Effective teaching practices to reduce math anxiety and increase student performance in mathematics

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Abstract

The level of math anxiety present in high school Math 1 students was identified using a modified version of the MARS (Mathematics Anxiety Rating Scale). Students' performance on mathematical tasks were assessed after math anxiety levels were determined. A negative correlation was found existing between math anxiety and performance on mathematical tasks. Teacher led interventions were designed and implemented with Math 1 students over the course of the study. The teacher led interventions were described to the students and they choose the three most effective in reducing their math anxiety. Math anxiety levels and performance on mathematical task scores were re-calculated. Data showed that teacher led interventions decreased overall math anxiety amongst Math 1 students but did not increase performance on mathematical tasks.

Keywords: Math, anxiety, math anxiety, MARS, teacher intervention

Effective teaching practices to reduce math anxiety and increase student performance in mathematics.

Research leading to our current understanding of "math anxiety" began in 1957 when Dreger and Aiken introduced the concept of "number anxiety" (1957, p. 344). In 1972, Richardson defined Mathematics anxiety to be "A feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in ordinary life and academic situations" (p. 551). Hembree (1990) described how math anxiety threatened a student's performance and achievement in mathematics, leading to math avoidance, and preventing otherwise capable students from pursuing activities that require mathematics. As students progress towards secondary level math classes, the anxiety they face when it comes to performing mathematical tasks can be debilitating, preventing them from demonstrating critical thinking. Upon graduation students in the United States are leaving high school with substandard levels of mathematical understanding and literacy (Steen, 1999). As performance in math courses declines students begin to lose interest in pursuing careers that are even tangentially related to mathematics. Math anxiety prevents these students from pursuing STEM related college pathways, resulting in decreased diversity in STEM fields (Hembree, 1990).

STATEMENT OF THE PROBLEM

Math anxiety, which affects a considerable proportion of society, prevents achievement in mathematics, warranting serious consideration and intervention (Ashcraft, 2009). Math anxiety has been shown to affect populations all over the world and is present in diverse populations spanning various levels of education (Dowker, Sarkar & Looi, 2016). Despite our understanding

that investment in math and science fields is necessary for the further technological development of our modern society, American schools, in particular, do a poor job teaching both subjects (Ashcraft & Krause, 2007). Over time, math anxiety causes students to avoid math related experiences preventing individuals from developing positive math mindsets and building confidence in performing math (Ashcraft , 2002). Also troubling is that math anxiety prevents students from choosing careers related to math and from pursuing STEM fields in college (Hembree, 1990).

Purpose of the project

Very few research projects have explored math anxiety and math performance beyond basic arithmetic (Ashcraft & Krause, 2007). Students with math anxiety have been found to struggle with accomplishing mathematical tasks and over time avoid experiences involving mathematics. The purpose of this study was to identify interventions that can be employed by teachers in order to reduce students' math anxiety and increase ability to perform mathematics in a Math 1 course, a secondary level math course involving Algebra, Geometry and Statistics. During the course of this study students selected the teacher led interventions that were most effective in reducing their math anxiety. This action research may contribute to the establishment of effective teacher interventions to reduce students' math anxiety and increase mathematical performance in students who have matured past elementary mathematics.

Research Questions

Over the course of this action research, the following questions were considered to guide the investigation:

1. What correlation exists between math anxiety and academic performance in math courses?

2. What teaching practices can be used to reduce math anxiety in students?

3. Does a reduction in math anxiety correlate to an increase in academic performance?

Literature Review

A review of existing literature pertaining to math anxiety, and effective teacher led interventions, identified three major themes: How Math anxiety is developed, effects of math anxiety on individuals and ways to target and reduce math anxiety in students. The works done by Ashcroft, Hembree and Marchis were particularly informative for this action research.

How Math Anxiety is Developed

Carey, Hill, Devine, & Szücs (2016) question the directional relationship between performance and math anxiety, an important consideration when looking at the development of math anxiety. Does poor performance in math lead to math anxiety or does an existing level of math anxiety lead to an individual's poor performance in the subject? Tobias (1986) explains Deficit theory. Deficit theory claims that poor performance in a certain subject, such as math, leads to increased anxiety about that subject in the future. Consequently, Deficit theory suggests low math skills lead to math anxiety. In contrast, researchers such as Hembree (1990) found that students avoid experiences involving math due to their already existing feelings of anxiety towards the subject, suggesting that math anxiety leads to low math skills.

Beilock (2008) found that while a link between low math skill and math anxiety exists, this is not the only consideration that must be made when looking at the root of math anxiety.

Society normalizes the difficulty in math, messaging that high performance on mathematical tasks is not only uncommon but unessential to being a productive member of society (Ashcroft, 2002). A number of other issues could potentially develop math anxiety including: negative predispositions towards math received from family members, peers or even teachers (Dowker, Sarkar & Looi, 2016). Olmez and Cohen (2018) stated that a student receiving poor instruction or feedback from unsupportive or unqualified instructors would develop math anxiety. Furner and Berman (2003) found that the lack of proper support materials in math courses could also cause students to develop math anxiety.

Effect Math Anxiety has on Individuals

Math anxiety has two major effects which prevent individuals from being successful in mathematics courses: avoidance of math related activity and a disruption of access to working memory.

Individuals who are highly math anxious often possess a negative attitude towards mathematics, causing them to avoid situations where math must be used (Hembree, 1990; Passolunghi, Caviola, De Agostini, Perin, & Mammarella, 2016). Math avoidance can also manifest in a student refusing to receive help from an instructor in a math course (Ashcroft, 2002). This avoidance of math experience and practice restricts an individuals mathematical development, preventing them from taking courses, receiving feedback or developing the problem solving skills that could build their confidence and ability to perform mathematics (Ashcroft, 2009). Despite the pervasive nature of technology in our modern world and the growing need for diversity in STEM fields, math avoidance eventually leads to restricted access to careers in STEM (Ashcroft, 2009).

Math anxiety disrupts cognitive processing by straining an individual's working memory, not allowing them to access areas of the brain which support math fluency and problem solving (Ashcraft, 2009) Particularly worrisome for secondary mathematics, the longer and more procedurally intense a math problem is, the more demanding it is on working memory resources (Ashcraft & Krause, 2007). Ashcraft and Krause further explained that access to working memory is integral to mathematical performance whenever math goes beyond basic operations , highlighting the devastating effect that math anxiety can have to an individual's performance in a secondary math course like Math 1.

Ways to target and reduce math anxiety in students

Reducing math anxiety and increasing a students' access to their full working memory resources is important as full access increases their overall ability to do mathematics (Ashcraft & Krause, 2007). Research shows that the most important factor in addressing a student's math anxiety is the teacher (Marchis, 2011). In his research Marchis found that, a teacher's attitude towards mathematics and the way that they present information to students has a major influence on a student's attitude towards the subject. Posamenteier and Stepelman (1999) reported the importance of effective math educators, detailing that effective math teachers increase positive attitudes towards mathematics, value their students' individual contributions and involve students in learning by making math interesting. Fatinah Zuhairah Haji Ismail, Shahrill & Mundia (2015) explained that effective math teachers can positively affect students attitude towards mathematics through connection of material to real life, the instructional materials they use in class, their personality and their classroom management. Furner and Berman (2003) stated that math instruction should have a heavier focus on problem solving rather than computational

processes and teachers need to help students develop communication skills by writing or speaking about mathematics and anxious feelings towards mathematics.

In reviewing existing literature pertinent to the study of math anxiety, three major focuses were identified: How math anxiety is developed in individuals, the effects that math anxiety has on individuals and ways to target and reduce math anxiety in students. Gaining insight into these three focuses, understanding the limiting nature that math anxiety has on individuals and previous work that had been done to reduce its effects on students, was important for informing the methodology of the action research conducted.

Methodology

Study Design

This study identified the level of math anxiety present in Math 1 students using a modified version of the MARS (Mathematical Anxiety Rating Scale), a tool that has been used in research and clinical studies since 1972 when it was created by Richardson and Suinn (Ashcroft, 2009). For this action research subjects were grouped by their class period. Subjects' performance on mathematical tasks was determined by computing their average score on all critical thinking tasks in their Math 1 course. Critical thinking tasks are defined as any quizzes or unit tests taken during the course of the action research. After identifying the subjects' level of Math anxiety, a correlation between math anxiety and performance on mathematical tasks was established. Math anxiety scores were graphed on the x-axis while math performance scores were graphed on the y-axis. After graphing the data the correlation coefficient was calculated to establish a negative correlation between math anxiety and math performance scores.

The average level of math anxiety and math performance was calculated for each group of subjects, separately. As the study progressed, teacher led interventions and new pedagogical approaches aimed at reducing math anxiety were implemented during normal classroom activities. Subjects choose the three teacher led interventions they felt were most effective in reducing their math anxiety. Subjects' overall math anxiety and mathematical performance were recalculated at the end of the action research in order to determine any increase or decrease to the averages of math anxiety or performance on mathematical tasks

A major difference in this action research from those conducted by Dreger and Aiken in 1957 and Hembree in 1990 was the assessment tool used to determine a students math performance and the setting where data is gathered. Dreger, Aiken and Hembree determined subjects' math proficiency levels by administering a basic arithmetic assessment, in a lab setting. In this action research, subjects' math proficiency was established using their performance on summative assessments: quizzes and tests, given in a classroom setting. This provided real time data and allowed the researcher to determine the evolving proficiency of the subjects over the course of applied teacher interventions.

The goal of the study was to identify a set of practices that can guide math teachers seeking to directly target and reduce student's math anxiety and increase students' capacity to perform mathematical tasks. Decreases in math anxiety and increases to math performance scores would indicate the effectiveness of teacher led interventions. Original surveys and data collection tools are included in the appendix.

Data Analysis and Interpretation

Detailed below is the data collected over the course of this action research. Table 1 summarizes the baseline data which was calculated before any teacher led interventions were introduced. Table 1 includes the baseline average level of math anxiety (AMA), the average mathematical performance scores (AMPS) and the correlation between both scores for each group of subjects. Figure 1 is the graphic representation of each individual subjects' baseline math anxiety vs. mathematical performance score, in their particular group. Figure 1 makes it clear that a negative correlation between AMA and AMPS was established for each group of subjects. Table 2 is a summary of the end of semester scores for AMA and AMPS re-calculated after teacher led interventions, at the end of the action research. Figure 2 is the graphic representation of each individual subjects' end of semester math anxiety vs. mathematical performance score, in their particular group.

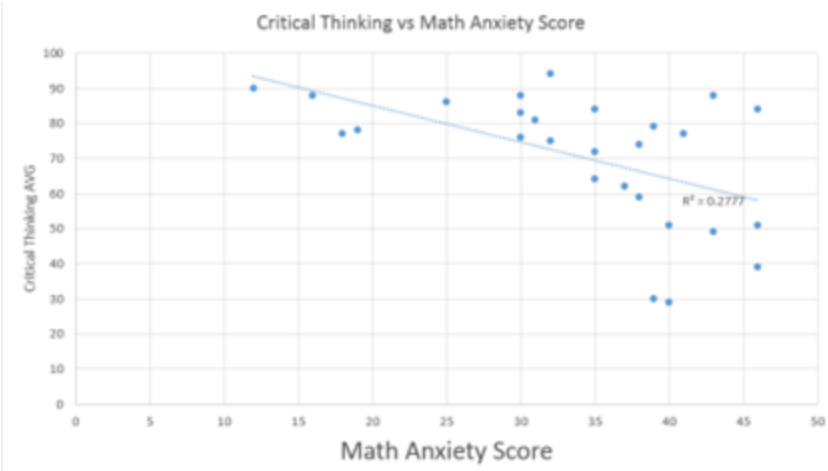
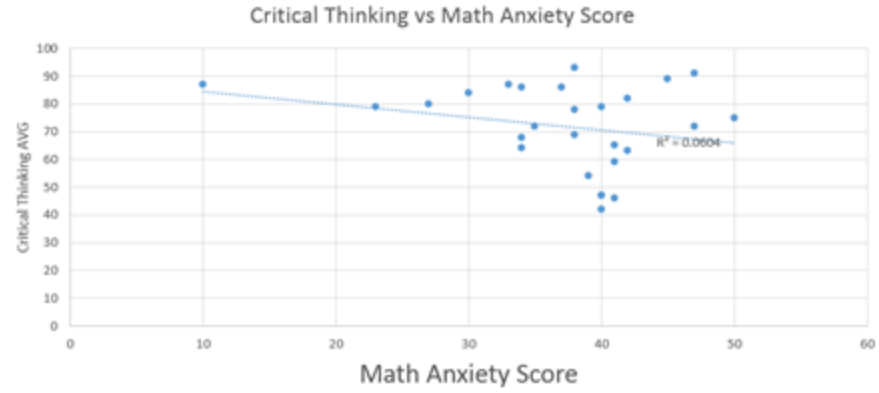
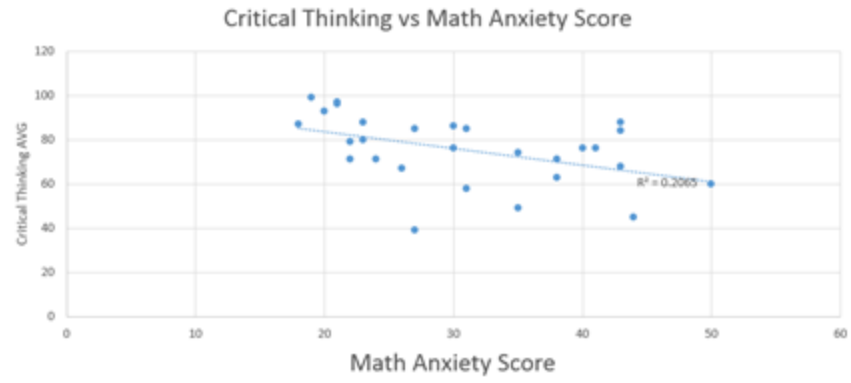
Table 1

Baseline correlation between average level of math anxiety (AMA) and average mathematical performance scores (AMPS)

Class Period	AMA	AMPS	Correlation
2	34	71	-.527
4	37	72	-.246
5	31	76	-.454
6	27	85	-.650

Note. The maximum AMA score is 50. The maximum AMPS score is 100.

Fig 1 Baseline correlation of AMA to AMPS

Math 1 - 2nd period	
Math 1 - 4th period	
Math 1 - 5th period	

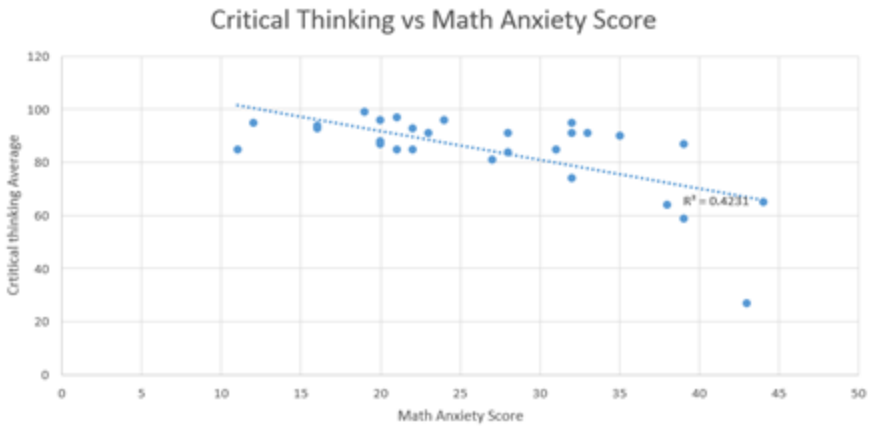
Math 1 - 6th period	

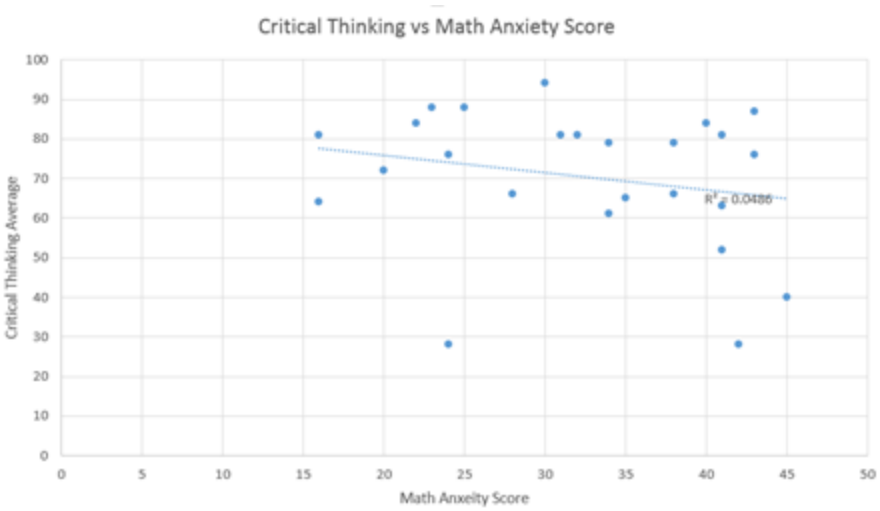
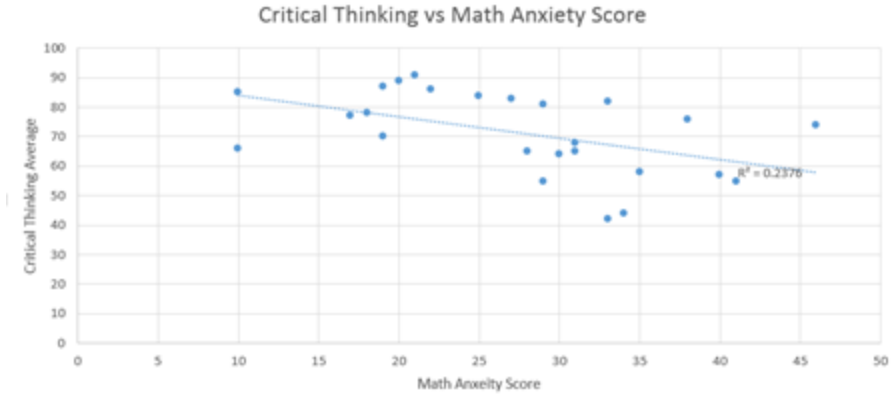
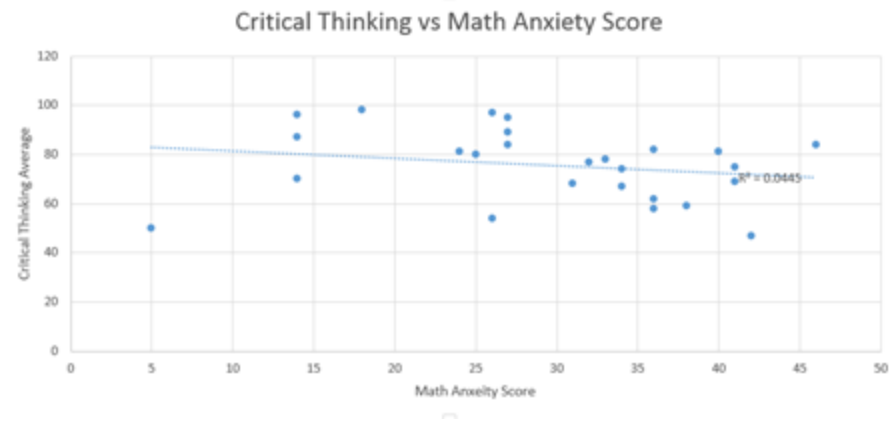
Table 2

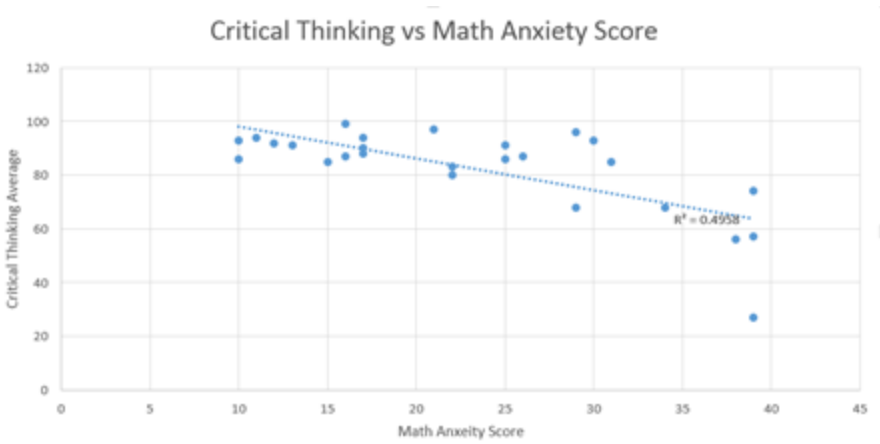
End of semester correlation between average level of math anxiety (AMA) and average mathematical performance scores (AMPS)

Class Period	AMA	AMPS	Correlation
2	32	70	-.220
4	27	71	-.487
5	30	74	-.211
6	23	83	-.704

Note. The maximum AMA score is 50. The maximum AMPS score is 100.

Fig 2 End of semester correlation of AMA to AMPS

Math 1 - 2nd period	
Math 1 - 4th period	
Math 1 - 5th period	

Math 1 - 6th period	

Teacher Interventions

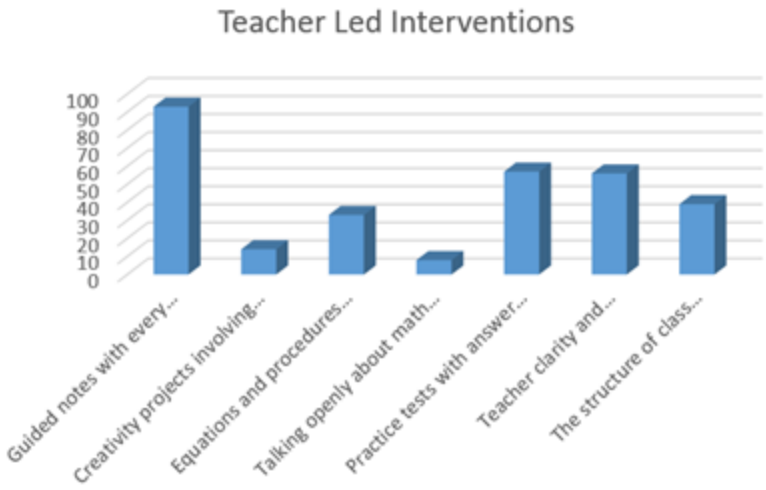
Teacher led interventions were developed as the researcher looked into work done by Hackworth (1992) as well as the suggestions for effective teaching of mathematics by Posamenteier and Stepelman (1999) and Fatinah Zuhairah Hajismail, Shahrill & Mundia (2015). All teacher interventions were designed to reduce math anxiety and increase student capacity by addressing students' ability to access working memory resources or increase positive attitudes towards mathematics. A list of teacher interventions, presented in no particular order, can be found below:

- Guided notes with every lecture
- Creativity projects involving math concepts
- Equations and procedures displayed in the classroom
- Talking openly about math anxiety and negative feelings towards mathematics
- Practice tests with answer keys
- Teacher clarity and interactions with students
- The structure of class (warm up, homework review, new instruction, group work time)

At the end of the action research subjects were given a list of all seven teacher led interventions and asked to choose the three that they felt most greatly reduced their feelings of

math anxiety over the course of the action research. Figure 3 highlights that the teacher led interventions chosen most frequently by the subjects were: guided notes with every lecture, practice tests with answer keys and teacher clarity and interactions with students.

Fig 3



Interpretation and Next Steps

A review of the data showed that all groups experienced a decrease in average level of math anxiety, indicating that the teacher led interventions were successful in decreasing the level of math anxiety experienced by students in Math 1. However, each group also experienced a decrease in the average critical thinking score indicating that despite a reduction in math anxiety levels there was no increase to the subject's math performance in a Math 1 course. This decrease in performance may be explained by the increasing difficulty of mathematical material over the course of the action research.

The questions guiding this research explored the connection between math anxiety and performance on mathematical tasks. The results of the collected data indicated that teacher

interventions were effective in reducing the levels of math anxiety experienced by students but not in increasing capacity to perform mathematical tasks. The results of the data suggest that there is no connection between a reduction in math anxiety levels and an increase to a subject's performance of mathematical tasks. Next steps would prompt a researcher to integrate effective teacher interventions with technology in order to further reduce levels of math anxiety. Effective teaching strategies will continue to be explored in order to identify ways to increase student capacity to perform mathematical tasks in Math 1.

SUMMARY

This study set out to examine the connection between math anxiety and performance on mathematical tasks in a Math 1 course. Teacher interventions were identified and showed to be effective in reducing the overall level of anxiety experienced by students but were not effective in increasing students' capacity to perform mathematical tasks in Math 1.

The study also determined teacher interventions that make the greatest impact on students' anxiety levels. Subjects in the study indicated that guided notes, practice test with answer keys and teacher clarity and interactions with students were most effective.

Reducing math anxiety in students' must be considered by all those in a position to effect change. Through following the interventions discussed in this paper, teachers can effectively address the worldwide concern over math anxiety.

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Appendix

Math anxiety survey

Please indicate in the space provided how strongly you agree or disagree with the statement

1: Strongly disagree | **2**: Disagree | **3**: Neither agree nor disagree | **4**: Agree | **5**: Strongly agree

_____ 1. Even when I know in advance, I am afraid to take a math test.

_____ 2. I do not like to work out problems on the board in a math class.

_____ 3. The idea of a pop quiz in math makes me nervous.

_____ 4. I am worried about being called on in math class.

_____ 5. I am not comfortable doing math without a calculator.

_____ 6. Learning new math skills is difficult for me.

_____ 7. I fear math tests more than any other kind.

_____ 8. I do not know how to study for math tests.

_____ 9. Material is clear to me while in class, but when I go home I do not remember math.

_____ 10. I am afraid I will not be at the same level as the rest of my math class.

_____ / 50

Teacher led interventions

Having been in my class for a semester, please indicate the **3 things** that most greatly reduced your feelings of math anxiety

(Mark your choices with an X)

_____ Guided notes with every lecture

_____ Creativity projects involving math concepts

_____ Equations and procedures displayed in the room

_____ Talking openly about math anxiety and negative feelings towards mathematics

_____ Practice tests with answer keys

_____ Teacher clarity and interaction with students

_____ The structure of class (warm up, homework review, new instruction, group work time)