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Math anxiety: trends, issues and challenges

Abstract

Mathematics anxiety can be found in all ages, from pre-school to graduate students and beyond. Defined as feelings of tension and anxiety that interfere with the solution process and manipulation of mathematical problems in a wide variety of real-life applications, academic and non-academic situations, math anxiety may be manifested in both cognitive and affective processes; and it has been linked negatively to various indices of success and to detrimental effects on future career and professional development. The objective of the qualitative study is to determine the recent prevalence and intensity of math anxiety among in terms of age and gender, its different components, the link between math anxiety and math performance, various causes (e.g., social & cognitive) that explain math anxiety, and methods to alleviate math anxiety.

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Introduction

Whether identified as "bystander theory," "diffusion of responsibility theory," or by other high-minded names, the problem is real and evolving. Millions of students sitting in math classes wonder why they have to study numbers and equations, and they do not perform well in mathematics. They cannot multiply or divide; perhaps they do not understand the connections between mathematics and their own lives. Perhaps, they do not appreciate that their precious cell phones could not work without graphing calculations or a myriad of other mathematical formulae. Furthermore, modern transportation systems (except for walking, of course) would collapse without math. Without transportation, the food these students eat, the clothes they wear, and even their purchases from Amazon would be unobtainable. However, far too many of these young learners apparently assume that someone else would come along to do the math for them. In reality, the facts are frightening.

Teenagers in the Deep South of the United States have math skills that are barely above their counterparts in Chile and Mexico, about the same as Kazakhstan and Thailand, and actually worse than Turkey. Privileged American youngsters across the nation do not fare much better, lagging behind their peers in other developed countries. A string of northern states - Massachusetts, Vermont, New Jersey, and Montana - perform well when their students are compared to those in wealthier European nations, but that achievement still leaves a lot to be desired. In fact, one out of every three college students in the United States is required to take at least one remedial mathematics course (Kim). Even though the U.S. Department of Education's National Assessment of Education Progress (NAEP) found that American students have made substantial gains in math since 1990, in 2012 the Program for International Student Assessment (PISA) ranked the U.S. an unimpressive 35th out of 64 countries in reading ability, math, and science literacy among 15-year-olds.

Recent data indicates that adults in the United States are not any better prepared than their children to compete in a global economy; let alone solve pressing issues related to energy consumption and distribution of wealth. A recent survey of 5,000 American adults shows that while their literacy skills are better than their numeracy and problem-solving skills, the average for all three is below the international average of 21 countries in the Organization for Economic Cooperation and Development and far behind such top performing countries as Japan or Finland.[1] Small degrees of improvement may not be enough to tackle the kinds of issues the country and the planet are facing in the form of drought, rising ocean levels, and the kind of violence that is current and that will continue to be associated with these phenomena. According to McLeod (1992), if students are going to be active learners of mathematics, who willingly attack non-routine problems such as these, "their *affective*.[emphasis added] responses to mathematics" are going to have to be much more intense "than if they are merely expected to achieve satisfactory levels of performance".

Literature review

Parajes & Miller.[2] wrote, "As early as 1957, Dreger and Aiken suspected that individuals suffered from 'number anxiety,' and various studies have since demonstrated a negative correlation between math anxiety and math performance". However, the presumption underlying many of the studies on math anxiety seems to be that everyone should be equally competent in math. Yet Geist,[3] among others, presented a different point of view in a paper about creating an anti-anxiety math curriculum: "If we can assume that these differences.[in math ability] are not a result of native potential, or some sort of genetic mathematical ability, then we must look for environmental variables to explain the intertwining outcomes of poor achievement and negative attitude toward mathematics". While using stereotypes to assume anything about a child's potential in any subject, including math, can be detrimental, presuming there are no innate differences in children's abilities seems to be equally as dangerous. In fact, Geist.[3] indicated that curricula need to be "gender responsive", meaning, it would seem, that the author accepts the fact there are innate gender differences. Why not innate differences in math ability?

One good thing about the study of math anxiety is the fact that it appears there are no disagreements on the definition. Most researchers accept a variant of Ashcraft's statement: "Math anxiety is commonly defined as a feeling of tension, apprehension, or fear that interferes with math performance".[4] Richardson & Suinn,[5] wrote similarly: "Mathematics anxiety involves feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations".[6]. Some researchers have taken a closer look at anxiety and have broken it down into different components. Using previous studies of general test anxiety, Wigfield & Meece,[7] found that researchers had broken down anxiety into two components: worry and an affective component (or emotionality). "*Worry* is the cognitive component of anxiety," Wigfield & Meece,[7] explained, "consisting of self-deprecatory thoughts about one's performance. *Emotionality* is the affective component of anxiety, including feelings of nervousness, tension, and unpleasant physiological reactions to testing situations". In previous studies, researchers found that "worry relates more strongly than emotionality to poor test performance". In their own study of 564 sixth-through twelfth-graders, Wigfield & Meece,[7] also discovered two components within math anxiety. "The two components of math anxiety emerging from the factor analyses were similar to those identified by test anxiety researchers," the authors wrote. "One component primarily taps negative affective reactions to math, such as nervousness, fear, and discomfort. The other component primarily taps worries about doing well in mathematics. The correlations between the two factors suggest there are some overlaps in the two components". Unlike other studies on general math anxiety, Wigfield & Meece's,[7] study found that the "negative affective reactions scale correlated more strongly and negatively than the worry scale to children's math ability perceptions, performance perceptions, expectancies, and math performance. In contrast, scores on the worry scale related more strongly (and positively) to the actual effort that students say they put into math, and to the importance that they attach to math", and "related negligibly to math performance." These findings contradict those on general test anxiety and suggest that more research needs to be done in the area of math anxiety components.

How math anxiety works

There is also a general agreement on how math anxiety interferes with math performance. Math anxiety negatively affects performance by "devoting resources to worrying about performance rather than application of problem solving strategies," thereby impacting working memory.[8] In other words, math anxiety "disrupts cognitive processing by compromising ongoing activity in working memory".[4] Trezise & Reeve.[9] and Maloney & Beilock.[10] agree with this processing efficiency theory. The latter two researchers tested this theory by asking students to remember things while working on math problems, and then observing how students performed as the things they were asked to remember became more complicated. In addition, Ramirez et al.[11] found a relation between math anxiety and math achievement for first- and second-graders with high working memory but not for those with low working memory. Studies have also shown that working memory plays an important role in the regulation of emotions, and that emotional states can impact cognitive ability by taking up cognitive capacity. However, tests following emotion-inducing protocols showed that some children were able to control the impact of emotions better than others.[9] To evaluate the relationship between working memory (WM) and anxiety, Trezise & Reeve.[9] assessed 126 fourteen-year-olds for their working memories and worry levels twice before giving them an algebra test. The findings were complicated. The high working memory/low worry subgroup remained stable over time and performed best, while the "unstable across time" low working memory/high worry performed worst. "Many students exhibited a stable WM-worry relationship between Time 1 and Time 2. For students whose WM-worry relationship changed over time, the general pattern of change was to move to a status with lower WM, indicating WM capacity declined over time for one-third of students," wrote the authors. "For students who initially displayed high WM capacity, those with high worry were more likely to change to a lower WM status over time, suggesting worry reduces WM capacity". In addition, "students in the moderate WM/low worry status were likely to change to the low WM/low worry or low WM/high worry statuses, indicating that moderate WM was associated with declines in WM, and possible increases in worry". The authors concluded that their "findings suggest that the cognition-emotion relationship can change over a short period of time" and that individuals with high working memory are better at regulating their emotions, even if this was not true for all their subjects.

Is math anxiety really the problem?

The fact that "math anxiety is only weakly related to overall intelligence" would seem to support the theory that anxiety affects math performance independently from math ability. However, that conclusion is not clear. Meece et al.[12], in a study of seventh through ninth graders, concluded that math anxiety was most directly related to math ability perceptions, performance expectancies, and value perceptions. Performance expectations, the authors observed, predicted subsequent math grades, while value perceptions predicted course enrollment. Nonetheless, they concluded that math anxiety did *not* have a significant direct effect on either grades or intentions. In an earlier study on 1,045 college freshmen, Resnick et al.[13] wrote about various "dimensions" of math anxiety, including two they found previous to their own study, math text anxiety and numerical anxiety (the fear of the everyday use of math). They added three new but related dimensions to this: evaluation anxiety, arithmetic computation anxiety, and social responsibility anxiety – the fear that the individual may not be able to take on arithmetic responsibility in an organization or club. Evaluation anxiety accounted for the "largest part of the variance" in math anxiety. Contrary to prior studies, the authors concluded, "There was no appreciable increment in the prediction of math performance by the use of MARS.[Math Anxiety Rating Scale] scores" once SAT scores and high school rank were taken into account. However, Englehard.[14] reported in a study of 13-year-old students in the U.S. and Thailand that the relationship between math anxiety and mathematics performance is significant in both countries after controlling for previous achievement, mother's education, and gender. Pajarers & Miller.[2] tested social cognitive theory, which suggests that self-efficacy is the most important predictor of performance, not math anxiety. According to the authors, Bandura defined self-efficacy as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances". Llabre and Suarez (1985) and Meece et al.[12] found in their studies that, "in most cases, math anxiety is not a powerful predictor when variables such as self-efficacy, self-concept, prior experience, and perceived usefulness are controlled".[2] Siegel, Galassi, and Ware (1985) also "found that a model that included self-efficacy accounted for a larger portion of the variance in math performance than did a model with anxiety and aptitude as the independent measures".[2] Jameson & Fusco.[15] tackled the differences among math anxiety, self-efficacy and self-concept in a study of adult learners. They found from previous studies that adult learners reported lower levels of self-efficacy and higher levels of math anxiety; as well as a negative correlation between math anxiety and self-concept. However, in their study, they found similar levels of self-concept between the adults and traditional college students, and their findings showed that self-efficacy was lower only in higher forms of math, not in areas such as fractions or decimals. Even though the authors used a Mathematics Confidence Scale (MCS) to measure self-efficacy, they later wrote, Hackett.[16] & Betz.[17] reported a significant relationship between globally assessed math confidence and ACT-Q scores but found that only self-efficacy was a significant predictor of choice of math-related major", suggesting there are some kind of inherented differences between confidence and self-efficacy. In order to differentiate self-efficacy from self-concept, Pajares & Miller.[2] insisted the required performances in any study must be very specific. The authors concluded from their study of 350 undergraduates that "math self-efficacy was more predictive of problem solving than was math self-concept, perceived usefulness of mathematics, prior experience with mathematics, or gender". In addition, mechanisms such as anxiety are "to a great extent, the result of self-efficacy judgements". In other words, how well one believes he or she can perform in math determines math anxiety, not the other way

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around. Ahmed et al.[18] provided limited support for such a finding. In a study of 495 seventh-grade students (51% girls), the authors found that higher self-concept led to lower anxiety, which led to higher self-concept, but self-concept impacted anxiety more than anxiety impacted self-concept.

In a somewhat confusing study of 1,200 secondary students in Singapore, Luo et al.[19] looked at "self-construal." Those who stress harmony with others practice interdependent self-construal, according to the authors, and people who emphasize their uniqueness practice independent self-construal. Without differentiating between the two kinds, the authors concluded that "self-construal predicts math self-concept and anxiety, which further predicts math achievement". However, they also noted: "Overall, self-construal was not associated with math achievement". Despite evidence to the contrary, Maloney & Beilock.[10] stated that "low math ability is not the entire explanation for why math anxiety and poor math performance co-occur". The authors cited a study by Ramirez et al.[20] indicating that children as young as first graders report math anxiety, which is inversely related to their math achievement. However, Maloney & Beilock.[10] go on to state that students with cognitive weaknesses in math may pick up cues that highlight math in negative terms; such an explanation for how math anxiety is created indicates that children who are bad at math develop math anxiety, and not the other way around. Wang et al.[21] reached a similar conclusion in a study of 514 twelve-year-old twins, writing that "genetic risks underlying poor math ability and general anxiety may already predispose children to the development of.[math anxiety]". Addressing anxiety symptoms through techniques such as desensitization or improving math learning experiences, the authors state, can reduce math anxiety but may have a little impact on motivation or performance in math.

Whether math anxiety can or cannot be easily differentiated from self-concept, self-efficacy, or confidence, the harder the math is, the higher the math anxiety occurs Ford, Boxer and Armstrong (2012) wrote that "the deleterious effect of anxiety appears to be greater for more difficult tests"; conversely, the "negative effect of test anxiety was attenuated on an easy anagram test". Ashcraft et al.[4] reported that math-anxious people perform "as well as their peers on whole-number arithmetic problems". In a study with a similar focus, Hart used 264 pairs of 12-year-old twins to look at numerosity, defined as "an innate set of skills representing, but not limited to, the nonsymbolic number approximation system that estimates large magnitudes, and also the symbolic number approximation system that maps numerical symbols onto magnitudes" In a study with similar findings, Wu, Barth, Amin, Malcame, and Menon (2012) used a Scale for Early Mathematics Anxiety (SEMA based on MARS) on second and third graders. Controlling for general anxiety, the researchers asked the subjects to self-rate on a five-point scale using anxious and non-anxious faces for the scale. The authors concluded that "math anxiety was significantly and negatively correlated with math proficiency, even in children who were at or above grade level in math". They even indicated that math anxiety scores significantly correlated with term grades, final exam grades, and a test of mathematic aptitude. However, they cautioned that a lack of psychometric data "leaves the validity and reliability" of some anxiety measures "unclear", while acknowledging that math anxiety increased over time, as one would expect if the math increased in difficulty. In fact, while suggesting that their study proves that "the specific effects of math anxiety can be detected in the earliest stages of formal math learning in school" and that math anxiety has a detrimental impact on math achievement, they admitted that it is more "pronounced…on more demanding calculations". Indeed, the authors cited several other studies that indicated just such a pattern. With simple math tasks, such as addition of single digit numbers, "did not find math ability to be correlated with math anxiety". Krinzinger found that math anxiety correlated only with attitude toward mathematics, not with math achievement, in six- to nine-year-old German children.

In a study of 368 college math students, Hendy et al.[22] reported that math anxiety is negatively correlated with math grades but this correlation explains only "a relatively small" percentage of the variance in student math performance. Rather, other factors may explain bad student math behaviors. The researchers queried their subjects about class attendance, rates of homework, ability to read, and their tendencies to ask for help, as well as their math beliefs, such as their self-efficacy in math (defined as confidence), their expectation that math will help them succeed in their goals, and any barriers to their decision to try at math. Expectancy-value theory suggests that some people think the effort is not worth the payback, and younger and male students were at increased risk for this attitude. Self-efficacy theory holds that even if the struggle is worth it, the students may not think they are capable. Older students suffer more from this perception. A health-belief model may also be influential, in that some students may believe that attending class and studying takes time away from other college pursuits, such as social activities. According to the authors, all three categories - self-efficacy, expectancy-value theory, and belief systems - were found to be significantly associated with measures of math behavior and performance. Therefore, a one-size-fits-all approach does not work as a valid explanation of math anxiety. Interestingly, the authors suggested that with younger students, instructors may have to deal more with expectancy, and with older students, self-efficacy. The authors did not make any suggestions about how to deal with the feeling among students whose studying cuts into time for other interests (the health-belief model). Whether or not math anxiety is real, it can have some real-world consequences. In a study of nursing students, for example, McMullan et al.[23] concluded that numerical ability made the strongest unique contribution in predicting drug calculation ability, followed by drug calculation self-efficacy, and finally by anxiety. The authors suggested that nursing schools needed to figure out which students do poorly in math and refresh their skills. Feng et al.[24] discovered that consumers with math anxiety tend to avoid alternatives that require price computations. Surprisingly, they found that classical music in a slow tempo may reduce math anxiety – but when the music's tempo was fast, the opposite effect occurred. Martin et al.[25] found in a study of over 1,600 Australian middle school students in 44 schools that math anxiety quite strongly predicted classroom disengagement but not future intentions regarding the study of math.

Math anxiety and other anxieties

In a study of undergraduates in a North Carolina university, Dew & Galissi.[26] found in a comparison of math anxiety scales - including Fennema and Sherman's Mathematics Anxiety Scale (MAS) and Suinn's MARS (first created in 1972) - that while the "math anxiety measures were moderately related to each other…almost invariably, they were more closely related to each other than to test anxiety and its components". On the other hand, Ashcraft.[4] reported a strong relationship between math anxiety and test anxiety. Wang et al.[21] found that math anxiety was moderately associated with general anxiety.

Gender

Griggs et al.[27] found no gender differences in their study of math and science anxiety; nor did Meece.[12] in their study of seventh through ninth graders. Wigfield & Meece.[7], however, they reported that girls indicated stronger negative affective reactions to math than boys did on the MARS survey. Dew & Galissi.[27] also found only small gender differences in math anxiety among university undergraduates in the United States. Prevatt, Welles, Li, and Proctor (2010) found no gender differences in their study of the effects of math anxiety and changes in working memory on 115 undergraduates with learning disabilities. Resnick et al.[13] found no gender differences in math anxiety among 1,045 college freshmen in a MARS survey. Still, the authors go on to say that in studies from the 1970s, that "little question those problems of math avoidance" were more apparent among women. Pajares & Miller.[2] reported higher rates of math anxiety in female undergraduates. Ashcraft.[4] also found math anxiety somewhat higher among women, with fewer men than women suffering from math anxiety at higher levels of education, but the reverse at the lower levels. Goetz et al.[28] found no gender differences for state anxiety, but some differences in trait anxiety (like math anxiety). Interestingly, these authors noted that girls did not experience any higher anxiety levels *during* a test. Hyde et al.[29] found that when gender differences existed, "the pattern is for females to hold more negative attitudes", a difference that increased as the subjects get older. In addition, the authors found that males outperformed females on mathematics tests, especially in problem-solving, a pattern that also increased with age. Paradoxically, despite the lower test scores, females got higher course grades. Yet even when females achieved equally as well as males, their competence beliefs were lower.[28] Ganley & Vasilyeva.[30] indicated that women's heightened anxiety explained gender differences in mathematical abilities among college students. Hyde et al.[29] suggested in their meta-studies that math anxiety predicted more variance in math performance among women than between women and men. While Pajares & Miller.[2] found that men reported higher math self-efficacy than did women, thus explaining the difference in any gender variations, Miller and Bichsel (2004) found math anxiety more common in males than females.[31] If gender differences do exist, the cause is probably societal, according to Gunderson et al.[20], because "parents' and teachers' expectancies for children's math competence are often gender-biased and can influence children's math attitudes and performance". In one study, Maloney & Beilock.[10] found that only the female students of highly math-anxious female teachers (>90% of elementary teachers in the U.S. are female) endorsed the stereotype that boys are better at math. In contrast, Widmer & Chavez.[32] found that among the 230 teachers who filled out their surveys, there was no relationship between math anxiety and gender, nor between math anxiety and recency of training. In a look at a broad scope of attitudes toward math from 1967 through 1988, Hyde et al.[29] found that gender differences in mathematics attitudes and affect were small. Using scales that measured confidence (self-efficacy), perceived math usefulness, attitude toward math as a male domain, attitudes about success, motivation, mother's attitude, father's attitude, and teacher's attitude, the authors found that except for stereotyping of math as a male domain, there was little to no gender difference in the ratings. As a result of their findings, Hyde et al.[298] suggested looking at sex discrimination, both in education and employment, as the culprit to explain the under-representation of women in mathematics fields, instead of attributing this shortfall to math attitudes or math anxiety. Some researchers have argued that boys have "more natural mathematical ability." Other biological theories such as "brain lateralization" have also been used to explain the differences between male and female attitudes toward math.[29] By far the most plausible explanation, however, rests with researchers such as Fennema and Peterson (1985) whose studies found gender differences to be based on combination of external and internal influences.[29]

Age

Jenssen et al.[31] wrote that math anxiety is a trait that is stable over time, not everyone agrees. In their literature review, Wigfield & Meece.[7] stated that anxiety appears to increase with age and with being female, while Meece (1981) concluded that age had more of an impact than gender.[7] The authors found in their own longitudinal study of sixth through twelfth graders that ninth graders "reported experiencing the most worry about math and sixth graders the least".

Math anxiety and other cognitive issues

Irish university students with dyslexia had higher levels of math anxiety than those without, while statistics anxiety and general mental health were comparable.[32] Prevatt et al.[33] found in a study of 115 college undergraduates with learning disabilities that a poor working memory and anxiety both had a direct impact on math performance. Furthermore, they reported that anxiety served as a moderator for most, but not all, measures of math achievement.

Causes of math anxiety

Clearly, not as much work has been on the causes of math anxiety as on the concept itself. Geist.[3] reported the "most consistent risk factor for low achievement in mathematics is family income level". To explain how a connection between income and math achievement occurs, the author suggested that children from low socioeconomic backgrounds can have parents who are math averse or math anxious and pass the trait onto their children. Such an inheritance can cause problems even before a child enters school, since many concepts are best learned before the age of five. "The seemingly simple understanding that numbers have a quantity attached to them," wrote the author, is actually a complex relationship that children must construct". If there is one group the blame for math anxiety most often focuses on, it is math teachers. Stodolsky.[6] found that elementary school students liked math just as much as reading, just below art and physical education. In one study, nine-year-olds even ranked math as their "best-liked subject". However, 17-year-olds ranked math as least liked, even though there was no decrease during those years in students' "perception that mathematics is important" Stodolsky.[6] blamed the poor attitudes on a reliance of recitation on the part of math teachers, poor text books and a reliance on text book-centered instruction, a lack of manipulatives in the classroom, and a lack of small-group work. Writing specifically about math anxiety, Stodolsky.[6] concluded that attitudes about math were "shaped by preference or interest, not ability". While many of the questionable teaching strategies Stodolsky.[6] found in 1985 no doubt have changed in the intervening three decades, Ashcraft.[4] continued to stress almost twenty years later that "some teaching styles are implicated as risk factors" for math anxiety, such as teachers being visibly annoyed at incorrect answers. Widmer & Chavez.[34] found several studies that cite instances of attitudes toward mathematics (often negative ones) being linked with the attitudes, approaches, or behaviors of teachers. The authors concluded from their own research that those elementary school teachers who went to schools that stressed understanding more than computation expressed lower levels of math anxiety. Menesses KF & Gresham.[35] reported math anxiety was more common among pre-school teachers than among teachers in higher grades.[31] Beckdemir (2010) found that teachers can transfer their own math anxiety to students.[31] Jenssene et al.[31] found results similar to Menesses KF & Gresham.[35] among the 354 prospective German pre-school teachers they tested with the Mathematics Anxiety Scale.

Obviously, these authors concluded, pre-school teachers need to be helped with their own math anxiety before passing it on. Since teaches are part of a larger system, it is certainly possible that the educational system itself might be to blame. An over-reliance on timed, high-stakes tests can reinforce any negative attitude children may already have developed toward mathematics or toward school in general. Boys seem to respond differently from girls to this traditional, competitive model, since they are overrepresented at both the bottom and top levels of mathematics achievement.[3] Clearly, some thrive, while others suffer. If math anxiety is indeed due to differences in ability, then biological factors might come into play. As brain scans get better and less expensive, more information will be forthcoming. However, a few studies have been done on biological factors related to math anxiety. For individuals with a large working memory and low level of math-anxiety, the higher their salivary cortisol, the better their performance. For individuals with a large working memory but higher levels of math-anxiety, the higher their salivary cortisol, the worse their performance.[36] Wang et al.[21] in a study of 514 twelve-year-old twins found that 40% of the variation in self-reported math anxiety was genetic, and just over half of the total variance was related to non shared environment factors, such as parental expectations and experiences in math class, a finding "consistent with previous quantitative work on temperamental fearfulness, general anxiety, and various specific phobias". Young, Wu, and Menon (2012 May) discovered that among seven- to nine-year-old children, "math anxiety was associated with hyperactivity in right amygdala regions that are important for processing negative emotions".

Help for math anxiety

Researchers have also turned their attention to ways to alleviate math anxiety. Smith et al.[37] reported humorous questions within a test helped with the overall performance on the test (although subsequent studies failed to confirm the team's findings). In a test of 33 men and 51 women in psychology classes, with the test administered in exchange for credit, Ford, Ford, Boxer, and Armstrong (2012) found that humor before the test helped buffer anxiety and enhance performance. In a similar vein, Park et al.[38] found that students from a Midwestern university were able to offset some of their anxiety-related performance issues on math tests by writing about their fears before the test. Geist.[3] predicted that a classroom curriculum that is "developmentally appropriate, individualized, and gender responsive" will prove to be the answer to math anxiety issues. While in theory this sounds like a goal worth pursuing, achieving such a desired state is difficult, especially in districts where there is little money for reduction in classroom sizes or innovation. As Geist suggests, computers can help, but they are not a panacea that will "fix" all troubled schools and teachers, as some reformists may secretly hope. As development psychologist Susan Pinker (2015) reported, poor children already spend at least 40 percent of their waking hours in front of a screen. Giving destitute children laptops "didn't live up to the ballyhoo….For one thing, the machines were buggy and often broke down. And when they did work, the impoverished students spent more time on games and chat rooms and less time on their homework than before, according to education researchers Mark Warschauer and Morgan Ames. It's drive-by education – adults distribute the laptops and then walk away" (p. A11). Although computers may not be the answer, more training for teachers may be. Griggs et al.[27] found that the negative association between students' anxiety and self-efficacy was attenuated in schools using more Responsive Classroom (RC) practices. In RC classrooms, teachers allow students to participate in rule creation, use group work, and engage in collaborative problem-solving. They also "support students' development of autonomy, and respond to misbehavior in ways that demonstrate respect for students" (p. 363). Legg & Locker.[8] found that work with metacognition moderated the effects of math anxiety, as reported by 56 Georgia State University undergraduates who participated in a revised MARS survey to measure anxiety and a State Metacognitive Inventory to measure metacognition. In this study, the authors divided metacognition into two domains. The first domain was metacognitive knowledge, which may be expressed in three ways: declarative, procedural, or conditional. "Knowing that a good night's rest and healthy breakfast can impact test performance" is an example of declarative metacognition. Knowing how to perform tasks is procedural metacognition. Conditional metacognition involves knowing when and why to choose specific strategies and alternates. The second domain of metacognition involves the regulation of cognition – planning, monitoring, and evaluation.

According to a study at Georgia State University, students who received metacognitive training on a linear graph unit did better than those who had what was called "traditional training". However, the authors did not make clear the difference between "traditional training" and metacognition training. The questions asked in the metacognition training (for example, Do I understand the vocabulary in the problem?) seemed to be very basic cognitive questions that any instructor might ask as part of any lesson. In other words, if the instructors doing the "traditional training" were so limited in their approach that they could not even ask their students if they understood the vocabulary, then no wonder the metacognitive training group performed better. However, in the final analysis, the researchers admitted that the "findings presented here may only apply to math tasks in which difficulty levels do not exceed the capabilities of the individuals". Obviously, metacognitive training cannot help students become better mathematicians than they are capable of becoming, but it might help them overcome any limiting effects of math anxiety to allow them to reach their potential. Maloney & Beilock.[10] also seem to support metacognitive training for math anxiety, suggesting that schools should identify at-risk math students and help them control their negative emotions by, for example, telling them to think positively about tests. Martin et al.[25] have similar suggestions, indicating that schools should help students deal with their fear of failure, develop effective relaxation techniques, prepare for pressure of tests, and deal with the stress of academic challenges. Despite their conclusion that "genetic risks underlying poor math ability and general anxiety may already predispose children to the development of MA", Wang et al.[21] still see a need to integrate cognitive and affective domains into the teaching of math. More than 20 years ago, Wigfield & Meece.[7] used almost the same language, writing that "intervention programs to alleviate the negative effects of math anxiety must deal with both affective and cognitive aspects of math anxiety". In support of such suggestions, Ashcraft.[4] indicated that treatments of math anxiety could bring test scores up even when those treatments did not involve practicing math. In a similar approach, Hendy et al.[22] suggested teaching students that math skills are "learnable," not innate, and that instructors can teach students steps to solve problems. In a similar vein, Prevatt et al.[33] recommended working on memory tricks with those students who have a poor working memory, and helping students deal with anxiety for those students with high anxiety.

According to Goldin, Epstein, Schorr, and Warner (2011), the challenge for the math teacher, then, is "to create an emotionally safe environment, with serious engagement based on many different, but appropriately active, structures that contribute to interest, utility, safety, status, self-image, self-concept, and understanding; ultimately,

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to fulfilling basic psychological needs". In other words, math teachers need not only to teach math but to instill a healthy respect and life-long interest in math in children from their earliest days in the educational system. As Fisher et al.[39] have noted, a "reciprocal relationship between math interest and math ability may be in place as early as preschool". To put it another way, early interest predicts later skills; and math skills predict math interest five months later. Several other schools of thought exist about the best way to reduce or eliminate math anxiety and the resulting test anxiety that follows in its footsteps. Wilson et al.[40], for example, cover a myriad of treatments for math and test anxiety: "Weiner (1986) has argued that the key is to get people to attribute past failures to unstable causes, so that they expect to do better in the future. Dweck (1999) suggests that the key is to change people's self-theories about intelligence; whereas Raufelder & Ringiesen.[41] agree that academic self-efficacy can help reduce test anxiety, as it mediates the association between academic self-concept and three facets of test anxiety. Self-efficacy is the belief by a person that he or she is capable of organizing and executing "courses of action required to achieve certain performance outcomes".[42] Pietsch et al.[42] suggest that self-efficacy is highly related to performance in mathematics and that helping students accomplish tasks improves their self-efficacy. Obviously getting students to successfully complete tasks improves their performance. Beyond that, according to self-efficacy theory, it helps them perform future tasks. Similar to self-efficacy theory, Wigfield & Eccles.[43] champion expectancy-value theory, in which they argue that individuals' choice, persistence, and performance can be explained by their beliefs about how well they will do on the activity and the extent to which they value the activity". Finally, there is a small group that dismisses academic anxiety as non-existent at best or chicanery at worst. When all is said and done, a wide range of treatments have been studied, from those that are relatively easy and inexpensive to implement to those that are more complicated, time consuming, and perhaps expensive-depending upon who is facilitating the treatment. The following section of the paper will cover other specific ways to lessen anxiety.

Inexpensive and relatively easy interventions to improve math

Something as simple as having classmates tutor each other with math flashcards can improve math outcomes. Menesses & Gresham.[35] found that both the tutor and tutee who worked in pairs on flashcards improved their math performance equally. Even tutors who did not see questions performed better in math, perhaps because they developed a better attitude.

Inexpensive but time-consuming interventions to improve math

Gottfried.[44] has stressed that parental expectations and encouragement of curiosity "are positively and significantly related to academic intrinsic motivation", which is important for a student's success. Writing specifically about mathematics, Schunk and Zimmerman (2007) have indicated that "parents can help improve students' math interest and performance by encouraging students and helping them believe that mathematical competencies can be improved through consistent effort".[45] Bouchey & Harter.[46] also stress that adults' belief in the importance of math and belief in students' competence in math/science and students' perceived support from adults predicted students' own perceptions of importance, competence, behavior, and actual performance. Hill & Craft.[47] and Salend.[48] agree that parental involvement in school is crucial, but that many guardians may not know how to assist. For younger students, Hill & Craft.[47] found that African American parents could help best by encouraging their children to stay on task and pay attention. For Euro-American kindergarteners, parents could best help by providing models of sharing, turn taking, and getting along with others. Teachers and school psychologists might be able to work together to create a plan to motivate the parents of recalcitrant students. Another inexpensive way to bolster math performance is to allow students to work in cooperative learning.[48,49] Johnson et al.[50] stress that "cooperative, compared to individualized, learning results in greater ability to take the affective perspective of others, more altruism, more positive attitudes toward classroom subject, and higher achievement". However, while having students work cooperatively should have no financial costs, using groups in a successful matter is not easy. It should probably come as no surprise that teams high in cognitive ability generally do well, while teams high in agreeableness traits did not do well because they may "foster premature consensus".[51] Obviously in school situations, teachers have learned or instinctively know not to put all the most socially focused students in a single group. While putting all the best students in a single group may facilitate that group's success, it may leave the other groups without the skills necessary to accomplish the task.

More expensive but relatively easy interventions

Amelink.[45] suggests organizing workshops for elementary teachers to give them information how to become better math instructors. Obviously the cost of providing an outside consultant as well as the costs of keeping instructors beyond the normal work day have to be taken into account. District personnel with expertise may be available, and "non-instructional days" may be utilized. The workshops should cover several different areas. First, teachers can be helped to recognize signs that students have test anxiety.[48], including both physiological and psychological symptoms. Since both Taffel & O'Leary.[52] and Salend.[48] suggest using games as a way to help students study for tests, workshop facilitators can have a session on educational games that focus on math skills. Workshops can also provide instructors with talking points about how math relates to a variety of careers and about mathematicians who worked hard to get where they are. Regarding the latter point, students who view math as something that can be mastered and is not innate are less likely to lose interest. Also, in these workshops, teachers can be encouraged to show and not tell when answering questions, especially for students whom they may think are not strong in math. When dealing specifically with girls, instructors need to make sure to praise effort and not just outcome.[45] In addition, teachers need to be made aware of the fact that they can pass on math anxiety and must be provided with ways to avoid doing that. Because social and emotional learning (SEL) practices helped 5th graders' self-efficacy in math and science, teachers can also be trained to work on SEL. These pointers, according to Griggs et al.[27], can include such things from letting students help create classroom rules to having teachers practice what they preach in the classroom. In addition, the authors include a couple techniques that have already been touched upon: working with families and collaborative problem-solving.

For older students, instructors must be made aware of ways to avoid stereotype threat. For example, negative stereotypes about women in math reduce their level of mathematical learning Rydell et al.[53] and Nguyen & Ryan.[54] also found that the performance of groups such as African-Americans and women "may be partially undermined when they encounter cues of a salient negative stereotype in the testing environment". Rydell et al.[53] insist that "creating environments that can reduce the impact of stereotype threat…is critical for facilitating the entrance of group members into domains in which they have been historically absent" (p. 895), such as women in math and science. For instance, Brown & Josephs.[55] found that women who were told a math test would show how weak they are in math did worse than

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those who were told it would show how exceptionally strong they were in math. In other words, simply by changing the way a test is introduced can change the outcome. Just as with parents, teachers who show an interest in their students tend to help those students perform better. Turner et al.[56] found that 6th-grade students who interacted with their teachers and were in classrooms where teachers were supportive showed less inclination to use avoidance strategies, such as not seeking help or not studying. Waples.[49] concurred that teachers who were approachable and built their students' self-esteem were more effective.

Variable cost and variable effort interventions

Because young women tend to lose interest in math (despite enrolling in math courses at the same rate and doing just as well on standardized math tests as young men), Amelink.[45] recommends introducing strong female math role models to women in math classes. The author also encourages schools to sponsor math conferences. Needless to say, sponsoring conferences can be expensive and involve a lot of extra work.

Although Wilson et al.[40] imply that some people can just be "untalented at math", the authors suggest "many problems become worse the more people worry about them. Further, the degree to which people worry about a problem depends on how they explain its causes". To counter these worries, the authors suggest schools can provide tutoring, target anxiety through relaxation training, or help students change their attributions. Having students watch a video of other students saying they improved over time helped anxious students, although with two caveats: It did not work with low-worrying African Americans and did not have lasting effects. Such positive results can be credited to attributional theory, which suggests that blaming an unstable cause (one that does not last over time) for their failures, students can improve their performance. However, in one experiment, Wilson et al.[40] found that only when the quality of instruction was good did such attributional interventions work.

Expensive and effort-intensive interventions

Cognitive treatments for anxiety can take several different forms, such as providing students with training on the best way to take tests or the best ways to stay on task. While some studies of treatments featuring reinforcing task-relevant cues, teaching relaxation techniques, or a combination of the two found no performance improvements.[57], other studies tend to suggest that some test anxiety interventions appeared to work. In six 45-minutes sessions devoted to desensitization and relaxation training, Ryan et al.[58] found that both were effective in reducing test anxiety. However, such treatments are time-intensive and require someone with a certain amount of skill to implement them. "Performing Beyond Fear," a test-anxiety reduction program developed in 2005-2006, was utilized by Lobman.[59] with one 4th-grade class. The author worked with the students one hour a week for ten weeks to destigmatize anxiety by stressing that fear can be a regular part of life. Besides creating a class voice to talk back to fears, Lobman.[59] also integrated anxiety-reduction techniques and taught test-taking skills, thereby mixing emotion and cognition. Meichenbaum.[60] used what the author called a modified desensitization procedure to help test-anxious college students. It employed

I. Coping imagery on how to handle anxiety.

II. Self-instructional training to attend to the task and not ruminate about oneself.

The eight weekly 60-minute sessions were more successful in reducing anxiety than was group desensitization, which used a similar group hierarchy construction and imagery training. But the author did not indicate whether either treatment helped improve outcomes. Salend.[48] stresses that teachers can help students improve the students' test grades before a test by helping them improve their study skills: Providing study guides which help students focus on specific goals, modeling the creation of outlines, and working with mnemonic devices are all ways to prepare students before a test. While the author generally sticks to cognitive tricks, Salend.[48] also acknowledges that targeted use of attribution-discussing the link between effort and success-may also play a role in test preparation. Teachers can also take the time to create exams that really do test what the teacher wants to students to know. By having the students involved in the test-creation process, teachers can try to ensure that they get the information they desire. In addition, Salend.[48] remind us that teachers at all levels need to provide appropriate testing space for all students, especially for those with special needs. Finally, teachers can, according to Salend.[48] think about collaborative tests as a way to reduce text anxiety. When it comes to taking the test, Salend.[48] suggests instructing students to do a memory dump (if allowed) as notes on the test or on scratch paper. Other strategies include such easy but often overlooked skills such as working on easier items first, and carefully reading and following directions. Kirkland & Hollandsworth.[61], used five 90-minute sessions to cover effective test taking strategies based on an over 70-year-old system developed by Robinson (1946): Preview the test for its length, see if certain sections count more, mark harder items and return to them, etc. These suggestions were reinforced by self-instructions for keeping on task and for reading questions carefully (similar to attentional self-control). Positive self-evaluations were also thrown into the mix. These cognitive strategies appeared to work better than cue-controlled relaxation (a deep muscle relaxation procedure) and meditation for calming the mind. Denny and Rupert (1977) successfully used desensitization to treat test anxiety. Their clients were trained how to recognize stress and then how to relax. Rather than terminating the stressful scenes when relaxation is disrupted, clients were told to "relax away the accompanying anxiety". According to the authors, these active coping strategies worked better than classical conditioning concepts. Smith & Nye.[37] used seven 45-minute sessions that involved deep-muscle relaxation and hierarchical fear triggers to reduce anxiety in simulated test environments and found that it improved the subjects' G.P.A. On the other hand, Laxer et al.[62] found that relaxation was more effective in reducing anxiety than systematic desensitization for highly test-anxious secondary school students. However, neither technique improved grades until they became college freshmen.

Rather than prescribing certain test anxiety interventions, Dundas, Wormnes and Hauge (2009) allowed their subjects to come up with their own, such as training themselves to attend to subtasks rather than the outcome or thinking of the task as work rather than as a test. Rather than simply working on relaxation procedures, the authors also focus on reducing negative self-focus because high levels of arousal don't necessarily negatively impact performance. Most important, according to the authors, is to keep the subjects' attention focused on a manageable task. Individual hour-long interviews with each subject make this a rather labor-intensive intervention. One 6-hour session of cognitive reevaluation was just as effective as six 1-hour sessions over three weeks to reduce test anxiety and improve performance, according to Crowley et al.,[63] They coaxed subjects from their least anxious to most anxious situations to replace "irrational, non-task-related thoughts and behaviors with coping/task-related thoughts and behaviors". Meta-analysis by O'Connor & Paunonen.[64] on the Big Five personality factors (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness) tend to confirm

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that effort is very important to academic performance such math. As Jordan PJ & Troth AC.[65] have pointed out, "cognitive ability reflects what an individual can do, personality traits reflect what an individual will do".[64] Although O'Connor & Paunonen.[64] suggest that narrow personality traits are better predictors of success, they conclude that personality predictors can account for variance in academic performance beyond measures of cognitive ability, conscientiousness being the most strongly and consistently associated with academic success based on a meta-analysis of the five factors. Furthermore, the narrow conscientiousness facets of achievement-striving and self-discipline, in particular, have been the strongest and most consistent predictors of academic performance". In a study of 30 narrow personality traits, Costa and McCrae (1992) discovered that impulsivity and anxiety were associated negatively with academic achievement, while in a study of 20 narrow personality traits Jackson (1984) reported a positive association between achievement-striving and GPA in an undergraduate psychology class and achievement-striving and dominance and success in an MBA program.[64] Even more concerning is the fact that some subjects seem to be able to turn test anxiety on and off at will. Jones and Berglas found their subjects used text anxiety as an excuse when they could. When they couldn't, they provided other excuses, such as effort, in order to "protect their conceptions of themselves as competent, intelligent persons".[66] According to Smith et al.,[66] test-anxious subjects reported more test anxiety half way through a test when they are told their scores can be influenced by anxiety than those who are told test anxiety has no bearing on scores. According to the authors, alcoholics, people with depression, and hypochondriacs all behave in the same way as those with text anxiety. While these last studies tend to indicate that motivation is the most important factor in performance, a significant number of researchers take the concepts of math anxiety and test anxiety seriously. They are also willing to provide methods to counter these anxieties.[67-80]

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Conflicts of Interest

None.

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