d.). We made adjustments to ensure that, for all studies, a positive effect size meant an improvement in math anxiety symptoms. Most of the studies provided adequate information to use the test "Means, Standard Deviations, and Sample Sizes." Kim et al. (2016) and Wittman (1996) only reported data into anxiety-level subgroups, so in these cases we employed the test "Means and Standard Deviations in Subgroups." White (1997) provided means and a T-test, but no standard deviation; as such, we used the test "T-Test, Unequal Sample Sizes." The math anxiety data that Walter (2018) provided was sparse. However, they because they reported an F-test, we were able to use the test "F-test, 2-group, Unequal Sample Sizes" to calculate an effect size.

Hocker (2017) provided means and mean differences for treatment and control, as well as a Cohen's d. They also provided two t-tests, one for treatment and another for control. Although they reported a standard deviation for the treatment group, the control group's standard deviation was absent. Additionally, no confidence intervals were reported for either group. To address these gaps, we had to assume that the control group standard deviations were relatively equal for both pre-test and post-test. We took an average of the SD from pre-test and post-test and made it the denominator and the mean difference of pre-test and post-test as the numerator. This process provided an estimated SD of 0.28. We applied this information in the Campbell's Collaboration

(Wilson, n.d.) test “Mean Gain Scores, Pre and Post SDs, and paired t-tests” to produce confidence intervals.

Zyl and Lohr (1994) was a complex case. Authors did not provide an effect size or t-test and did not report standard deviations. They only presented a mean decrease in anxiety level for treatment and control. We conducted a search in all articles that cited Zyl and Lohr (1994) but could not find any additional versions of this article, or additional data. As such, based on article parameters, we imputed random hypothetical participants for treatment and control. We adjusted this data until it lined up with the provided means, which also outputted standard deviations that we could utilize alongside our means to generate a t-statistic. The result of this t-test was t = -3,65674, which was then put into the test “Student’s T-test and Total Sample Size” to generate an estimate effect size. Although we strived to be as conservative as possible to avoid effect size inflation, the resulting effect size was 14.94 standards deviations above the omnibus grand mean. A summary of all Cohen’s d effect sizes can be found in the table, Campbell’s Collaboration (n.d.) Calculations, found in Appendix A, as well as pre/post data used in this process.

We conducted a random model analysis with Comprehensive Meta-Analysis (Borenstein et al., 2013), and elected to convert effect sizes to Hedge’s g for the individual and omnibus effect size estimation. We used Hedge’s g because it uses the same underlying metric but is less biased in circumstances like this review where the sample size is small (Card, 2011). We presented results in form of a forest plot. We addressed outliers, compared confidence intervals, and referenced p-values. Additionally, we conducted tests for heterogeneity. Homogeneity is decided when all confidence intervals overlap a common effect, and that any deviation can be ascribed to “random sampling fluctuation” (Card, 2011, p. 184). Lastly, we analyzed publication bias, the tendency of authors to publish only desirable results (Card, 2011). We displayed publication bias results using a funnel plot.

Dependent Variable: Math Performance

We did not conduct analyses with math performance data beyond converting all results into Cohen's d using Campbell's Collaboration (Wilson, n.d.). Walter (2018) and Wei (2010) included sufficient data to use the test "Means, Standard Deviations, and Sample Size." In the case of Wittman (1996), we used the F-test from their provided ANOVA and conducted the "F-test, 2-group, Equal Sample Sizes." This is because they did not provide data for the control group but did provide an ANOVA for the treatment. Kim et al. (2016) broke down reporting into anxiety-level subgroups so we used "Means and Standard Deviations with Subgroups." Lastly, White (1997) did not provide standard deviations, but gave means and a t-test, so we used "T-test, Unequal Sample Sizes." We adjusted effect sizes to indicate that a positive effect size meant that math performance increased. A summary of the Campbell's Collaboration (Wilson, n.d.) process, including pre/post data, can be found in Appendix A.

Moderating Variables

Based on patterns in the literature and availability of data, we conducted moderating analyses on three moderating variables we felt might highlight factors that improve intervention efficacy. We ran two analysis as random effect models comparing two binary groups. The last analysis was a meta-regression, because the variable was not a categorical characteristic. For the first two analyses, we compared effect sizes, referenced p-values, compared confidence intervals, and measured homogeneity within each group and across groups.

Methodological Quality

Methodological quality was measured by absolute and weighted scoring. Absolute scoring measured the number of indicators in which all sub-indicators were met for a particular study. For example, one point is awarded if an article meets both 4.1 and 4.2. But if only 4.1 is met, then that indicator is not awarded a point. Weighted scoring was calculated by taking an indicator and dividing the number of sub-indicators from one. In the case of indicator 7, that would be 1/6, because there are six sub-indicators. If an article got two out of six sub-indicators, the score would be 0.167 + 0.167 = .33. We rounded to two decimals. All eight indicator scores were then added together to be provided an overall weighted score for that study.

CHAPTER 4

Results

We included 11 studies in the final analysis. Three studies were peer reviewed articles and the remaining eight were either a dissertation or thesis. The mean publication year was 2011, the range being 1994 to 2019. We organized results of the meta-analysis by research question: efficacy of interventions, moderating variables, and methodological quality.

Research Question 1: Efficacy of Math Anxiety Interventions

We examined the efficacy of math anxiety interventions by converting all effect sizes to a common metric and calculating an omnibus effect size using a random effects model, accessed through Comprehensive Meta-Analysis (Borenstein et al., 2013). We present results of this model in Figure 2.

Omnibus Effect

For purposes of uniformity, a positive effect indicates an improvement in math anxiety symptoms. The omnibus effect size was $g = 0.316$, [0.158, 0.475], $p = 0.000$. Guidelines for interpreting Cohen's d can also be used for Hedge's g, "$d = 0.20$ considered a small effect, $d = 0.50$ considered a medium effect, and $d = .80$ considered a large effect" (Card, 2011, p. 92). The omnibus effect size $g = 0.316$ is considered a small effect.

Individual Effect

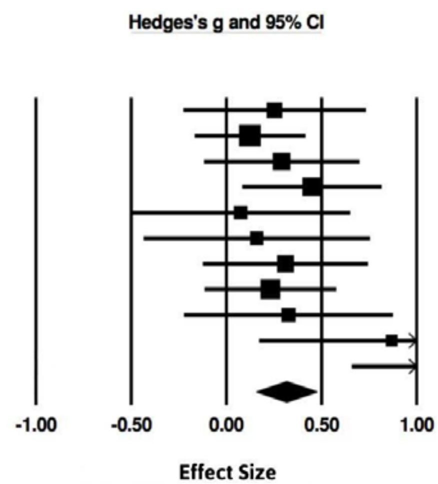
Individual effect sizes ranged from 0.075 and 1.566. Accordingly, nine studies had small effects sizes (Batton, 2010; Henderson, 2019; Hines et al., 2016; Hocker, 2017; Kim et al., 2016; Ruark, 2018; Walter, 2018; Wei, 2010; White, 1997). Two studies had large effects (Wittman, 1996; Zyl & Lohr, 1994). Two studies exceed the omnibus upper limit of 0.475, meaning they are likely outliers (Wittman, 1996; Zyl & Lohr, 1994).

Figure 2

Hedge's g Forest Plot

Meta Analysis

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study						
Batton (2010)	0.253	0.243	0.059	-0.224	0.729	1.040	0.298
Henderson (2019)	0.124	0.147	0.022	-0.164	0.412	0.844	0.399
Hines et al. (2016)	0.290	0.207	0.043	-0.115	0.695	1.403	0.160
Hocker (2017)	0.449	0.185	0.034	0.085	0.812	2.421	0.015
Kim et al. (2016)	0.075	0.292	0.085	-0.498	0.647	0.255	0.799
Ruark (2018)	0.159	0.302	0.091	-0.433	0.751	0.526	0.599
Walter (2018)	0.310	0.220	0.048	-0.121	0.740	1.410	0.159
Wei (2010)	0.231	0.175	0.031	-0.112	0.574	1.321	0.186
White (1997)	0.326	0.279	0.078	-0.220	0.872	1.170	0.242
Wittman (1996)	0.868	0.354	0.126	0.173	1.563	2.449	0.014
Zyl & Lohr (1994)	1.566	0.462	0.213	0.661	2.471	3.393	0.001
	0.316	0.081	0.007	0.158	0.475	3.914	0.000



Meta Analysis

Note. The table on the left includes Hedge's g statistics. The final, unlabeled row represents the mean of all studies. A forest plot is located on the right. The larger the black box, the larger the sample size. Horizontal lines represent confidence intervals and the rhombus in the bottom center represents the grand mean.

Heterogeneity

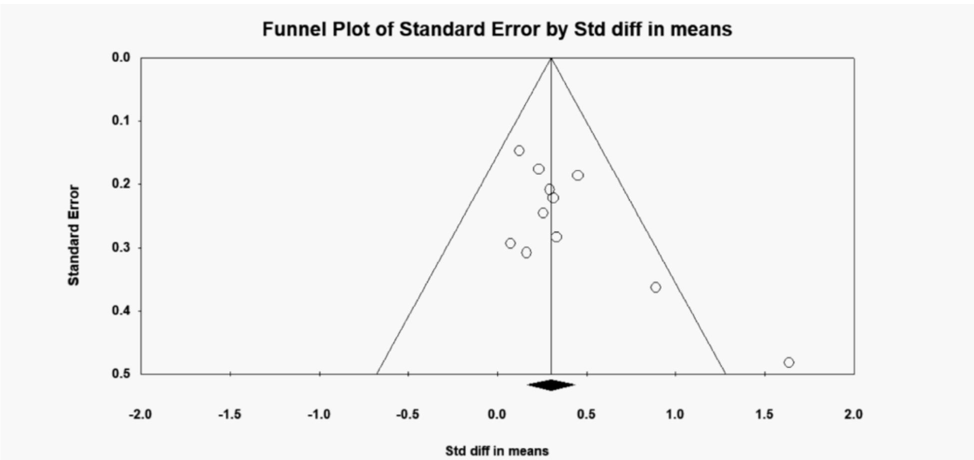
When we tested heterogeneity, we ensured that all measures assessed the same outcome of math anxiety. We assessed chi-squared by calculating a Q-statistic from all Hedge's g effect sizes. For the output Q to be considered sufficiently homogeneous, it could not exceed its correlating df(q) and the corresponding p-value (Card, 2011). For this study, the df(q) = 10, p = .204. The chi-square critical value at df(q) 10 and p-value .2 is 13.442. Because our q-value of 13.370 did not exceed its corresponding chi-square value, we can conclude that our studies had sufficient homogeneity. Because the Q statistic only indicates whether studies are homogeneous, we also calculated an I-squared index to examine the degree of heterogeneity evident in our data. For the present study, $I^2 = 25.207\%$, which is considered a small amount of heterogeneity (Card, 2011). However, Card (2011) suggests a visual test of the forest plot to determine heterogeneity. Because not all confidence intervals cross over the omnibus mean, this visual test does not indicate homogeneity.

Publication Bias

The funnel plot in Figure 3 illustrates the level of publication bias in the present review. The y-axis represents standard error, and the x-axis represents the standard difference in means. Each dot signifies a study. The solid funnel lines suggest what a symmetric shape might look like. Typically, the larger the sample size, the smaller the standard error (Card, 2011). A funnel plot that exhibits less publication bias will have a symmetric shape around the grand mean, whereas one with more publication bias will appear asymmetric. The bottom left area of the quadrant is typically the area where studies with smaller sample sizes and smaller effects are located (Card, 2011). Studies with smaller sample sizes, larger standard errors, and small to negative effects are less likely to be published. The furthest right outlier, Zyl and Lohr (1994), was a study with a small sample size. The second furthest right outlier was Wittman (1996). The asymmetric shape of the funnel plot may be indicative of publication bias. Additionally, Card (2011) stated that another way to measure publication bias is to conduct a visual test on the funnel plot by comparing placement of published versus non-published studies. Graphed on the funnel plot, two of the published articles were just around the grand mean, while one was an extreme positive outlier. This may mean that the publication bias may be less severe. The inclusion of many non-published studies is a strength to this analysis, as it mitigates the tendency of a field to not publish smaller effects (Card, 2011). However, the small number of studies included in this review limits our conclusions in this area.

Figure 3

Funnel Plot



Note. Open circles represent each study. The x-axis represents the standard difference in means of a study and the y-axis with the standard error. The lines indicate what a symmetric spread of data should look like.

Independent Variables

Table 1 contains a summary of intervention elements for each study. Researchers administered technology mediated interventions in four studies. Teachers conducted the intervention in the rest of the studies. In 73% of the studies, treatment locus was the classroom, 1% in the library, 1% in the computer lab, and 1% in a private room. Entire class treatments were administered in 64% of studies; small group settings comprised 37% of studies. Session length in minutes ranged from one minute to seventy minutes. Batton (2010) tested the effectiveness of cooperative learning. Henderson (2019) studied the influence of mindfulness exercises. Hines et al. (2016), Ruark (2018), and Walter (2018) tested the impact of expressive writing interventions where students were directed to write about their math experience and emotions. Hocker (2017) developed a math mindset training for students, followed by collaborative math investigations where students implemented those mindset strategies. Kim et al. (2016) and Wei (2010) implemented the same computer-based math curriculum that included an "embodied agent" that provided encouraging feedback targeted at math anxiety. White (1997) tested the effectiveness of positive teacher attitudes, cooperative learning, and hands-on group activities. Wittman (1996) studied a computer program that intended to encourage multiplication automaticity. Zyl and Lohr (1994) created a cassette tape intervention for students, recorded with muscle relaxation strategies followed by guided imagery through math scenes that may provoke math anxiety.

Table 1

Independent Variables

Study	Intervention type	Research design	Interventionist	Treatment Location	Instructional group size	# of sessions	Session length in mins
Batton (2010)	A	Q	Teacher	Classroom	W	18	70
Henderson (2019)	T	Q	Teacher	Classroom	W	30	5-10
Hines et al. (2016)	T	Q	NR	Classroom	W	3	15-30
Hocker (2017)	A	E	Teacher	Classroom	W	NR	300 total from all sessions
Kim et al. (2016)	A	E	Tech	Classroom	W	4	35-45
Ruark (2018)	T	E	Teacher	Classroom	S	10	"At least one min"
Walter (2018)	T	Q	Teacher	Classroom	W	5	10
Wei (2010)	A	E	Tech	Computer lab	S	4	50
White (1997)	A	Q	Teacher	Classroom	W	NR	NR
Wittman (1996)	A	E	Tech	School library	S	Up to 13	NR
Zyl & Lohr (1994)	T	E	Tech	Private listening room during study hall	S	>6	30

Note. A = academic T = therapeutic; E = group experimental Q = group quasi-experimental; Tech = technology-aided instruction, W = whole class S = small group.

Dependent Variable

Table 2 contains all information researchers provided on the math anxiety rating scale enlisted in their studies. In most cases, researchers employed commonly used and previously validated measures of math anxiety. These authors usually did not test for reliability and validity themselves, rather cited past work.

Reliability

In some cases, authors did test for reliability on popular measures. Kim et al. (2016) tested reliability on Revised Mathematics Anxiety Rating Scale (RMARS; Plake & Parker, 1982) and reported a pretest coefficient of a = 0.91 and posttest coefficient of a = 0.94 posttest. Walter (2018) reported their own numbers, and cited that previous researchers found overall a = 0.87. They broke their results down into two categories: negative and worry. Results were between 0.04 and 0.19 points lower than the reliability cited from Ganley and McGraw (2016). Wei (2010) reported previous reliability on RMARS, and conducted an internal consistency coefficient alpha. Their result of 0.91 it was 0.07 points lower than the cited Plake and Parker (1982). Zyl and Lohr (1994) employed the Negative Affective Reaction Scale (Wigfield & Meece, 1988) and mentioned that it had previously tested as reliable but did not cite any data. In one case, the authors developed their own measure. Hocker (2017) created their own math anxiety scale and did tests for both reliability and validity. They reported an alpha for treatment (0.84) and control (0.88).

In summary, other than Zyl and Lohr (1994) who reported no reliability data, all alpha coefficients scores, whether cited from past researchers or conducted by the researchers in the present studies, were above 0.70, and most even higher. Meaning, all studies with reliability data for their measure of math anxiety had sufficient reliability.

Validity

Seven studies mentioned validity. Batton (2010) measured validity but did not report if it was adequate. Five studies reported that validity was adequate but did not provide data. Hocker

(2017) mentioned that three mathematic experts, four educational experts and two research experts vetted their scale. They also said they piloted for validity but did not report data beyond mentioning that it was adequate. Wittman (1996) was the only study that presented validity data. They measured construct validation for MARS-E (Suinn et al., 1988), and reported significant correlation to the Stanford Achievement Test at (-0.31).

Table 2

Dependent Variable: Math Anxiety

Study	Math Anxiety Measure	Sample Size	Reliability	Validity
Batton (2010)	The Mathematics Anxiety Scale for Children (MASC)	Reliability (n = 562) Validity (n = 287)	Cronbach alpha 0.90 to 0.93, median 0.924	Cited Beasley, Long, and Natali (2001) and reported that it was measured
**Henderson (2019); Ruark (2018)	The Modified Abbreviated Math Anxiety Scale (mAMAS)	NR	Ordinal alpha 0.89 for year 4 students Cronbach alpha 0.85 Test-retest reliability .85	Cited Carey et al. (2017) and reported good construct and divergent validity
Hines et al. (2016)	The Math Anxiety Rating Scale (MARS)	NR	Reliability coefficient 0.90 Cronbach alpha 0.96 Test-retest reliability 0.90	NR
Hocker (2017)	Created by researcher, no name given	*Reliability control (n = 63) treatment (n = 48)	*Cronbach alpha (treatment 0.84) (control 0.88)	*Validity reviewed by three mathematic experts, four educational experts, and two research experts. *Piloted scale and reported adequate validity
Kim et al. (2016)	Revised Mathematics Anxiety Rating Scale (RMARS)	*Reliability (n = 138)	* Cronbach alpha (pretest 0.91) (posttest 0.94)	NR

Study	Math Anxiety Measure	Sample Size	Reliability	Validity
Walter (2018)	Math Anxiety Scale for Young Children Revised (MAYSC-R)	*Reliability (n = 80)	Cited Cronbach alpha 0.87 from Ganley and McGraw (2016) *Cronbach alpha - Negative reactions (pretest 0.64) (posttest 0.71) - Numerical confidence (pretest 0.63) (posttest 0.69) - Worry (pretest 0.79) (posttest 0.83)	Cited Ganley and McGraw (2016) and reported strong validity
Wei (2010)	Revised Mathematics Anxiety Rating Scale (RMARS)	*Reliability (n = 128)	Cited Cronbach alpha 0.98 from Plake & Parker (1982) * Coefficient alpha 0.91	NR
White (1997)	Mathematics Anxiety Rating Scale (MARS)	NR	Cited "great reliability from Fulkerson, J. Galassi (1984)	Cited Fulkerson, J. Galassi (1984) and reported great validity
Wittman (1996)	Mathematics Anxiety Rating Scale, Elementary Form (MARS-E)	Reliability and validity (n = 1119)	Cronbach alpha's a = 0.88	Construct validation data correlated (-0.31) with the Stanford Achievement Test, Mathematics Test - Individual skill (applications, computations, concepts) correlation range -0.26 to -0.29
Zyl & Lohr (1994)	Negative Affective Reaction Scale	NR	Authors stated scale is reliable because of polarity in third item reversed	NR

Note. Table contains information on the scale used to measure math anxiety, as well as the reported reliability and validity associated with those scales; *Measured during and by the experiment.

Math Performance

As summarized in Table 3, five authors measured math performance. Walter (2018) modified addition and subtraction fluency content from the curriculum program "i-Ready" (Curriculum Associates, n.d.) and used it as their math performance measure. The content of this assessment was addition and subtraction fluency. This is the only assessment that we know sourced outside curriculum. In two studies, the classroom teachers and researchers collaborated to create an Algebra 1-level assessment (Kim et al., 2016; Wei, 2010). White (1997) did not specify who created their measure and did not describe the content beyond being basic algebraic level. Wittman (1996) utilized flashcards as their assessment but did not specify if they were created or purchased.

We converted results into Cohen's d effect sizes. For purposes of our review, a positive effect size indicates that math performance increased. As mentioned previously, a small effect size must be at least 0.20 (Card, 2011). Only Wittman (1996) exceeded 0.20, but their effect of $d = 5.2126$ was also a likely outlier, as was their anxiety effect size. Lastly, two authors reported a negative effect. Although most effects are not significant, it must still be mentioned that researcher-created measures typically result in inflated effect sizes (Cheung & Slavin, 2016).

While authors often relied on pre-established validity and reliability for their anxiety measures, all reports of reliability and validity were tested during the study for math performance measures. This is likely because, unlike anxiety measures, most performance assessments were created during the study, and were not outside norm-referenced measures. This cautiously includes Walter (2018), who did take content from i-ready (Curriculum Associates, n.d.), but then modified it to meet the needs of his study. The only exception is White (1997), who did not clarify who created their measure.

Kim et al. (2016) was the only study to report validity. They developed the measure to mirror current classroom instructional content and reported sufficient face validity after researchers and teachers inspected the test questions. Three studies reported reliability. Kim et al. (2016) reported a high test-retest $r = 0.79$. Wei (2010) also reported = 0.79 for their test-retest reliability. While Walter (2018) included i-ready's (Curriculum Associates, n.d.) pre-established report of reliability, they also tested it on their own modified assessment, which is what we chose to include in the present review. They stated that results were strongly reliable, reporting pretest ($\alpha = 0.89$) and posttest ($\alpha = 0.87$).

Table 3

Math Performance Data Collection Procedures and Effect Sizes

Study	Measure	Assessment procedures	Sample Size	Reliability/validity	Effect size
Kim et al. (2016)	Teacher and researcher created	Pre/posttest in every session covering: fundamentals of algebra, signed number arithmetic, combining like terms and distribution, factoring, and graphing linear equations using slope and y-intercept	T: 58 C: 70	*Face validity *Test-retest reliability Pearson pretest/posttest correlation r = 0.79	0.045 9
Walter (2018)	i-Ready computational fluency practice	Pre/posttest addition and subtraction fluency	T: 38 C: 42	*Test-retest Reliability pretest (α = 0.89) and posttest (α = 0.87) measures	- 0.154 2
Wei (2010)	Teacher and researcher created	Algebra pre/posttest in every session covering: order of operations, simplifying expressions, prime factorization, greatest common factor, and graphing concepts	T: 60 C: 68	*Test-retest reliability Pearson pretest/posttest correlation r = 0.79	0.058 9
White (1997)	Not specified	Pre/posttest covering “basic algebraic skills”	T: 23 C: 25	NR	- 0.068 8
**Wittman (1996)	Flashcards	Pre/posttest measuring mean reaction time of 2 through 9 multiplication tables	T: 21 C: 12	NR	5.212 6

Note. T= treatment C = control; Effect size as Cohen’s D as measured by Campbell’s Collaboration (Wilson, n.d.); Positive effect size indicates increase in mathematic performance; *asterisk indicates that reliability or validity was measured during the experiment; **only measured performance in treatment group.

Research Question 2: Moderating Variables

We selected moderators based on availability of data and common patterns found in the literature. Interventions were either administered to an entire class, or to a small group of students that were pulled out of their class. Some interventions were therapeutic strategies used with the goal of ameliorating math anxiety, while other authors employed math-based interventions to attempt the same goal. The last pattern we decided to run in a moderator analysis is the length of study. Some authors implemented their intervention for a couple days, while others did so for a month.

Group Size

As found in Table 4, whole class settings resulted in a small effect size $g = 0.257$, $p < .05$. Studies using a small group targeted intervention format resulted in a medium effect size of $g = 0.603$, $p < .05$. However, there is substantial overlap in confidence intervals, the small group confidence interval being over twice as large as the whole class confidence interval. It is also worth noting that the two outliers of the overall review were small group studies (Wittman, 1996; Zyl & Lohr, 1994). Based on these limited data, small group and universal interventions produce significant improvements in math anxiety but targeted small group interventions are more likely to produce a larger effect size.

For whole class studies, the chi-square value for $df(q) = 6$, $p = 0.877$ is 2.423. Because the corresponding q-value = 2.426 is essentially equal to its chi-square value, the data may be considered homogenous. For small group studies, the chi-square value for $df(q) = 3$, $p = 0.022$ is 9.630. Because the corresponding q-value = 9.673 exceeds its corresponding chi-square value, there is evidence of heterogeneity. The I^2 for whole class functions as the reference group at zero, and the 68.987% for small group relative to that indicates medium heterogeneity between the two groups.

Table 4

Moderator Analysis: Intervention Group Size

Statistic	Whole class	Small group
Number of studies	7	4
Hedge's g	0.257	0.603
Standard error	0.079	0.274
Variance	0.006	0.075
Lower limit	0.102	0.067
Upper limit	0.411	1.140
Z-value	3.259	2.203
p-value	0.001	0.028
Q-value	2.426	9.673
df (q)	6	3
p-value (heterogeneity)	0.877	0.022
I-squared	0.000	68.987

Note. Calculated as a random effects model.

Intervention Type

As reported in Table 5, our analysis of academic interventions resulted in a small effect size $g = 0.331$, $p < .05$. Therapeutic interventions also resulted in a small effect size $g = 0.342$, $p < .05$. It should be mentioned that the biggest outlier of the overall review, Zyl and Lohr (1994), was a therapeutic intervention. The other outlier, Wittman (1996), was an academic intervention. Substantial overlap in confidence intervals exists, which alongside similar effect sizes, may indicate that there is no distinctive discrepancy in effectiveness between academic and therapeutic interventions for math anxiety.

In terms of heterogeneity for academic studies, the critical chi-square value for df(q) = 5 and p-value = 0.564 is 3.899. Because the corresponding q-value = 3.899 is equal to its chi-square value, and does not exceed it, this groups may be sufficiently homogeneous. For therapeutic studies, the critical chi-square value for df(q) = 4 and p-value = 0.060 is 9.044. Because the corresponding q-value = 9.047 is essentially equal, this group is likely sufficiently homogenous. The I^2 for academic functions as the reference group at 0, and the 55.788% for therapeutic relative to that indicates medium heterogeneity between the two groups.

Table 5

Moderator Analysis: Intervention Type

Statistic	Academic	Therapeutic
Number of studies	6	5
Hedge's g	0.331	0.342
Standard error	0.095	0.160
Variance	0.009	0.026
Lower limit	0.146	0.028
Upper limit	0.517	0.656
Z-value	3.496	2.135
p-value	0.000	0.033
Q-value	3.899	9.047
df (q)	5	4
p-value (heterogeneity)	0.564	0.060
I-squared	0.000	55.788

Note. Random effects model.

Number of Sessions

Number of sessions ranged from 3-30. Two studies did not report the exact number of sessions, so only nine studies from our review were eligible for this analysis. Hocker (2017) reported that their intervention was a "minimum of five hours" (p. 59) but did not explain how these hours were divided into sessions. White (1997) explained they implemented their` intervention across six weeks, but also did not specify the number of sessions. The findings from this meta-regression analysis are found in Table 6. As this is not a categorical characteristic, we opted to perform a meta-regression. Although the session coefficient b = -0.00064 is suggestive of a slightly negative slope, it is so close to zero that it likely means that there is no change in effect size relative to number of sessions. This means that the number of sessions might not influence the efficacy of the intervention, or that there is too little data reported in the reviewed studies. Reinforcing this result, the p-value for sessions b = -0.00064, p = 0.5549, is above 0.50, meaning this moderating variable is not significant. Because the session coefficient confidence interval overlaps with zero, there is no significant difference between that coefficient and zero.

Table 6

Moderator Analysis: Number of Sessions

Covariate	Coefficient	Standard Error	95% Lower	95% Upper	Z-value	p
Intercept	0.3879	0.1634	0.0676	0.7082	2.37	0.0176
Sessions	-0.0064	0.0108	-0.0275	0.0148	-0.59	0.5549

Note. Meta-regression calculated from Hedge's g effect sizes of 9 studies to analyze number of sessions as a moderating variable.

Research Question 3: Methodological Quality

A visual representation of methodological quality can be found in Figure 4. Studies with a circle or triangle graphed above the horizontal 80%-met dotted line may be considered a somewhat methodologically rigorous study. Absolute scoring is more rigorous because the study is rewarded a point for an indicator only if all components are met, while the weighted system awards partial points if only a few components are met.

Methodologically Rigorous Studies

None of the reviewed studies met the requirements to be identified as methodologically rigorous based on the absolute scoring method. Three of the reviewed studies scored above 80% based on the weighted coding method (Henderson, 2019; Wei, 2010; Wittman, 1996). Interestingly, Wei (2010) and Wittman (1996) tested the same computer program, barring small modifications to the overall intervention process. Wittman (1996) had the second highest effect size g = 0.868. While Wei (2010) had a smaller effect g = 0.221, it was still significant. The fact that these studies reported an impact on lowering math anxiety, as well as decent methodological rigor, is indicative of trustworthiness and dependability. Unfortunately, Henderson (2019) reported no significant effect.

Methodological Strengths

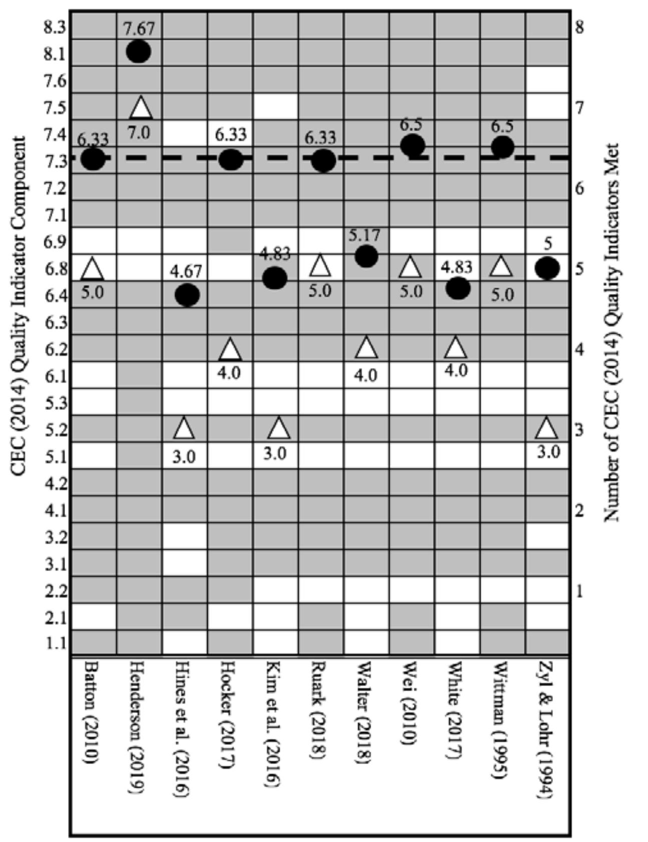
All 11 studies met each component of indicator four, meaning authors reported critical elements of intervention procedures and materials utilized. All studies met 5.2, where it was required to report on length and duration of the intervention. Components 6.2, 6.3, 6.4 were also all met, covering the difference in control and treatment environments, ensuring the control participants could not access the treatment, and how participants were assigned to groups. Components 7.1, 7.2, 7.3 were also all met, requirements included socially important outcomes, clearly defined dependent variable, and reporting of all measures even when there was not a positive effect. Lastly, 8.1 and 8.2 were met by all studies. These questions asked that statistical measures were included, such as ANOVAs or t-tests, effect sizes, or data from which an effect could be calculated.

Methodological Weaknesses

Component 2.1 was not met in 55% of the articles, which required information on participant demographics such as age, gender, ethnicity, language status, and socioeconomic status. Age and gender were the most consistently reported characteristics. There was no pattern in how often the other demographics were omitted, what was reported was quite variable across studies. Component 2.2 was unmet by 64% of the articles, where it was required that authors report on disability or risk status in their participant population. Component 5.1 was not fulfilled by 91% of the studies, in which they had to collect and report implementation fidelity through direct measurement. In 91% of the articles, component 5.3 was not met, where they should have reported on the implementation fidelity process and data collected through all stages of the intervention, on all interventionists, settings, and participants. Studies did not pass component 6.1 in 91% of cases, which could not be met if 5.1 was not met. This indicator claims that an article cannot prove that the researcher was in control of the independent variable without implementation fidelity measures. Component 6.8 was unmet by 64% of the articles, in which authors needed to report an overall attrition rate below 30%. Component 6.9 was unmet by 82% of articles, being required to report a differential attrition rate below 10%. Most of the studies that did not pass 6.8 and 6.9 simply did not report if attrition happened at all.

Figure 4

Council of Exceptional Children Quality Indicators



Note. Study name is graphed on the x-axis. Each quality indicator is graphed on the left y-axis marks. Shaded boxes mean that indicator was met by the corresponding study. The right y-axis represents the total number of indicators met. Absolute scoring is indicated by a triangle and weighted scoring by a circle. The dotted line represents the point in which 80% of the indicators are met and apply to both absolute and weighted scoring.

Chapter Summary

In summary, the omnibus effect on reducing math anxiety was a small effect. Not enough studies included measures of mathematic performance to calculate a trustworthy omnibus effect, and the range of effect sizes was quite sporadic. Additionally, there was considerably more consistency in authors selecting common, well-tested metrics for math anxiety as compared to math performance. The moderating analysis that had the most significant discrepancy was the difference between entire class interventions and small groups. Small groups being more effective in improving math anxiety symptoms. Lastly, only three studies met the criteria to qualify as potentially methodologically rigorous.

CHAPTER 5

Discussion

The present review is the first meta-analysis evaluating math anxiety interventions since Hembree's (1990) analysis. It is also the only review exclusively focused on interventions implemented in K-12 school settings. The omnibus effect of our review indicated that these interventions have small effect in improving math anxiety symptoms. In context of practical significance, we discovered that even a small effect may be valuable. While Hembree (1990) did not generate an omnibus effect, they reported a large effect for certain therapeutic treatments outside the classroom, and no significant effect for classroom-based interventions. Through our moderator analysis, we uncovered variables that expand Hembree's (1990) work to understand what may make classroom-based interventions effective. We then continue this chapter by discussing additional moderating variables, our methodological assessment, limitations, implication for practitioners, and end with a call for future research.

Practical Significance of Effects

Most studies reported no significance in the improvement of math anxiety symptoms because of confidence intervals that overlapped with zero. For studies that reported at least some improvement, authors reported practical significance in a myriad of ways. In one case, the author reported a benefit in terms of math behavior. Wittman (1996) reported that students increased their knowledge of multiplication facts and improved automaticity. Other times, authors reported benefit in terms of emotional intelligence, self-confidence and attitudes towards math. Batton (2010) explained that at the beginning of their study, several students would often ask for the nurse because of stomach aches or try to call home. After the study, these students expressed excitement and did not try to escape class anymore. Henderson (2019) reported that as math anxiety symptoms improved, so did self-efficacy. Hines et al. (2016) shared that students demonstrated increased ability to analyze their thought patterns and became more effective at processing emotions. Hocker (2017) cited that improvement in math anxiety symptoms was associated with improved growth mindset and viewing math positively. One student who previously exhibited reluctance in math participation, asked if they could sign up for additional mindset classes. Hocker (2017) also reported higher attendance and increased math engagement. Zyl and Lohr (1994) reported a large effect but did not include a description of practical significance.

Comparison of Findings to Hembree (1990)

While Hembree (1990) did include K-12 interventions in their review, they also incorporated post-secondary studies. As such, while our comparisons may provide important insight, they must be approached with prudence.

Math Anxiety

Academic Interventions. Hembree's (1990) "curricular change" intervention category is comparable to our academic category. Hembree (1990) was insistent that these curricular interventions were not successful. Their effect $\Delta = -.04$ [-0.46, 0.48], $p < 0.01$, is not significant. It is important to note that, in their study, a negative indicated an improvement in math anxiety symptoms. Additionally, their confidence intervals overlap with zero, which also suggests there was no effect. Our academic result $g = 0.331$[0.146, 0.517], $p = 0.000$ is a small effect. Confidence interval overlap exists between these two effects, indicating that our present study could have a small measure of homogeneity with Hembree (1990). Although caution must be exercised when comparing a Glass's Δ with a Hedge's g, it is still clear that there is a significant discrepancy between the two effects. One reason for this discrepancy could be because

Hembree's (1990) analysis included 17 studies, while our academic intervention analysis only included six. The fewer studies in a meta-analysis, the more influence outliers can have on the overall effect (Meta-Analysis, 2013). In contrast, because Hembree (1990) did not report a detailed methodological assessment, we cannot determine which analysis contained more rigorous studies. Our limited number of studies and Hembree's (1990) lack of methodological quality means we should approach both reviews with some measure of caution.

Therapeutic Interventions. Hembree's (1990) several psychological intervention categories equate with our therapeutic category. Their effect for whole-class psychological interventions $\Delta = -0.10$ [-.38, 0.18], $p < 0.01$ was inadequate because the confidence intervals overlap with zero, and the effect size was not significant. Hembree's (1990) out-of-class categories ranged in effect from $\Delta = 0.03$ to $d = 1.15$, with an estimated mean of 0.642. The present review's therapeutic intervention analysis included five classroom-based studies and one out-of-class study. This analysis produced a small effect $g = 0.342$ [0.028, 0.656], $p = 0.033$. It is difficult to compare our present study to Hembree's (1990) because we did not separate our therapeutic analysis into subgroups by location of treatment as they did. However, it is interesting to note that our one out-of-class intervention (Zyl & Lohr, 1994) had a much larger effect in comparison to the classroom-based interventions, which does seem to validate Hembree's (1990) results. In one of our moderator analyses, we discovered that small-group settings produced higher effects. Because the out-of-class studies for both Hembree (1990) and our review were small-groups, the results of this moderator analyses could be the explanation for why out-of-class therapeutic interventions were more effective.

Our third highest effect size, and the highest non-outlier, Hocker (2017) $g = 0.449$ [0.085, 0.812], $p = 0.015$, combined mindset training with math activities that then applied mindset strategies. Hembree's (1990) largest effect size Δ = 1.15 [0.46, 1.83] was the result of interventions that combined cognitive and behavioral strategies. Cognitive interventions included reappraisal, which, according to Ramirez et al. (2018), is a key mindset skill. Systematic desensitization is one type of behavioral intervention that Hembree (1990) reviewed. There may be some parallels to consider between systematic desensitization and targeted math instruction. However, it is important to note that, (a) Hocker's (2017) effect size is much lower with no confidence interval overlap, (b) Hocker (2017) was conducted in a whole-class setting, while in contrast, Hembree's (1990) cognitive-behavior category was out-of-class.

Math Performance

Hembree (1990) reported their math performance dependent variable in seven subgroups. Of their seven categories, only one was a small effect, and only two were medium effects. The remaining four had no significant effect. In our review, we did not calculate the overall effect for our included studies. Of our five studies, the Cohen's d range was -0.1542 to 5.2126. This effect size range is rather large and overlaps with zero, indicating there could be no effect. If Hembree (1990) and our present review reported such little impact of math anxiety interventions on math performance, it's important to discuss the point of implementing these interventions. It is possible that one issue is that of timing. For example, while patterns gathered in the present review demonstrate that math anxiety symptoms can improve even with relatively few intervention sessions (average interventions lasting only 7.4 sessions), it is logical to conclude that even with an abrupt drop in math anxiety, time is needed to then remediate math skills lost during the period of high math anxiety.

Moderator Variables

Setting

The response to intervention framework (RTI) advocates for continuous assessment of performance to discern when a student may need more intensive support. All students receive universal tier one supports, small groups of students receive more intensive tier two supports, and individualized plans are created at tier three. A key variable in this framework is utilizing evidence-based practices to address student needs (Jimerson et al., 2016). When developing these interventions, it is imperative to determine in which tier that practice will be most efficacious. The results of our moderator analysis indicated that small group settings were slightly more effective at reducing math anxiety than whole-class, otherwise called universal settings in the RTI framework. Of the small-group studies, 50% were academic-based, which may contradict Hembree's (1990) assertion that these types of interventions are not effective. Hembree (1990) never ran an analysis to determine the efficacy of universal versus small-group settings for academic (curricular) interventions. By analyzing the difference between whole-group and small-group settings, when Hembree (1990) did not, we discovered a pattern that otherwise couldn't be determined from a single omnibus effect. As such, our analysis suggests that academic interventions may actually be effective when conducted in small group settings.

Intervention Type

The results of the intervention type moderator analysis indicated that there was virtually no difference between therapeutic and academic interventions within our included studies. Practitioners should be allowed flexibility to implement interventions that meet students' needs and fit the classroom context. However, as noted previously the most beneficial interventions are typically a combination of both types.

Number of Sessions

There was no significant difference in efficacy when we moderated for number of sessions. Meaning, more sessions did not improve math anxiety symptoms at a larger effect as compared to fewer sessions. Therefore, it may be justified to anticipate changes in math anxiety levels in even just seven sessions, the average intervention length. Knowing how fast an intervention should work can help inform when to decide if a student needs to move to more intensive tiers in the RTI framework. However, the quick improvement of math anxiety symptoms does not necessarily mean it wouldn't be beneficial to continue these practices in longer term. Perhaps, there is value in implementing these interventions as a form of maintenance. Lastly, it is important to note that this meta-regression included below the recommended number of studies, so these results should be generalized with caution.

Methodological Quality

Under the CEC (2014) requirements, studies must meet all indicators to be considered methodologically sound. None of our studies met this requirement. Three studies met more than 80% of the indicators, which means they are potentially methodologically sound studies. One of the most glaring deficits was that 91% of studies did not meet questions covering implementation fidelity. This is concerning because, as mentioned in indicator 6.1, one cannot prove that the researcher had control over the independent variable without reporting implementation fidelity (CEC, 2014).

Additionally, while Wittman (1996) was a positive outlier, this study was also one of the most methodologically rigorous studies in our review. Their attention to rigor increases the credibility of their reported effect. As Wittman (1996) was an academic intervention, this indicates that this treatment category may truly be more efficacious than it currently appears.

This might also be suggesting that we have a large research gap in academic interventions for math anxiety, and if addressed through conducting methodologically rigorous academic interventions, we might find that Wittman (1996) may not be an outlier.

Limitations

It must be noted that the criteria to include articles after the year 1990 may have inadvertently missed articles that Hembree's (1990) analysis also missed. If Hembree (1990) submitted their paper for publication in the late 1980's there might have been new studies published before the beginning of our inclusion criteria. Additionally, although coding reliability was acceptable, the article search reliability was very low. It is unclear if directions were ambiguous, or if training was insufficient. However, because the reliability process did not produce new qualifying articles, and because we conducted both an ancestral and index search, we remain confident that we did our due diligence to represent the current field.

When conducting a meta-analysis, it is important to include at least 10 studies (Meta-Analysis, 2013). Unfortunately, when we ran our "number of sessions" meta-regression, we only included nine. As such, these results should not be widely generalized. Secondly, because Hocker (2017) did not provide the reader all necessary standard deviations, we had to perform some estimation to generate the control group's standard deviation. This comes with some measure of risk of altering the overall effect. Additionally, Zyl and Lohr (1994) reported the mean change for treatment and control, but no standard deviation. Because we had to create hypothetical participant data to fill in these gaps, caution should be maintained when generalizing the effect size. Although we strived to be conservative, Zyl and Lohr (1994) was still a notable outlier. With a standard deviation of 0.084, they were located 14.94 standard deviations above the omnibus mean.

Implications for Practitioners

Based on our meta-analysis, it is our recommendation that practitioners should consider implementing math anxiety treatments as tier two interventions within an RTI framework. These interventions may reduce math anxiety quickly. If math anxiety symptoms do not improve after approximately seven sessions, a more intensive intervention might be necessary. Additionally, although math anxiety can be treated quickly, maintenance interventions might be valuable while the teacher remediates math deficiencies. Academic and therapeutic interventions were equally efficacious in the present study; meaning, practitioners may select the intervention type makes the most sense in their setting. That said, the most effective intervention in the present study involved teaching of a therapeutic skill followed with structured math lessons where the therapeutic skill was applied. This was also confirmed in Hembree (1990).

Future Research

We had hoped to collect enough data to run a moderator analysis with disability status; unfortunately, authors rarely reported disability status of their participants. The special education population often has additional barriers to math performance, and surely, those barriers contribute to math anxiety. This field would benefit from studies that measure the prevalence of math anxiety in these diverse populations, as well as what interventions are most efficacious for which disabilities. In general, this field would benefit from increased commitment to methodological rigor. There is greatest need for improvement in the reporting of implementation fidelity. As defined by CEC (2014), this can take the form of direct measures such as "Observations using a checklist of critical elements of the practice." When measuring dosage, self-reporting is also appropriate. These checklists would be used to record that the interventionist and participants completed required tasks, and that they completed tasks in the right setting. The interventionist or observer should document a checklist at the "Beginning, middle, and end of the intervention period" (CEC, 2014, p. 4). Lastly, math performance improvement was quite low in both the present study and in Hembree (1990). As remediating math performance, may take time, improvement might not show up in a week or month long study. The field would benefit from longitudinal research on math anxiety interventions' impact on math performance. It may be useful to shift the framework from measuring math performance to math engagement. There may be more immediate changes in math engagement as compared to the time it may take to remediate math performance. As such, measuring engagement may more quickly reveal if improvement in math anxiety symptoms is translating into learning outcomes. This framework also provides a way to track observable behavior.

Conclusion

School-based interventions for math anxiety address a very relevant and concerning trend of high levels of math anxiety within K-12 student populations. High math anxiety can affect an individual's monetary decision-making skills and the ability to assess risk in day-to-day life. Math anxiety may also contribute to workforce-demand deficits in STEM-related fields. The interventions included in the present review can be effective tier-two interventions within the RTI framework. The most effective format is the combination of therapeutic elements, such as mind-set training, expressive writing, and mindfulness applied within math instruction. Most studies included in the present review were not statistically significant because confidence intervals overlapped with zero. Yet, the omnibus effect was significant, which attests to the power of the meta-analysis aggregate.

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APPENDIX A

Calculation Details

Table A1

Math Anxiety: Campbell's Collaboration Calculations

Study	Sample Size	Test Used	Effect size	Confidence Intervals
Batton (2010)	T: 32 C: 32	Means, Standard Deviations, and Sample Sizes	-0.2561	-0.2561, -0.74
Henderson (2019)	T: 102 C: 82	Means, Standard Deviations, and Sample Sizes	-0.1244	-0.2359, 0.1666
Hines et al. (2016)	T: 54 C: 39	Means, Standard Deviations, and Sample Sizes	-0.2925	-0.7065, 0.1215
Hocker (2017)	T: 48 C: 63	Mean Gain Scores, Pre and Post SDs, and Paired T-tests	0.4517	0.082, 0.8215
Kim et al. (2016)	T: 55 C: 63	Means and Standard Deviations with Subgroups	-0.075	-0.6572, 0.5072
Ruark (2018)	T: 18 C: 22	Means, Standard Deviations, and Sample Sizes	-0.1621	-0.7861, 0.4618
Walter (2018)	T: 38 C: 42	F-test, 2-group, Unequal Sample Sizes	-0.3126	-0.7541, 0.1288
Wei (2010)	T: 60 C: 68	Means, Standard Deviations, and Sample Sizes	-0.2326	-0.5809, 0.1157
White (1997)	T: 23 C: 25	T-test, Unequal Sample Sizes	-0.3313	-0.9015, 0.2388
Wittman (1996)	T: 21 C: 12	Means and Standard Deviations with Subgroups	-0.8898	-1.6308, 0.1488
Zyl & Lohr (1994)	T: 10 C: 10	Student's T-test and Total Sample Size	-1.6353	-2.6478, -0.6229

Note. The Campbell's Collaborative Cohen's d calculator (Wilson, n.d.) used for each study is indicated; Effect size as Cohen's d; T = treatment C = Control; negative effect indicates improvement in math anxiety symptoms.

Table A2

Math Performance: Campbell's Collaboration Calculations

Study	Sample Size	Test Used	Effect Size	Confidence Intervals
Kim et al. (2016)	T: 58 C:70	Means and Standard Deviations with Subgroups	0.0459	-0.3021, 0.394
Walter (2018)	T: 38 C: 42	Means, Standard Deviations, and Sample Sizes	-0.1542	-0.5937, 0.2853
Wei (2010)	T: 60 C: 68	Means, Standard Deviations, and Sample Sizes	0.0589	-0.2883, 0.4062
White (1997)	T: 23 C: 25	T-test, Unequal Sample Sizes	-0.0688	-0.6352, 0.4977
Wittman (1996)	T: 21 C: 12	F-test, 2-group, Equal Sample Sizes	5.2126	3.4191, 7.0062

Note. The Campbell's Collaborative Cohen's d calculator (Wilson, n.d.) used for each study is indicated; Effect size as Cohen's d; T = treatment C = Control; Positive effect indicates increase in math performance, except for Wittman (1996).

Table A3

Math Anxiety: Pre/Post Data

Study	Control Pre	Control Post	Treatment Pre	Treatment post
Batton (2010)	M = 38 SD = 9.09	M = 37.53 SD=10.74	M = 41.44 SD = 10.93	M=35.06 SD=8.41
Henderson (2019)	M = 21.79 SD = 6.91	M = 20.82 SD=8.26	M = 23.32 SD = 8.89	M=19.79 SD=8.30
Hines et al. (2016)	M = 209.3 SD = 71.9	M = 196.8 SD=71.6	M = 232.7 SD = 74.5	M=218.8 SD=77.7
Hocker (2017)	*M = 3.99 SD = 0.28	*M = 3.90 SD = 0.28	M = 4.36 SD = 1.23	M=3.89 SD=1.25
Kim et al. (2016)	*High* M = 49.95 SD = 12.54 *Medium-high* M = 32.71 SD = 3.06 *Medium-low* M = 23.39 SD = 2.19 *Low* M = 17.38 SD = 1.41	*High* M = 49.47 SD = 15.66 *Medium-high* M = 28.84 SD = 4.98 *Medium-low* M = 19.33 SD = 2.93 *Low* M = 16.81 SD = 1.56	*High* M = 46.31 SD = 5.59 *Medium-high* M = 32.69 SD = 3.09 *Medium-low* M = 24.67 SD = 2.50 *Low* M = 17.36 SD = 1.22	*High* M= 40.38 SD= 10.99 *Medium-high* M= 34.56 SD= 11.43 *Medium-low* M= 24.80 SD= 7.31 *Low* M= 16.50 SD= 0.94
Ruark (2018)	M = 25.18 SD = 7.17	M = 23.09 SD = 7.48	M = 26.22 SD = 7.67	M=24.33 SD=7.85
Walter (2018)	NR	NR	NR	NR (F-test= 1.949)
Wei (2010)	M = 28.44 SD = 10.27	M = 26.10 SD = 10.63	M = 29.57 SD = 11.00	M=28.75 SD=12.20

Notes. High, medium, lows indicate level of anxiety; *Estimated by the present research team.

Study	Control Pre	Control Post	Treatment Pre	Treatment Post
White (1997)	M = 194.652	M = 198.739	M = 217.88	M = 223.04 (T-test = -1.1467)
Wittman (1996)	*Comparison-boys* M = 52.67 SD = 11.36 *Comparison-girls* M = 47.67 SD = 11.89	*Comparison-boys* M = 38.50 SD = 7.00 *Comparison-girls* M = 54.33 SD = 35.08	*High-boys* M = 72.67 SD = 2.08 *Low-boys* M = 39.00 SD = 4.60 *High-girls* M = 85.83 SD = 12.68 *Low-girls* M = 38.83 SD =5.56	*High-boys* M = 75.00 SD = 6.55 *Low-boys* M = 37.16 SD = 6.11 *High-girls* M = 58.50 SD = 24.93 *Low-girls* M = 37.00 SD = 4.19 (F-test = 142.65)
Zyl & Lohr (1994)	NR	Mean reduction = 4.1	NR	Mean reduction = 11.3 *(T-test = -3.65674)

Notes. High, medium, lows indicate level of anxiety; *estimated by the present research team.

Table A4

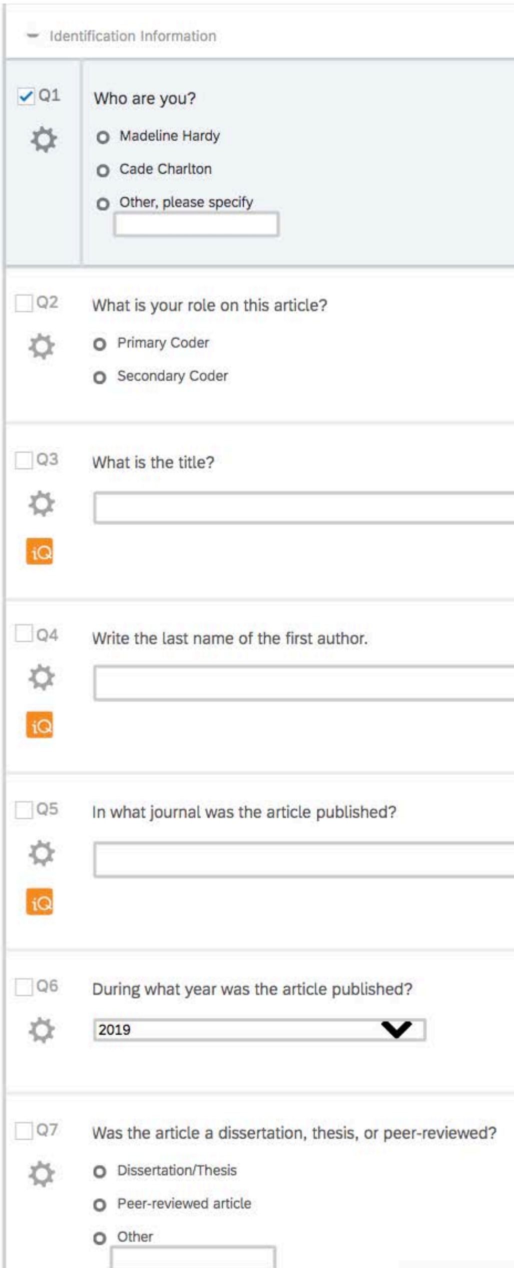
Math Performance: Pre/Post Data

Study	Control Pre	Control Post	Treatment Pre	Treatment Post
Kim et al. (2016)	*High* M = 16.21 SD = 6.20 *Medium-high* M = 17.47 SD = 4.98 *Medium-low* M = 15.12 SD = 6.54 *Low* M = 18.50 SD = 4.12	*High* M = 18.63 SD = 6.34 *Medium-high* M = 21.21 SD = 6.06 *Medium-low* M =19.00 SD = 6.51 *Low* M = 22.69 SD = 2.55	*High* M = 15.27 SD = 5.64 *Medium-high* M = 17.88 SD = 5.90 *Medium-low* M = 17.44 SD = 5.67 *Low* M = 16.31 SD = 5.68	*High* M = 18.40 SD = 6.20 *Medium-high* M = 22.06 SD = 5.79 *Medium-low* M = 21.38 SD = 6.52 *Low* M = 19.94 SD = 5.81
Walter (2018)	M = 15.10 SD = 5.09	M = 16.50 SD = 4.15	M = 15.16 SD = 4.78	M = 15.79 SD = 5.06
Wei (2010)	M = 16.76 SD = 5.47	M = 20.34 SD =5.81	M = 16.93 SD = 5.46	M = 20.68 SD = 5.72
White (1997)	M = 5.24	M = 7.28	M = 5.435	M = 7.13 (T-test = -0.238)
Wittman (1996)	NR	NR	High M= 8.5 Low M= 3	High M = 3 Low M = 2 (F-test = 142.65)

Notes. Positive increase indicates increase in math performance, except for Wittman (1996); High, medium, low indicate level of anxiety level.

APPENDIX B

Qualtrics Coding Survey



Identification Information

Q1 Who are you?
- Madeline Hardy
- Cade Charlton
- Other, please specify

Q2 What is your role on this article?
- Primary Coder
- Secondary Coder

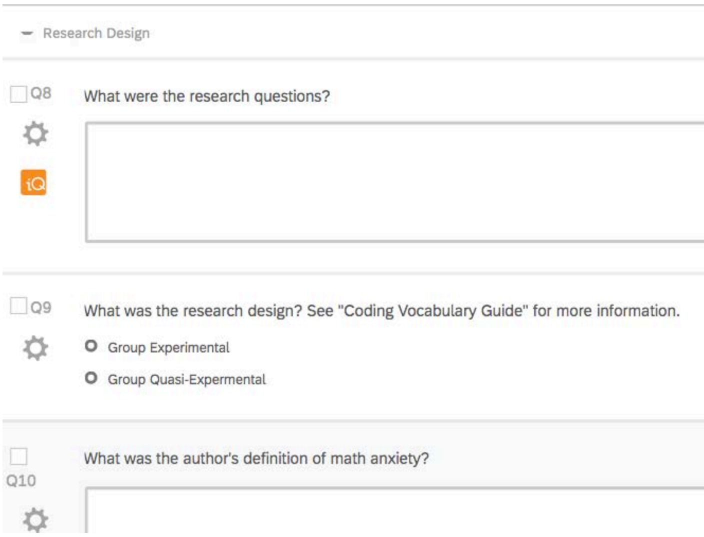
Q3 What is the title?

Q4 Write the last name of the first author.

Q5 In what journal was the article published?

Q6 During what year was the article published?
2019

Q7 Was the article a dissertation, thesis, or peer-reviewed?
- Dissertation/Thesis
- Peer-reviewed article
- Other



- Research Design

Q8 What were the research questions?

Q9 What was the research design? See "Coding Vocabulary Guide" for more information.

- Group Experimental
- Group Quasi-Expermental

Q10 What was the author's definition of math anxiety?

Participant Information

Q11

Answer the following questions ONLY for participants who are included in the "Results" section of the article. For example, if a participant is listed in the participants section but leaves the study early or was not eligible to participate due to inclusion criteria, DO NOT report them in this section. When paraphrasing or copying text from the article be sure to include a page number as well.

Q12

What was the total number of participants for each condition (i.e., sample size)?

Q13

What was the average age/grade-level of the participants? Was it equal between groups?

Q14

What percent of participants were male?

	0	10	20	30	40	50	60	70	80	90	100	Not Reported
Percentage of male participants												▢

Q15

Did the study include any LGBTQ+ participants (e.g., students identified as gender neutral, transgender, or non-binary)?

- Yes
- No

Q16

Please specify the percentage of minority participants.

	0	10	20	30	40	50	60	70	80	90	100	Not Reported
% of minority participants												

Q17

What was the school percentage of students on free or reduced lunch?

	0	10	20	30	40	50	60	70	80	90	100	Not Reported
% of students on free or reduced lunch												

Q18

Was disability status reported?

- Yes
- No

Q19

Was "at risk" status reported? Ask risk includes past math failure, overall past academic failure, and behavioral patterns that cause missing instruction and not completing coursework.

- Yes
- No

Setting

Q20

What school type were participants selected from?

- Public
- Private
- Charter
- Residential
- Other

Q21

Where did the students receive treatment?

- Classroom
- Clinician Office (school counselor, psychologist, or therapist)
- Other

Q22

Was the intervention given to an entire class, small group, or individual?

- Entire Class
- Small Group
- Individual

Intervention Procedures

Q23

Who administered the intervention?

- Teacher
- Clinician (school counselor, psychologist, or therapist)
- Technology-aided Instruction
- Other

Q24

How many intervention sessions occured?

Q25

What was the duration of each session, in minutes?

Q26

How long was the intervention in place, in days?

Q27

Did the interventionist teach a math concept, a therapeutic concept, or other? See "Coding Vocabulary Guide" for more information.

- Math concept
- Therapeutic Concept

Display This Question:

If Did the interventionist teach a math concept, a therapeutic concept, or other? See "Coding Vocabu... M

Q28

What math concept(s) was taught?

Display This Question:

If Did the interventionist teach a math concept, a therapeutic concept, or c

Q29

What therapeutic skill(s) was taught?

Q30

Describe all activities the participant engaged in during the intervention.

Dependent Variable

Q31

What type of measurement was used in this study? See "Coding Vocabulary Guide" for more information.

- Direct
- Indirect

Q32

What target behaviors were measured?

- Math Anxiety
- Math performance
- Other

Q33

How was anxiety measured? Please include the name of a professional scale or measure that was used. If not measured, write NR.

Q34

How was math performance measured? If not reported or measured, write NR.

Q35

If authors categorize students as high math anxiety (HMA) and low math anxiety (LMA), do they provide cut offs for each category? If so, what are the cut offs?

Q36

Did authors say a Functional Behavioral Assessment (FBA) was administered to participants?

If FBA not administered, select not reported. See "Coding Vocabulary Guide" for more information.

- Yes
- No

Results

Q37

If authors report data for high math anxiety (HMA) vs low math anxiety (LMA) groups, only report HMA group data.

Q38

Copy and paste the author's data analysis.

Q39

Did the authors report effect sizes? What metric did they use? See "Coding Vocabulary Guide" for more information.

- Cohen's d
- Correlation coefficient
- Odds/risk ratio
- Other

Q40

What analysis did the authors run? See "Coding Vocabulary Guide" for more information.

- ANOVA
- ANCOVA
- t-test
- Other:

Q41

What was the effect of the intervention on mathematics performance? Was it statistically significant? What was the effect size? If not reported, copy and paste the tests of significance. If no data reported at all, write, "no data".

Q42

What was the effect of the intervention on mathematics anxiety? Was it statistically significant? What was the effect size? If not reported, copy and paste the tests of significance. If no data reported at all, write, "no data".

2014 CEC QIs

Q43

For all CEC 2014 quality indicator components: "when reviewers can reasonably infer that the quality indicator is met on the basis of other, related information reported—they can decide that a study has met a quality indicator, even if the research report does not explicitly report addressing it" (p. 2).

Q44

1.0. Context and setting: "The study provides sufficient information regarding the critical features of the context or setting."

Q45

"1.1. The study describes critical features of the context or setting relevant to the review; for example, type of program or classroom, type of school (e.g., public, private, charter, preschool), curriculum, geographic location, community setting, socioeconomic status, physical layout."

- Met
- Not met

Q46

2.0. Participants: "The study provides sufficient information to identify the population of participants to which results may be generalized and to determine or confirm whether the participants demonstrated the disability or difficulty of focus."

Q47

"2.1. The study describes participant demographics relevant to the review (e.g., gender, age/grade, race/ethnicity, socioeconomic status, language status)."

- Met
- Not met

Q48

"2.2. The study describes disability or risk status of the participants (e.g., specific learning disability, autism spectrum disorder, behavior problem, at risk for reading failure) and method for determining status (e.g., identified by school using state IDEA criteria, teacher nomination, standardized intelligence test, curriculum-based measurement probes, rating scale)."

Supplemental description:

"To meet QI 2.2, study authors must describe (a) the disability/risk status of participants and (b) either report how disability/risk status was determined or provide information from which determination of disability/risk status can be inferred. Reporting that participants were identified as having a disability using state or district criteria meets QI 2.2. Reporting that participants have a disability specified by Individuals With Disabilities Education Improvement Act (IDEA) and are served in a special education setting/receiving special education services also meets QI 2.2, as it can be reasonably inferred that participants were identified as having the disability using state/district criteria. Studies that describe participants as having non-specified disabilities, having a specific disability (e.g., autism), or being at risk without providing additional information indicating how the disability/risk status was determined do not meet QI 2.2" (p. 225).

- Met
- Not met

Q49

3.0. Intervention agent: "The study provides sufficient information regarding the critical features of the intervention agent."

Q50

"3.1. The study describes the role of the intervention agent (e.g., teacher, researcher, paraprofessional, parent, volunteer, peer tutor, sibling, technological device/computer) and, as relevant to the review, background variables (e.g., race/ethnicity, educational background/licensure). "

Supplemental description:

"We require that (a) the role of the interventionist is noted or can be reasonably inferred and (b) interventionists are described so it can be determined whether the study should be included in the review (QI 3.1). ... To meet the latter condition for a review of the effectiveness of a practice for secondary students with learning disabilities delivered by paraprofessionals, reviewers must be able to tell whether interventionists were paraprofessionals. If a review is not specific to a population of interventionists, the latter condition does not apply" (p. 225).

- Met
- Not met

Q51

"3.2. The study describes any specific training (e.g., amount of training, training to a criterion) or qualifications (e.g., professional credential) required to implement the intervention, and indicates that the interventionist has achieved them."

Supplemental description:

"If specific training or qualifications are required to implement a practice appropriately, they must be noted and interventionists must have achieved them (QI 3.2). Describing training and noting that it was delivered to/ completed by interventionists are acceptable. ...QI 3.2 is still met if (a) study authors note that no training or qualifications were required or (b) reviewers consider the intervention can be reasonably implemented without special training/ qualifications" (p. 226).

If the study author is the interventionist and designed the intervention, this QI is met (e.g., self-trained by virtue of designing)

- Met
- Not met

Q52

4.0. Description of practice: "The study provides sufficient information regarding the critical features of the practice (intervention), such that the practice is clearly understood and can be reasonably replicated."

Q53

"4.1. The study describes detailed intervention procedures (e.g., intervention components, instructional behaviors, critical or active elements, manualized or scripted procedures, dosage) and intervention agents' actions (e.g., prompts, verbalizations, physical behaviors, proximity), or cites one or more accessible sources that provide this information."

Supplemental description:

"Reporting every detail about a practice is neither feasible nor required to meet QI 4.1. For example, a checklist of critical elements including interventionist actions that enables readers to understand how to implement the essential aspects of the intervention satisfies this QI. Merely naming the practice is unacceptable, although providing one or more citations to publicly available sources appropriately describing the practice is acceptable" (p. 226).

- Met
- Not met

Q54

"4.2. When relevant, the study describes materials (e.g., manipulatives, worksheets, timers, cues, toys), or cites one or more accessible sources providing this information."

Supplemental description:

"QI 4.2 is not applicable if no materials are mentioned and none appears to be needed to implement the practice. The QI is met by merely noting materials used if materials are common, self-explanatory, and appear to be used in a typical manner (e.g., a stopwatch used to time duration of behavior does not need to be described further)" (p. 226).

- Met
- Not met

Q55

5.0. Implementation fidelity: "The practice is implemented with fidelity."

Q56

"5.1. The study assesses and reports implementation fidelity related to adherence using direct, reliable measures (e.g., observations using a checklist of critical elements of the practice)."

Supplemental description:

"We require that adherence to implementation procedures be directly and reliably assessed and reported (QI 5.1). Typically, this is accomplished through observations using a checklist of critical elements. Because the field has not agreed on a particular level of acceptable adherence (Harn, Parisi, & Stoolmiller, 2013; Johnson & McMaster, 2013), we do not require a specific level of adherence—only that it be assessed and reported" (p. 226). See "Coding Vocabulary Guide" for more information.

- Met
- Not Met

Q57

"5.2. The study assesses and reports implementation fidelity related to dosage or exposure using direct, reliable measures (e.g., observations or self-report of the duration, frequency, curriculum coverage of implementation)."

Supplemental description:

"Similarly, no particular threshold of dosage/exposure must be achieved to address QI 5.2. Rather, dosage or exposure must be assessed and reported, or information from which dosage or exposure can be inferred must be reported. Describing how long intervention sessions lasted or how many days/classes the intervention occurred is acceptable. For single-subject studies, information typically shown on the single-subject graph (indicating for how many days/classes the intervention occurred) and a description of the intervention (how long each intervention session lasted) meet this indicator" (p. 226).

- Met
- Not met

Q58

"5.3. As appropriate, the study assesses and reports implementation fidelity (a) regularly throughout implementation of the intervention (e.g., beginning, middle, end of the intervention period), and (b) for each interventionist, each setting, and each participant or other unit of analysis. If either adherence or dosage is assessed and reported, this item applies to the type of fidelity assessed. If neither adherence nor dosage is assessed and reported, this item is not applicable."

Supplemental description:

"Researchers should ideally (a) specify when, where, and for whom fidelity is assessed and (b) report implementation separately for each level of these variables. However, indicating that fidelity was assessed across relevant elements and reporting aggregate measures of fidelity (e.g., average percentage of critical elements implemented) meet QI 5.3. For example, noting that adherence and dosage were assessed at the beginning, middle, and end of a study for each interventionist and reporting aggregate measures of fidelity are acceptable for a group comparison study involving multiple interventionists and conducted in one setting" (p. 226).

- Met
- Not met

Q59

6.0. Internal Validity: "The independent variable is under the control of experimenter. The study describes the services provided in control and comparison conditions and phases. The research design provides sufficient evidence that the independent variable causes change in the dependent variable or variables. Participants stayed with the study, so attrition is not a significant threat to internal validity." See "Coding Vocabulary Guide" for more information.

Q60

"6.1. The researcher controls and systematically manipulates the independent variable."

Supplemental description:

"Implementation of the practice must be under the control of the researcher (QI 6.1). Retrospective studies (e.g., natural experiments) do not meet this QI" (p. 226).

If 5.1 = Not met, then 6.1 and 6.7 = Not met

- Met
- Not met

Q61

"6.2. The study describes baseline (single-subject studies) or control/comparison (group comparison studies) conditions, such as the curriculum, instruction, and interventions (e.g., definition, duration, length, frequency, learner: instructor ratio). "

Supplemental description:

"Although detailed information on comparison conditions is desirable, reporting every detail is neither feasible nor required to meet QI 6.2. Reporting information that enables readers to understand the essential aspects of the conditions and instruction involved in comparison condition(s) or baseline/comparison phase(s) satisfies this QI. Merely noting that the comparison conditions were "business as usual" is unacceptable" (p. 226).

- Met
- Not met

Q62

"6.3. Control/comparison-condition or baseline-condition participants have no or extremely limited access to the treatment intervention."

Supplemental description:

"When exposure to the intervention is unlikely for comparison groups or during baseline/comparison phases, QI 6.3 is addressed without reporting any additional information. For example, the QI is met automatically in a group comparison study if the comparison group received instruction in a different school or classroom from the treatment group" (p. 226).

- Met
- Not met

Q63

Group Design Studies Only

"6.4. The study clearly describes assignment to groups, which involves participants (or classrooms, schools, or other unit of analysis) being assigned to groups in one of the following ways:
(a) randomly;
(b) nonrandomly, but the comparison groups are matched very closely to the intervention group (e.g., matched on prior test scores, demographics, a propensity score; see Song & Herman, 2010);
(c) nonrandomly, but techniques are used to measure differences and, if meaningful differences are identified—for example, statistically significant difference, difference greater than 5% of a standard deviation (What Works Clearinghouse, 2011)—to statistically control for any differences between groups on relevant pretest scores or demographic characteristics (e.g., statistically adjust for confounding variable through techniques such as ANCOVA or propensity score analysis); or
(d) nonrandomly on the basis of a reasonable cutoff point (regression discontinuity design)."

Supplemental description:

"Although researchers should ideally report the specific procedures used when randomly assigning participants to groups (e.g., online random number generator), simply reporting that units of analysis were randomly assigned is acceptable to address QI 6.4. Functionally random processes (e.g., school administered lottery) meet this QI (WWC, 2011). With the exception of regression discontinuity designs, some indication of functional equivalence of groups is required when groups are non-randomly assigned. Groups may be matched (e.g., on pretest scores, on a propensity score) or differences between groups on relevant variables can be assessed and, if meaningful differences are identified, controlled for statistically. ... Studies using non-random assignment that report groups are equivalent or comparable without providing details to support the claim do not meet QI 6.4" (p. 226-227)

- Met
- Not met

Q64

Group Design Studies Only

"6.8. Overall attrition is low across groups (e.g., <30% in a 1-year study)."

Supplemental description:

"Considering the lack of empirical guidance, we suggest reviewers use a liberal criterion for overall attrition (QI 6.8), such as <30% (Gersten et al., 2005). Reviewers should consider the context of the studies reviewed when setting a criterion for attrition (see Amico, 2009; Valentine & McHugh, 2007). ... In the absence of reported attrition, reviewers can sometimes infer attrition rates from the research report [e.g., initial participants vs. degrees of freedom]" (p. 227). See "Coding Vocabulary Guide" for more information.

- Met
- Not met

Q65

Group Design Studies Only

"6.9. Differential attrition (between groups) is low (e.g., ≤10%) or is controlled for by adjusting for noncompleters (e.g., conducting intent-to-treat analysis)."

Supplemental description:

"Given the lack of evidence linking differential attrition to ESs, we suggest reviewers use a relatively liberal criterion (e.g., ≤10%) for QI 6.9. QI 6.9 is met even when a study exhibits differential attrition exceeding reviewers' criterion when researchers demonstrate it had no impact (e.g., demonstrating pretest equivalence of groups after attrition) or is controlled for by using intent-to-treat analysis. If attrition rates for groups are not reported and cannot be inferred, QI 6.9 is not met, except when overall attrition is reported and is less than the review team's criterion for differential attrition" (p. 227).

- Met
- Not met

Q66

7.0. Outcome measures/dependent variables: "Outcome measures are applied appropriately to gauge the effect of the practice on study outcomes. Outcome measures demonstrate adequate psychometrics."

Q67

"7.1. Outcomes are socially important (e.g., they constitute or are theoretically or empirically linked to improved quality of life, an important developmental/learning outcome, or both)."

Supplemental description:

"Although researchers should ideally make the case for the social validity of outcomes in their research report, QI 7.1 is also met when outcomes clearly constitute or are linked to improved quality of life or an important developmental or learning outcome" (p. 227).

A pre-intervention social validity questionnaire is sufficient, or if a strong case is made in the introduction (e.g., there is a strong rationale and the intervention worked)

- Met
- Not met

Q68

"7.2. The study clearly defines and describes measurement of the dependent variables."

Supplemental description:

"If a study measures multiple outcomes, reviewers should consider effects only for outcomes relevant to their review. For example, for a review of the effect of a practice on reading fluency, if a study measured effects of the practice on both reading fluency and reading comprehension, only the former effects should be considered. If a study examines the effects of a practice on two or more measures of the outcome of focus (e.g., two measures of reading fluency), each dependent variable is treated as a separate case when determining the overall effect of the study. For example, in an ABAB study examining the impact of a practice on two different measures of reading fluency for three participants, meaningful, positive effects of the IV on the DV must occur for at least five of the six graphed outcomes (≥ 75%) for the study to be categorized as having positive effects" (p. 8).

"Providing a description of the measure and the process of administering/conducting the measure (or a reference to a publicly available source that describes the measure and its administration) in sufficient detail so that the reader could reasonably replicate the measurement procedure is necessary to meet QI 7.2. Merely mentioning the construct measured (e.g., spelling performance) without specifying the measure and its administration does not meet this QI" (p. 227).

- Met
- Not met

Q69

"7.3. The study reports the effects of the intervention on all measures of the outcome targeted by the review (p levels and effect sizes or data from which effect sizes can be calculated for group comparison studies; graphed data for single-subject studies), not just those for which a positive effect is found."

Supplemental description:

"To avoid outcome reporting bias (Dwan et al., 2008), researchers must fully report findings for all the analyses and outcomes described in the research report for outcomes relevant to the review (QI 7.3). For example, for a review on the effects of a practice on math outcomes, reporting a p level and an ES for the effect on multiplication fluency but merely noting the analysis on solving word problems was insignificant (without a p value or an ES estimate) would not meet QI 7.3" (p. 227).

- Met
- Not met

Q70

"7.4. Frequency and timing of outcome measures are appropriate.

Supplemental description:

"QI 7.4 requires the outcome measures be conducted with appropriate timing and frequency. For group comparison studies, outcomes must be measured in reasonable proximity of the intervention. For example, using a pretest measure assessed 3 months before the intervention or a posttest measure assessed 3 months after the intervention poses a serious threat to validity and would not meet QI 7.4. Delays in posttesting are acceptable if done purposefully to investigate long-term effects of the practice. Because at least three data points are necessary to establish a trend, at least three data points must be measured for each phase in a single-subject study to be considered part of a possible demonstration of experimental effect (QI 6.5 requires at least three demonstrations of experimental effects at three different times). As alternating treatment designs do not involve comparisons between phases, to meet QI 7.4, they must involve four repetitions of the alternating sequence (Kratochwill et al., 2013)" (p. 227).

- Met
- Not met

Q71

"7.5. The study provides evidence of adequate internal reliability, interobserver reliability, test-retest reliability, or parallel-form reliability, as relevant (e.g., score reliability coefficient ≥ .80, interobserver agreement ≥ 80%, kappa ≥ 60%)."

Supplemental description:

"Outcome measures should be both reliable and valid. QI 7.5 is met when any relevant type of reliability is assessed, reported, and shown to be adequate for outcomes relevant to the review. We recommend that reviewers use typical criteria for acceptable reliability (e.g., score reliability coefficient ≥ .80, inter-observer agreement ≥ 80%, kappa ≥ 60%). Study authors must report a specific coefficient or agreement level. Noting that "disagreements were reconciled" or "reliability was found to be acceptable" does not address QI 7.5. QI 7.5 does not apply to extremely low-inference measures. For example, graduation status as reported by the school does not require evidence of reliability when used to measure graduation. ... QIs 7.5 and 7.6 can also be addressed by citing previously published reports. If evidence of reliability or validity is imported from another study, the sample and scores must be similar enough to make generalization to the current study sensible. Adequacy of score and sample comparability can be indicated in the research report or determined by reviewers, which assumes the cited source is publicly available. If reliability or validity is established solely by citing another source that is not publicly available, the QI is not met" (p. 228). See "Coding Vocabulary Guide" for more information.

- Met
- Not met

Q72

Group Design Studies Only

"7.6. The study provides adequate evidence of validity, such as content, construct, criterion (concurrent or predictive), or social validity."

Supplemental description:

"Validity can be assessed in multiple ways, and commonly accepted, uniform standards do not exist for validity. For example, standards for concurrent validity coefficients tend to be lower in the area of writing than for other academic outcomes (e.g., McMaster, Du, & Pétursdóttir, 2009), content validity is typically determined by judgment, and construct validity is defined and examined in multiple ways. QI 7.6 is met by (a) study authors reporting adequate validity coefficients (as determined a priori by the review team) or (b) the outcome adequately representing the content being measured (i.e., content validity; as justified by study authors or as determined by reviewers). Adequate content validity can be assumed when a discrete behavior, whether a microbehavior, such as tying shoes, or a macrobehavior, such as graduating, is measured" (p. 228). See "Coding Vocabulary Guide" for more information.

- Met
- Not met

Q73

8.0. Data Analysis: "Data analysis is conducted appropriately. The study reports information on effect size."

Q74

Group Design Studies Only

"8.1. Data analysis techniques are appropriate for comparing change in performance of two or more groups (e.g., t tests, ANOVAs / MANOVAs, ANCOVAs / MANCOVAs, hierarchical linear modeling, structural equation modeling). If atypical procedures are used, the study provides a rationale justifying the data analysis techniques."

Supplemental description:

"QI 8.1 is met when (a) researchers use statistical analyses generally recognized as appropriate for comparing change in the performance of two or more groups (e.g., t tests, ANOVAs/MANCOVAs, hierarchical linear modeling, structural equation modeling) or (b) atypical procedures are used but justified by researchers. Justification for atypical analytic procedures can be provided through publicly available references. Using analyses with which special education researchers with advanced research training are unfamiliar and that are not explained does not meet this QI" (p. 228).

- Met
- Not met

Q75

Group Design Studies Only

"8.3. The study reports one or more appropriate effect size statistic (e.g., Cohen's d, Hedge's G, Glass's Δ, η^2) for all outcomes relevant to the review being conducted, even if the outcome is not statistically significant, or provides data from which appropriate effect sizes can be calculated."

Supplemental description:

"To meet QI 8.3, researchers must report an appropriate ES statistic (e.g., Cohen's d, Hedge's G, Glass's Δ, η^2) or provide data from which a common ES statistic can be calculated (e.g., group means and standard deviations, t values and sample sizes, F values and degrees of freedom) for each analysis examining the targeted practice's effect in group comparison studies. QI 8.3 is also met when study authors report atypical ESs but describe and justify their use or cite a publicly available source justifying their use" (p. 228).

- Met
- Not met

APPENDIX C

Coding Vocabulary Guide

Part 1 Nearpod Code: DFBSG
Part 2: Nearpod Code: DJUMW

Term	Definition
Independent Variable	The intervention
Dependent Variable	Math anxiety (and sometimes math performance)
Research Design	The procedures and steps used to implement the intervention and to collect/analyze the data (e.g., randomized control trial, quasi-experimental).
Group Experimental Design	Measures the impact of an intervention with random assignment of participants into control and treatment groups.
Group Quasi Experimental Design	Measures casual impact of an intervention without random assignment.
Control Group	The group of participants that is **not** receiving the intervention.
Treatment Group	The group of participants that **is** receiving the intervention.
Random Assignment	Participants are placed randomly into control or treatment groups. Experiments that are randomized typically include random selection for the study and/or random assignment to groups.
At Risk	Students at risk may display past math failure, overall past academic failure, and/or behavioral patterns that relate to poor academic performance (e.g., absences causing missed instruction or not completing coursework).
Math Concept	An intervention teaches a math concept when it teaches how to solve math problems.
Therapeutic Concept	An intervention teaches a therapeutic concept when it teaches emotional and mental strategies to treat math anxiety.
Direct Measurement	Measuring dependent variable as the behavior is occurring.

Indirect Measurement	Measuring dependent variable by measures that record the behavior while it is not happening. May include interviews, rating scales, and surveys.
Functional Behavioral Assessment	Functional Behavioral Assessment (FBA) is a multifaceted process that discovers the function of a participant's behavior. Meaning why they are doing that behavior.
Effect Size Calculators	Include: Cohen's d, correlation coefficient, odds/risks ratio.
Tests of Significance	Include: ANOVA, ANCOVA, t-test.
Implementation Fidelity	Quantitative measurements to see if the intervention was implemented like it was intended.
Overall Attrition	How many participants left the study before it was over, usually presented as a percentage.
Differential Attrition	How many participants left the control group versus how many left the experimental group before the study was over. (if overall attrition less than 10%, then met, even if not reported)
Inter-rater-reliability, Inter-observer-reliability, Internal-reliability	These are all tests to see how similar multiple data collectors measured the dependent variable during data collection.
Social Validity	Can be quantitative or qualitative measurement on how helpful this intervention is. Commonly measured factors are how easy it is to implement, if it is time efficient, if it is cost effective, and if it actually lowers math anxiety.

Tricky Questions Guidance

Question Number	Note
Q9	Sometimes a study will be a mixed review. Meaning it collects qualitative data and quantitative data. If this happens, just look at the quantitative data and decide whether that is experimental or quasi-experimental
Q10	In dissertations, there is often a definitions page where you can find math anxiety. I just search definition or similar words.
Q15	Some will explain socioeconomic status and not free reduced lunch. Say not reported. A CEC indicator will later cover that.

*Q21	(From example paper) If computer lab, don't just say classroom, specify "other: computer lab"
Q22	Most likely, the selection will be the entire class or small group, in terms of tiered support. Small group is defined by multiple people receiving the intervention. Doesn't have to be a group activity.
Q23	If the teacher is the researcher, still select teacher.
Q26	Count school days only!
Q38	There should be a data analysis section that says how they calculated things before providing results. It will typically be describing what kind of anova, ancovas, or t-tests used. And effect sizes sometimes. Sometimes they measure lots of things and it can be confusing to know what's applicable. If in doubt, just copy and paste. But ultimately we are looking for conditions impact on math anxiety. Time is sometimes a part of that analysis, and there are different combinations, and it can be complicated, so just include if not sure
Q39	Another effect size you may see is eta squared (n squared)
Q50	In selecting what data to copy and paste, use the same logic as described for Q35.
Quality Indicators	
2.1	I selected met if 3/5 demographics were reported.
5.2	Counts if authors explained how many classes occurred and/or how long the sessions were.
6.1	Asking if researchers are in control of the difference between treatment vs control groups, instead of a natural random event causing the difference. Basically, it's met or not met mirroring your answer to 5.1.
6.4	You will either see (a) or (b) occurring. So, don't worry about the other examples.
7.1	I say yes even if the results aren't super significant.

*7.5, 7.6	For all of our studies, these measurements are on the anxiety rating scale (and sometimes a math test too). If they cite where they got the rating scale from and say it's reliable and valid, that's good enough. If they use their own scale, they have to prove the validity through their own testing.
8.3	Don't have to have effect size to say "met" As long as there was an Anova, Ancova, or t-test you can say "met."