Understanding and Overcoming Math Anxiety in the US

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Abstract

This paper is a part of planning and implementing ODC so necessary to reduce math anxiety in the US. The importance of this study is to reduce math anxiety in US by minimizing the resistance of change in the individual level. Educational leaders, teachers, parents, and students should understand math anxiety; identify the causes; and find the procedures, the techniques, and the strategies to overcome math anxiety in US. The causes of math anxiety were separated into three main sources: Negative experiences, math anxiety from the teacher, and math anxiety from the parents. To overcome effectively math anxiety, several conventional and non-conventional procedures, techniques, and strategies were summarized.

Introduction

Background

For the past 20 years, studies such as TIMSS (the Trends in International Mathematics and Science Study) and PISA (the Program of International Student Assessment) have played a transformative role in how educational researchers think about K-12 math teaching and learning. Star (2016) reported that being able to examine students' academic performance comparatively across countries, as well as studying differences in math teaching practices, has been an eye-opener in many countries across the world and has led us to examine our own educational system with a fresh math perspective. Jackson and Kiersz (2016) reported that when looking at a comparable sample of countries that participated in the PISA exam in both 2012 (the last time the test was administered) and 2015, the US ranking fell to 35th from 28th in math achievements.

In fact, many Americans admit that there have been times that they've found themselves saying they cannot do math and have had difficulty figuring out the sale discount at a store or calculating the waiter's tip at a restaurant. For example, Harari, Vukovic, and Bailey (2013) reported that only 7% of Americans have had positive experiences with mathematics from kindergarten through college, and two-thirds of adults admit that they fear mathematics (Furner & Duffy, 2002). Richardson & Suinn (1972) defined Math anxiety as feelings of tension that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations. The literature review reported that mathematics anxiety has long been accepted as an impediment to mathematical development. For example, Moses and Cobb (2001) explained that individuals with higher levels of mathematics anxiety tend to avoid taking high school and college mathematics courses. However, the overwhelming

majority of Americans believe that the lack of emphasis on developing good math skills will have a negative impact on the future of our economy (Change the equation, 2017).

In this comprehensive literature review, the author outlines the current state of the field of math anxiety research, unpacks the impact that math anxiety has on American student's math achievement, provides the latest insights into what causes math anxiety, and what we can do to reduce math anxiety in the US. This comprehensive literature review will explore the literature review to find solutions for American students to change from a high math anxiety status to a math excitement status.

Purpose

The purpose of this comprehensive literature review was to identify, understand, analyze, and overcome math anxiety in the US. This comprehensive literature review explores the current literature review to answer questions such as: What is math anxiety? What are the causes of math anxiety? How can you overcome math anxiety?

Importance of Study

Many Americans admit that there has been times that they have found themselves saying they cannot do math and have had difficulty figuring out the sale discount at a store or calculating the waiter's tip at a restaurant. An online survey with a national sample of over 1,000 American adults concluded that although some Americans report positive feelings when they have to do math, such as feeling confident (36%), knowledgeable (34%), at ease (30%) and prepared (20%), one in five Americans report that they typically feel frustrated (21%) or anxious (18%) when they have to do math (Change the equation, 2017). In fact, math anxiety is a serious and pervasive problem in many forms and degrees, from "freezing up" during a math exam, to at-

tempting to avoid anything having to do with numbers. Math anxiety may be psychological or physiological characteristics and may include any of the following symptoms: Physical: Nausea, shortness-of-breath, sweating, heart palpitations, increased blood pressure. Psychological: Memory loss, paralysis of thought, loss of self-confidence, negative self-talk, math avoidance, isolation (thinking you are the only one who feels this way). The Organization Development and Change (ODC) should be implement in the US to makes a transition from its current state of high percent of American students who suffering from moderate and high levels to some desired future state of low levels of math anxiety. This paper is a part of planning and implementing ODC so necessary to reduce math anxiety in the US. The importance of this study is to reduce math anxiety in US by minimizing the resistance of change in the individual level. Educational leaders, teachers, parents, and students should understand math anxiety; identify the causes; and find the procedures, the techniques, and the strategies to overcome math anxiety.

Statement of the Problem

Math anxiety has been widely considered as one of the key reasons for students' weakness in mathematics. Burns (1998) reported that two-thirds of adults in the USA report a fear of mathematics. In fact, the United States is currently not producing enough graduates in science, technology, engineering, and math (STEM) fields to meet the demands of a technology-dependent society. The United States is currently facing what many have deemed a STEM crisis because it is not producing enough graduates to work in STEM fields. Although many efforts are in place to improve math education in the United States, efforts that focus solely on increasing math requirements are overlooking the very important role that the social and emotional factors play in math achievement. Beilock and Maloney (2015) explained that we tend to focus on addressing

affective factors, such as math anxiety, that are known to affect math learning, math performance, and an interest in pursuing STEM majors and careers.

All of the following research questions for this comprehensive literature review study were drawn to explore the literature review to find solutions for American students to change from a high math anxiety status to a math excitement status.

Sub-problem 1. Define math anxiety.

Sub-problem 2. Research the causes of math anxiety.

Sub-problem 3. Procedures, techniques, and strategies to overcome math anxiety and achieve math excitement.

To change from a math anxiety state to a math excitement state in the US, we need to define, understand the causes, and establish procedures/techniques/strategies to overcome math anxiety. This comprehensive literature review explores the current literature review to answer the following research questions: What is math anxiety? What are the causes of math anxiety? How can you overcome math anxiety to achieve math excitement?

Research Questions

All of the following research questions for this comprehensive literature review study were drawn to explore the literature review to find solutions for American students to change from a high math anxiety status to a math excitement status.

Research Question 1. What is math anxiety?

Research Question 2. What are the causes of math anxiety?

Research Question 3. How can we overcome math anxiety?

The next section introduces the literature review, which is related to the previous studies about understanding math anxiety, the causes of math anxiety, and the procedures, the techniques, and the strategies to overcome math anxiety.

Literature Review

Understanding Math Anxiety

To understand math anxiety it is fundamental to know the dimensions of math anxiety and the correlations that math anxiety has with parenting, performance, gender, and demographics.

The Dimensions of Math Anxiety. Mathematics anxiety in young children is unidimensional and mathematics anxiety in older children and adults is multidimensional. For example, Krinzinger, Kaufmann, and Willmes (2009) published a study conducted with young children by creating a scale that tapped worry and general mathematics-related attitudes to express mathematics anxiety. The authors did not find the dimension to be predictive of children's arithmetic skill from first through third grade meaning that worry and general mathematics-related attitudes does not affect young children's mathematics performance, or that their measure did not adequately capture mathematics anxiety. Krinzinger and colleagues hypothesized that their null findings reflected a methodological limitation in their measure. Specifically, the authors concluded that the questions they asked children were too indirect (e.g., "How happy or unhappy are you if you have problems with mathematics?" "How good are you at mathematics?"), and that the response that required children to infer emotional reactions from pictorial representations were too difficult for children. Beasley, Long, and Natali (2001) explained that young children might not have the cognitive capacity to distinguish between different types of mathematics anxiety. On the other hand, Harari, Vukovic, and Bailey (2013);

Ho et al. (2000); Wigfield and Meece (1988); Hopko, Mahadevan, Bare, and Hunt (2003); and Suinn et al. (1988) indicated that mathematics anxiety in older children and adults is multidimensional, with the most commonly assessed dimensions including numerical anxiety, test anxiety, worry, and negative reactions. Numerical anxiety is the anxiety involved in using mathematics in ordinary life and academic situations. Mathematics test anxiety is the anxiety related to testing and evaluation in mathematics. Worry is the anxiety related to negative cognitions and concerns about mathematics. The negative reaction is the anxiety related to feelings of tension and unpleasant physiological reactions to mathematics. More recently studies explained that mathematics anxiety is likely influenced by a complex interplay among other dimensions. Roos et al. (2015) included two important dimensions: performance and assessment of anxiety. The performance refers to high and low achieving, and the assessment of anxiety refers to trait (habitual anxiety) and state (momentary anxiety). The authors examined mathematics anxiety in over 237 students from grades 9 and 10, and they found that trait anxiety measures are typically rated higher than state measures. This study also reported that the academic self-concept has been identified to playing a moderating role in the trait-state dimension. Therefore, the authors assumed that high achievers who were expected to have high academic self-concepts would exhibit a smaller trait-state discrepancy than low achievers. Results confirmed these assumptions and revealed that high achievers even underestimated their trait anxiety. Also, Ashcraft, Krause, and Hopko (2007) included other dimensions such as: biological predisposition toward anxiety, prior negative experiences with mathematics, maladaptive cognitive schemata, and distal and proximal experiences. At this time, no study of mathematics anxiety is designed to assess all of these dimensions simultaneously.

Math Anxiety by Demographics. The nature of mathematics anxiety in students is the relation between mathematics anxiety and demographic characteristics including gender, age, language, and ethnicity (Ho et al. (2000); Meece, Wigfield, and Eccles (1990); Hyde, Fennema, Ryan, Frost, and Hopp (1990); Else-Quest, Hyde, and Linn (2010); and Wigfield and Mecce 1988).

There are sex differences on mathematics anxiety. Hyde, Fennema, Ryan, Frost, and Hopp (1990) concluded that female students report higher levels of mathematics anxiety than do male students, as documented in meta-analyses of studies with secondary-school students from around the globe. For example, meta-analyses conducted by Hembree (1990) and Ma (1999) indicated that meaningful sex differences on mathematics anxiety do not emerge until adulthood. In addition, Ho et al. (2000); Meece, Wigfield, and Eccles (1990); Hyde, Fennema, Ryan, Frost, and Hopp (1990); Else-Quest, Hyde, and Linn (2010); and Wigfield and Mecce (1988) reported few sex differences on levels of mathematics anxiety among the elementary, middle and high school students. However, Blascovich, Spencer, Quinn, and Steele (2001) explained that stereotypes about female inferiority in mathematics can impair math test performance and cause anxiety via stereotype threat. Meece, Wigfield, and Eccles (1990) shown that math anxiety negatively predicts career choices, course enrollment, and lifelong learning in mathematics related fields including science, technology, engineering, and mathematics (Meece, Wigfield, & Eccles, 1990). However, Else-Quest et al. (2010) reported that studies on mathematics anxiety is almost exclusively based on self-reports of trait like (habitual) anxiety, as opposed to state (momentary) anxiety assessed during real-life experiences.

Similarly, there are not statistically significant differences on mathematics anxiety between white and non-white (Ma, 1999). The author did not find differences in mathematics anxiety between white and minority samples. In addition, Suinn, Taylor, and Edwards (1989) identified that Hispanic did not differ from White students on levels of mathematics anxiety from fourth to sixth grades.

Similarly, there are statistically significant differences on mathematics anxiety between native English speakers and those who speak a primary language other than English at home, which are known as language minority learners (August & Shanahan, 2006). In a recent meta-analysis, Kieffer, Lesaux, Francis, and Rivera (2009) found that language minority learners demonstrate substantially lower mathematics achievement than their native English-speaking peers. However, Harari, Vukovic, and Bailey (2013) demonstrated that language minority learners and native English speakers do not differ in their levels of mathematics anxiety, at least in first grade.

There are statistically significant differences on mathematics anxiety among low-medium-and-high-income backgrounds. August and Shanahan (2006) reported that low-income background learners demonstrate lower math anxiety than their medium-and-high-income background peers.

Finally, math anxiety is not limited to a minority of individuals nor to one country. Beilock and Willingham (2014) reported that international comparisons of high school students show that some students in every country are anxious about math. However, countries where kids are less proficient in math (as measured by the Program for International Student Assessment, or PISA) tend to have higher levels of math anxiety. Additionally, the authors

reported that the most students had at least one negative experience with math at some point during their education. Beilock and Willingham (2014) reported that in the United States, an estimated 25 percent of four-year college students and up to 80 percent of community college students suffer from a moderate to high degree of math anxiety.

Math Anxiety and Performance. The negative correlation of math anxiety on students' achievement in mathematics has interested researchers for several years. First studies in the beginning of 1970s have documented that math anxiety has a negative relationship with mathematics performance and achievement (Richardson and Suinn, 1972; Suinn, Edie, Nicoletti, and Spinelli, 1972). After virtually two decades, Hembree (1990) reported the results of 151 studies were integrated by meta-analysis to conclude that mathematics anxiety is related to poor performance on mathematics achievement tests. The author concluded that mathematics anxiety relates inversely to positive attitudes toward mathematics and directly to avoidance of the subject. In the past, studies have reported a consistent but small negative relationship between math anxiety and performance, with correlations generally ranging from - 0.11 to - 0.36, indicating that students with higher levels of math anxiety tend to have lower levels of mathematics performance (Morris, Davis, and Hutchings, 1981; Cooper and Robinson, 1989; Engelhard, 1990; Eccles and Jacobs, 1986; Green, 1990; Wigfield and Meece, 1988; and Tocci and Engelhard, 1991). In another example, Ma & Zu (2004) found that prior poor mathematics achievement was related to high mathematics anxiety across all junior and senior high school grade levels for males. The authors concluded that females experienced this relationship during junior high and senior high transition periods.

Although most studies tend to report the correlation between overall mathematics anxiety and mathematical performance, even though mathematics anxiety is most often found to be a multidimensional construct. Harari, Vukovic, and Bailey (2013) suggested that although mathematics anxiety might be multidimensional, not all dimensions affect student's mathematical performance. It is necessary a deeper understanding of the relation between dimensions of mathematics anxiety and mathematical performance to provide theoretical insight into and practical guidance about the nature, identification, and treatment of mathematics anxiety. Wigfield, and Meece (1988) assessed math anxiety from 6th to 12th grade children (N = 564) for a comprehensive longitudinal investigation of children's attitudes, beliefs, and values concerning mathematics. Confirmatory factor analyses in this study concluded that the affective component of math anxiety related more strongly and negatively than did the worry component to children's ability perceptions, performance perceptions, and math performance. On the other hand, the worry component related more strongly and positively than did the affective component to the importance that children attach to math and their reported actual effort in math. Wigfield, and Meece (1988) concluded that girls reported stronger negative affective reactions to math than did boys, and ninth-grade students reported experiencing the most worry about math and sixth graders the least.

In a meta-analysis of 26 studies, Ma (1999) concluded that high achievers tend to be less anxious about mathematics than their low achieving peers. In particular, math anxiety and math achievement can be better investigated using trait (habitual math anxiety) or state (momentarily experienced math anxiety) assessment methods. Goetz and Hall (2013) demonstrated that academic self-concept plays an important role in the discrepancy between trait and state

mathematics anxiety. For example, Roos, Bieg, Goetz, Frenzel, Taxer, and Zeidner (2015) concluded that high achievers exhibited a smaller trait-state discrepancy than low achievers because of their higher academic self-concepts. However, the underestimation of trait anxiety could impact high achievers in several ways. Pekrun, Goetz, Titz, and Perry (2002) concluded that underestimation of trait anxiety was advantageous among high achievers because high levels of trait anxiety is negatively related to well being, motivation, and learning behavior. On the other hand, Johnson and Fowler (2011) concluded that when high achievers believe they are less anxious than they actually are it may lead them to overestimate their abilities, which could in turn negatively impact students' academic performance. In another similar study, Roos et al. (2015) examined mathematics anxiety among high and low achieving students (N = 237, grades 9 and 10) by contrasting trait (habitual) and state (momentary) assessments of anxiety. In summary, their results were in line with previous studies, and they found that high achievers exhibited a smaller trait-state discrepancy than low achievers because of their higher academic self-concepts. Since state measures are believed to reflect actual anxiety, this study shows that math anxiety is an important math-learning factor to be considered even among high achieving students.

The relationship between math anxiety and achievement can vary across nations. For example, Engelhard (1990) conducted using nationally representative samples of 13-year-old children in the United States (N = 4,091) and Thailand (N = 3,613) collected as a part of the Second International Mathematics Study (Garden, 1987). The author concluded that the relationship between math anxiety and mathematics performance is significant in both countries (in United States r = - 0.24 and in Thailand r = - 0.14) after controlling for previous achievement,

mother's education, and gender. Kai Kow Joseph, Y. (2004) investigated the level of mathematics anxiety among 116 high math ability students in Singapore. Singapore is the top performing country at Secondary 2 (13 to 14 year olds) for the TIMSS and TIMSS-R studies; little research is available on mathematics anxiety by Singapore's Secondary 2 students. Singapore is well known to have a better attitude towards mathematics where students need to enjoy doing mathematics, to show confidence in using mathematics and to appreciate the beauty and power of mathematics. The results suggest that Mathematics anxiety did exist among this group of 116 high ability students in two secondary schools. The results also showed that 57 girls in this study exhibited a higher level of Mathematics Anxiety than the 59 boys. In addition, Stuart (2000) observed that some students were academically very capable, yet still struggled with mathematics. He also observed that some high math ability students from Singapore perform very well during mathematics lessons and assignment yet fail to perform well during examinations or tests. Stuart (2000) explained that most of these high math ability students who failed in examinations or tests, just panic. Therefore, it is significant to identify high ability students who experience mathematics anxiety. This study on Singaporean students can contribute significantly towards the professional development of classroom mathematics teachers in US.

The causes of math anxiety

Math anxiety is usually linked to a negative math experience from a person's past, a punishment by a parent or teacher for failing to master a mathematical concept, or an embarrassment in front of a sibling or group of peers when failing to correctly complete a math problem (Ashcraft and Moore, 2009; Bekdemir, 2007; Bekdemir 2010; Brady and Bowd, 2005; Curtain-Phillips, 2017; Gierl and Bisanz, 1995; Harper and Daane, 1998; Hembree, 1990;

Maloney et all, 2015; Patall, Cooper and Robinson, 2008). To a parent, this could have been the smallest or silliest mistake, but it very well could have left an impression on the student if made to feel ashamed or embarrassed. Since the outcome of math exams usually affects a student's overall math grade, the negative results of math anxiety reinforce their feeling of inadequacy, thus creating a cycle of failure and anxiety.

The causes of math anxiety can be separated into three categories: environmental, intellectual, and personality factors. Hadfield and McNeil (1994) summarized these three categories of the mathematics anxiety causes. Environmental factors are important sources of math anxiety including parental pressure, negative experiences in the classroom, insensitive teachers, and non-supportive class environment. The Intellectual factors are directly related with the student's cognitive abilities and skills including low persistence, self-doubt, and lack of confidence in mathematical ability, and negative attitude. The personality factors are directly related with the combination of the student's characteristics or qualities including gender bias, reluctance to ask questions due to shyness, and lack of self-respect.

The causes of math anxiety can be also separated the mathematics anxiety causes into three main sources: Negative experiences, math anxiety from the teacher, and math anxiety from parents.

Negative Experiences (The Cycle of Failure). Math anxiety is usually linked to a negative math experience from a person's past (Ashcraft and Moore, 2009; Bekdemir, 2007; Bekdemir 2010; Brady and Bowd, 2005; Curtain-Phillips, 2017; Gierl and Bisanz, 1995; Harper and Daane, 1998; Hembree, 1990; Maloney et all, 2015; Patall, Cooper and Robinson, 2008).

Bursal and Paznokas (2006); Harper and Daane (1998); and Jackson and Leffingwell, (1999) reported that people who have mathematics anxiety stated that the anxiety started after a negative experience in one of the education levels. Miller and Mitchell (1994) and Jackson and Leffingwell (1999) that people who have mathematics anxiety after a negative experience still remember these negative experiences after many years. Bekdemir (2010) explained that negative math experience generally came from being punished by a parent or teacher, failing a math exam, or being embarrassed in front of a sibling or group of peers when mastering a math concept. In addition, mathematics anxiety can produce destructive results due to the cutback in learning effort, the limited persistence, the low independence, and the math avoidance (Hembree, 1990; Gresham, 2007). Consequently, mathematics anxiety is prevalent among students and negatively affects their motivation and success (Ashcraft and Faust, 1994; Bekdemir, 2007; Erol, 1989; Ma, 1999; Perry, 2004; Trujillo and Hadfield, 1999; Zakaria and Nordin, 2008). Curtain-Phillips (2017) reported that millions of adults are blocked from professional and personal opportunities because of negative experiences in mathematics during secondary school, and their fear or poorly perform can remain throughout their adult lives.

Negative math experiences may lead to a vicious cycle in which fear of math interferes with learning math that leads to more negative math experiences. Preis and Biggs (2001) concluded that negative math experiences may lead to a vicious cycle in which fear of math interferes with learning math which leads to more negative math experiences. This Math Anxiety Cycle of Failure may lead students to delay or stop taking math courses that often limits their educational opportunities. Pries and Biggs (2001) have described a cycle of math avoidance as having the following four phases:

- Phase 1: The math-anxious person experiences negative reactions to math situations.
- Phase 2: The person avoids math situations.
- Phase 3: Poor mathematics preparation.
- Phase 4: Poor math performance.

Poor math performance generates more negative experiences with math and brings students back to phase one. This cycle can be repeated so often that the math-anxious person becomes convinced they cannot do math and the cycle is rarely broken.

Math Anxiety from the Teacher. Math anxiety is also linked to negative math experiences from their teachers in the past. Andrew (2004) and Frank (1990) reported that people who suffer from math anxiety establish a relationship between negative math experiences and their teachers in the past. In particular, some researchers support these ideas by stating that mathematics anxiety is created by primary school teachers (Frank, 1990; Hembree, 1990; Hadfield and McNeil, 1994; Harper and Daane, 1998; Perry, 2004). Perry (2004) explained that teachers cause mathematics anxiety through hostile behaviors, difficulty of contents, gender bias, unrealistic teacher expectation, insensitive and careless teacher attitude, communication and language barriers and quality of education. Harper and Daane (1998) explained that teachers cause mathematics anxiety when they impose activities, examinations, and problems that are unrealistic or not relevant to daily life. Bush (1989), Trujillo and Hadfield (1999), and Wood (1988) explained that teachers with mathematics anxiety tend to transfer their anxiety to their students by using more traditional teaching methods such as devoting more time to seatwork and whole-class instruction, teaching rote memorization of algorithms, and neglecting to consider their students' learning styles. In addition, Greenwood (1984) considered the causes of

mathematics anxiety is related with teaching methods that do not support creative thinking and deep understanding. For example, Richardson and Woolfolk (1980) discussed how certain features of math, such as its precision, logic, and emphasis on problem solving, make it particularly anxiety provoking for some individuals.

Some researchers state that most of the primary school mathematics teachers and pre-service teachers, who are the teachers of the future, have mathematics anxiety themselves (Frank, 1990; Harper and Daane, 1998; Hembree, 1990; Perry, 2004; Beilock, Gunderson, Ramirez, and Levine, 2010; and Geist, 2010). Bekdemir (2010), Brady and Bowd (2005 and Harper and Daane (1998) explained that some teacher trainees are mathematically anxious, and they have a very good chance of becoming teachers who lack confidence in their own mathematical ability, have a negative attitude towards mathematics itself, and hence teach in ways of developing mathematics anxiety in their own students. National Council of Teachers of Mathematics (1989) supported cooperative learning and projects to minimize teacher math anxiety.

Math Anxiety from the Parents. Cannon and Ginsburg (2008) studied children in first and second grade exploring how parents' anxiety about math relates to their children's math achievement. The authors reported that parents of young children widely believe that math education is primarily the function of schooling and that their role in their children's math achievement is not as important as their role in other subjects, such as reading. Eccles (2007) explained that although the classroom is usually viewed as the primary source for learning, parents also play an important role in students' academic success. Math anxiety and parenting focused on early elementary school because children as early as first-grade experience math anxiety, which is negatively related to their math achievement (Ramirez, Gunderson, Levine, and

Beilock, 2013), and those students who start behind their peers in math skills tend to stay behind throughout schooling (Committee on Early Childhood Mathematics, 2009). Indeed, children may turn to their parents for math help, teachers may ask parents to work with their children on homework, or both. Consequently, parents in some way are their children's first and most sustained teachers. Robinson (2014) reported that a positive relationship holds more for verbal subject matter than for mathematics. For example, Patall, Cooper, and Robinson (2008) explained that parents' help on math homework is sometimes negatively linked with students' math achievement and math anxiety. This is a somewhat counterintuitive idea given that parent involvement in homework is generally believed to have positive effects on children's academic achievement. However, this positive relation holds more for verbal subject matter than for mathematics (Robinson, 2014). Beilock, Gunderson, Ramirez, and Levine (2010) considered the possibility that it is specifically parents with high math anxiety whose homework help is negatively related to their children's math achievement. The authors explained that parents rigidly use instructional strategies or may have inadequate math-helping skills that conflict with those that teachers use in the classroom, which could confuse children and negatively affect their achievement or increase their math anxiety. Furthermore, frequent involvement of parents with high math anxiety in their children's math homework could also create opportunities to communicate their fears about math to their children (Maloney, Ramirez, Gunderson, Levine and Beilock, 2015).

Procedures, Techniques, And Strategies To Overcome Math Anxiety.

There are several procedures, techniques, and strategies to reduce math anxiety. The previous section revealed that mathematics anxiety is substantially caused by the teacher's behavior and

teaching approach and persistent in numerous pre-service teachers. Beilock and Willingham (2014) reported that to reduce math anxiety the education system should focus on teacher training. Bekdemir (2010) explained that to decrease or limit mathematics anxiety, teacher candidates should exclusively know their own level of anxiety. The teachers with high anxiety should find ways to deal with it or at least decrease their anxiety level to prevent the effects of anxiety on their classroom behavior and teaching methods in the future. Further research is suggested to find ways for the candidates to cope with their anxiety. Bekdemir (2010) explained that teachers should know that the worst experiences and most troublesome mathematics classroom experiences are the main causes of mathematics anxiety. Then, teacher should eliminate the origins of mathematics anxiety at each grade so that anxiety level decreases and eventually disappears. The authors also suggested that teachers at least should be calm and understanding when students ask for help avoiding creating occasions that can build negative experiences. Also, teachers should encourage and reward their students, know and use effective teaching methods, offer and guide their students to use alternative problem-solving techniques and improve themselves personally and professionally. In addition, the National Council of Teachers of Mathematics (2000) suggested that professors who teach college courses for pre-service teachers should themselves incorporate the strategies to reduce mathematics anxiety including:

- Remove the importance of ego from classroom practice,
- Make mathematics relevant,
- Allow for different social approaches to learning mathematics,

- Emphasize the importance of original, quality thinking rather than rote manipulation of formulas,
- Characterize mathematics as a human endeavor,
- Let student share some input into their own evaluations,
- Design positive experiences in mathematics classes,
- Accommodate for different learning styles,
- Emphasize that everyone makes mistakes in mathematics.

There are many studies using conventional teaching that can effectively overcome math anxiety (Beilock and Willingham, 2014; Chapman, 2010; Supekar, Iuculano, Lang, and Menon, 2015; Willingham, 2014; and Springer et al. (1999). Chapman (2010) summarized the following strategies to reverse math anxiety:

- Breaking the Math Anxiety Cycle of Failure by starting with material accessible to the entire group,
- Switching from a large class size to small-group teaching,
- Fostering a learning environment where the students can support each other.

Learning in small groups improves attitudes towards learning and academic achievement in math (Springer et al., 1999). Savage and Roper (2003) concluded that learning environment with larger class sizes reduces student feedback increasing math anxiety.

Another conventional teaching that can effectively overcome math anxiety is an intensive cognitive tutoring program. Supekar, Iuculano, Lang, and Menon (2015) concluded that an intensive 8-week one-to-one cognitive tutoring program designed to improve mathematical skills reduces childhood math anxiety. In their study, forty-six children in grade 3 with high level of

math anxiety participated in the cognitive tutoring program. High math-anxiety children showed a significant reduction in math anxiety after tutoring.

In addition to the previous conventional techniques to overcome math anxiety, Beilock and Willingham (2014) explained that teachers should ensure fundamental math skills and think carefully about what to say when students struggle in solving math problems. To ensure fundamental skills, the authors suggested to enhance basic numerical and spatial processing could help guard against the development of math anxiety in young students. For example, encouraging parents to engage with young children around math can help ensure that children come to school with basic mathematical competencies. To know what to say when students struggle in solving math problems, the authors explained that it's natural that teachers and parents want to console anxious students by saying for example, ”It's OK”. However, consolation sends a subtle message that validates the student's opinion that he's not good at math, and can lower a student's motivations and expectations for future performances. A better message is to say, "Yes, this work is challenging, but I know that with hard work you can do it!" In addition, giving concrete strategies for changing up study habits or for approaching a particular problem differently in the future helps him understand that, with added hard work and effort; he has the potential for success.

On the other hand, there are non-conventional teaching that can effectively overcome math anxiety. For example, Wood (1988) explained that the most successful programs were those which change the way mathematics was perceived and learned and through changes the usual-instructional strategies. Seymour (1996) and Tobias (1998) concluded that an effective mathematics instruction would prevent the development of or reduce mathematics anxiety. For

example, Wood (1988) concluded that to reduce math anxiety the material should be introduced slowly, and the instructor should assume no prior mathematical knowledge, and students were encouraged to discuss their own thought processes in learning. According to qualitative interviews with teachers across the United States, Tobias (1998) and Vinson (2001) suggested that the most effective mathematics instruction to reduce math anxiety is the technique called ‘‘learning in action’’. The authors explained that this technique is based on math activities related with simulations, discoveries, challenges, problem solving activities, and games involving real-world situations and explorations.

Relaxing study environment can effectively overcome math anxiety. Feng, Suri, and Bell (2014) explained that math-anxious consumers tend to avoid alternatives that require price computations. They concluded these consumers find relief from math anxiety when slow classical music plays in the background. In fact, a considerable amount of research suggests that listening to music may improve cognitive skills. For example, Brain Balance (2017) explained that listening to music activates a certain portion of the brain to relax anxiety.

Pet stimuli can reduce math anxiety. For example, Torres, Arnold, and Shutt (2016) reported that visual pet stimuli have been shown to both reduce stress and improve performance during mathematical tasks, and thus may be used to alleviate math anxiety. Their study tested the effects of visual pet stimuli by presenting math problems in sets with either images of pets, images of desks, or color blocks displayed vertically along the left hand side of the page. Torres, Arnold, and Shutt (2016) concluded that participants reported the lowest levels of stress for the math problems presented with the pet images which confirmed their hypothesis that the presence of a comforting stimulus as visual pet stimuli could be an aid to help students relieve math anxiety.

Expressive Writing Intervention (EWI) can reduce math anxiety. Hines, Brown, and Myran (2016) explained that the Basic Writing Paradigm (Pennebaker, 1997) was used and each class was assigned to either an experimental group or a control group. Each group was tasked with writing for 15 to 30 minutes over three consecutive days about an assigned topic. The experimental group wrote about their feelings about school, mathematics, and the state tests. The control group wrote about favorite time of year, plans after high schools, and perceptions of teachers. Groups were compared from 1 to 3 days after the last EWI. Pre and post-tests were administered, and the results shown that the EWI reduced both general and mathematics anxiety for the experimental group, and the control group showed decreased mathematics anxiety.

The next section, the conclusions about math anxiety, the causes of math anxiety, and the procedures, the techniques, and the strategies to overcome math anxiety. In the end of the next section the author shows his contributions to overcome math anxiety.

Conclusions

An exhaustive research over the current literature review about math anxiety was done. The following three research questions were answered: What is math anxiety? What are the causes of math anxiety? How to overcome math anxiety?

Question 1. What Is Math Anxiety?

There are numerous descriptions of mathematics anxiety involving psychological and physiological characteristics. The psychological characteristics of math anxiety include: the feelings of tension and anxiety, the panic, the helplessness, the paralysis and the mental disorganization, the memory loss, the loss of self-confidence, the negative self-talk, the math avoidance, and the isolation (thinking you are the only one who feels this way) that arises among some people

when they are required to solve a mathematical problem. The psychological characteristics of math anxiety include: Nausea, shortness-of-breath, sweating, heart palpitations, increased blood pressure. In short, math anxiety has been widely considered as one of the key reasons for students weakness in mathematics, and the literature review shown that two-thirds of adults in the USA report a fear of mathematics. The United States is currently facing what many have deemed a STEM crisis because it is not producing enough graduates to work in STEM fields. Many past studies have looked at sex differences on mathematics anxiety. Female students report higher levels of mathematics anxiety than do male students. Stereotypes about female inferiority in mathematics can impair math test performance and cause anxiety via stereotype threat. Ma (1999) concluded that there are not statistically significant differences on mathematics anxiety between white and non-white. August and Shanahan, T. (2006) concluded that there are statistically significant differences on mathematics anxiety between native English speakers and language minority learners. However, a few studies demonstrated that language minority learners and native English speakers do not differ in their levels of mathematics anxiety, at least in first grade. There are statistically significant differences on mathematics anxiety among low-medium-and-high-income backgrounds where low-income background learners demonstrate lower math anxiety than their medium-and-high-income background peers. Finally, math anxiety is not limited to a minority of individuals nor to one country. Several studies concluded that some high school students in every country are anxious about math. However, countries where kids are less proficient in math (as measured by the Program for International Student Assessment, or PISA) they tend to have higher levels of math anxiety. Also, the current literature reported that in the

United States, an estimated 25 percent of four-year college students and up to 80 percent of community college students suffers from a moderate to high degree of math anxiety.

First studies in the beginning of 1970s have documented that math anxiety has a negative relationship with mathematics performance and achievement. After two decades, the results of 151 studies were integrated by meta-analysis to conclude that mathematics anxiety is related to poor performance on mathematics achievement tests, indicating that students with higher levels of math anxiety tend to have lower levels of mathematics performance. Also, mathematics anxiety relates inversely to positive attitudes toward mathematics and directly to avoidance of the subject. In a meta-analysis from 26 studies concluded that high achievers tend to be less anxious about mathematics than their low achieving peers. Their results found that high achievers exhibited a smaller trait-state discrepancy than low achievers because of their higher academic self-concepts. Since state measures are believed to reflect actual anxiety, this study shows that math anxiety is an important math-learning factor to be considered even among high achieving students. However, the underestimation of trait anxiety could impact high achievers in several ways. Underestimation of trait anxiety was advantageous among high achievers because high levels of trait anxiety is negatively related to well being, motivation, and learning behavior. Underestimation of trait anxiety was disadvantageous among high achievers because high achievers believe they are less anxious than they actually are may lead them to overestimate their abilities, which could in turn negatively impact students' academic performance.

Question 2. What Are The Causes Of Math Anxiety?

Several studies are focused on the causes of mathematics anxiety. Math anxiety is usually linked to a negative math experience from a person's past, a punishment by a parent or teacher

for failing to master a mathematical concept, or an embarrassment in front of a sibling or group of peers when failing to correctly complete a math problem.

The causes of math anxiety can be separated the mathematics anxiety causes into three categories: environmental, intellectual, and personality factors. Environmental factors include parental pressure, negative experiences in the classroom, insensitive teachers, and non-supportive class environment. The Intellectual factors include low persistence, self-doubt, lack of confidence in mathematical ability, and negative attitude. The personality factors include gender bias, reluctance to ask questions due to shyness, and lack of self-respect.

The causes of math anxiety can be also separated the mathematics anxiety causes into three main sources: Negative experiences, math anxiety from the teacher, and math anxiety from the parents. Negative math experience generally came from being punished by a parent or teacher, failing to a math exam, or being embarrassed in front of a sibling or group of peers when mastering a math concept. Several studies concluded that mathematics anxiety could produce destructive results due to the cutback in learning effort, the limited persistence, the low independence, and the math avoidance. Consequently, mathematics anxiety is prevalent among students and negatively affects their motivation and success. The negative math experiences may lead to a vicious cycle in which fear of math interferes with learning math that leads to more negative math experiences. This Math Anxiety Cycle of Failure may lead students to delay or stop taking math courses that often limits their educational opportunities. The current literature reported that millions of adults are blocked from professional and personal opportunities because

of negative experiences in mathematics during secondary school, and their fear of poorly performing can remain throughout their adult lives.

Several studies have shown that teachers cause mathematics anxiety through hostile behaviors, difficulty of contents, gender bias, unrealistic teacher expectation, insensitive and careless teacher attitude, communication and language barriers and quality of education, imposed activities, examinations, and problems which are unreal or not relevant to daily life. Also, several studies concluded that the causes of mathematics anxiety is related with teaching methods that do not support creative thinking and deep understanding. Some researchers state that most of the primary school mathematics teachers and pre-service teachers, who are the teachers of the future, have mathematics anxiety themselves. Consequently, some teacher trainees are mathematically anxious, and they have a very good chance of becoming teachers who lack confidence in their own mathematical ability, have a negative attitude towards mathematics itself, and hence teach in ways of developing mathematics anxiety in their own students.

Many studies of children in first and second grade explored how parents' anxiety about math relates to their children's math achievement. The literature review reported that although the classroom is usually viewed as the primary source for learning, parents also play an important role in students' academic success. Math anxiety and parenting may happen on early elementary school because children may turn to their parents for math help, teachers may ask parents to work with their children on homework, or both. Consequently, parents in some way are their children's first and most sustained teachers. However, parents' help on math homework is sometimes negatively linked with students' math achievement and math anxiety. A few studies concluded parents rigidly use instructional strategies or may have inadequate math-helping skills

that conflict with those that teachers use in the classroom, which could confuse children and negatively affect their achievement or increase their math anxiety. Furthermore, frequent involvement of parents with high math anxiety in their children's math homework could also create opportunities to communicate their fears about math to their children.

Question 3. How To Overcome Math Anxiety?

There are several strategies to overcome math anxiety. Several studies concluded that to reduce math anxiety the education system should focus on teacher training, and teacher candidates should exclusively know their own level of anxiety. The teachers with high anxiety should find ways to deal with it or at least decrease their anxiety level to prevent the effects of anxiety on their classroom behavior and teaching methods in the future. Further research is suggested some ways for the candidates to cope with their anxiety. Teachers should know that the worst experiences and most troublesome mathematics classroom experiences are the main causes of mathematics anxiety. Then, teacher should eliminate the origins of mathematics anxiety at each grade so that anxiety level decreases and eventually disappears. The research suggested that teachers at least should be calm and understanding when students ask for help and encourage and reward their students, know and use effective teaching methods, offer and guide their students to use alternative problem-solving techniques and improve themselves personally and professionally. The current literature suggested that professors who teach college courses for pre-service teachers should themselves incorporate the strategies to reduce mathematics anxiety including: Remove the importance of ego from classroom practice; make mathematics relevant, allow for different social approaches to learning mathematics; emphasize the importance of original quality thinking rather than rote manipulation of formulas; characterize mathematics as a

human endeavor; let student share some input into their own evaluations; design positive experiences in mathematics classes; accommodate for different learning styles; and emphasize that everyone makes mistakes in mathematics.

There are many studies using conventional teaching that can effectively overcome math anxiety. The literature review summarized the following strategies to reverse math anxiety: Breaking the Math Anxiety Cycle of Failure by starting with material accessible to the entire group; switching from a large class size to small-group teaching; and fostering a learning environment where the students can support each other.

Another conventional teaching that can effectively overcome math anxiety is an intensive cognitive tutoring program (2015) concluded that an intensive 8 week one-to-one cognitive tutoring program designed to improve mathematical skills reduces childhood math anxiety. In theSupekar, Iuculano, Lang, and Menon's study concluded that high math-anxious children showed a significant reduction in math anxiety after tutoring.

In addition, the current literature concluded that teachers should ensure fundamental math skills and think carefully about what to say when students struggle in solving math problems. In fact, teachers and parents want to console anxious students by saying for example, ”It's OK”. However, consolation sends a subtle message that validates the student's opinion that he's not good at math, and can lower a student's motivations and expectations for future performances. A better message is to say "Yes, this work is challenging, but I know that with hard work you can do it!".

On the other hand, there are also several studies using no-conventional teaching that can effectively overcome math anxiety including: The material should be introduced slowly, the

instructor should assume no prior mathematical knowledge, the students should be encouraged to discuss their own thought processes in learning. The current literature suggested that the most effective mathematics instruction to reduce math anxiety is the technique called ‘‘learning in action’’ based on math activities related with simulations, discoveries, challenges, problem solving activities, and games involving real-world situations and explorations. Another no-conventional procedures that can effectively overcome math anxiety including: providing a relaxing study environment by playing classical music in the background, using visual pet stimuli, and adopting Expressive Writing Intervention.

The last section, the author shows his contributions to overcome math anxiety.

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