

QUALITATIVE REVIEW OF INTERVENTIONS USED TO MITIGATE MATH ANXIETY

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Math anxiety is pervasive in our society, and it is causing problems for students who want to enter a science, technology, engineering and mathematics (STEM) pathway. Recent research has suggested that math anxiety, and not math ability, is a better predictor of performance and perseverance in STEM. Interventions to mitigate this anxiety must get to the root of the problem and provide students tools to help ease these feelings when they come to disrupt performance. Our approach uses techniques from mindfulness and self-compassion, which have been linked to reducing anxiety. We have developed modules that can be used in a math (or science) courses to help students understand the anxiety they face. In this paper we examine one of the interventions used, the pre-exam writing, and how it showed a 75 percent increase in statements of confidence and a doubling of statements of positive feelings over the semester.

Keywords: math anxiety, self-compassion, mindfulness

Tobias (1976) coined the phrase “math anxiety” to describe the feelings of panic, anxiety, paralysis, and mental confusion that occur when people face computational challenges. Math anxiety is a major barrier to broadening participation in STEM. First year college mathematics (math) courses are a gateway to STEM majors (Schleicher, 2018) and nearly one third of STEM-intending students in the U. S. enroll in remedial math courses at the college level (Chen & Simone, 2016). Math is a major source of stress and anxiety for many college students (Ramirez et al., 2018). Many students have the cognitive ability to carry out mathematical tasks successfully, but their fear and anxiety regarding math gets in the way (Tobias, 1976; Beilock & Maloney, 2015; Brunyé et al., 2013; Henslee & Klein, 2017; Samuel & Warner, 2019). Neuroscience research has established that the worries and anxiety that arise in math-anxious students usurp cognitive resources needed for thinking, reasoning, working memory, and maintaining focused attention (Beilock & Maloney, 2015; Brunyé et al., 2013). This causes students to perform below their actual ability and affects their motivation and interest in math (Brunyé et al., 2013).

Researchers have been examining ways to address math anxiety through non-academic interventions (Beilock & Maloney, 2015; Brunyé et al., 2013). Factors such as grit, mindfulness, self-compassion, and self-efficacy have been studied and are associated with anxiety, resilience, and academic achievement (Jarukasemthawee et al., 2021; Neff et al., 2005; Neff & Germer, 2013; Tubbs et al., 2019). In addition, research findings have indicated an inverse relationship between grit and math anxiety in college students (Holtby, 2018; Darrah et al., 2023) suggesting that increasing grit may foster resilience and perseverance by reducing math anxiety.

Our research team, including mathematics professors and a counselor who specializes in mindfulness and self-compassion, has developed and implemented modules aimed at reducing math anxiety in college students enrolled in entry level mathematics courses. The seven student modules focused on three main topics (math anxiety, mindfulness, and self-compassion) and were titled: Math Anxiety Introduction, Introduction to Mindfulness, Mindfulness as a Kosko, K. W., Caniglia, J., Courtney, S., Zolfaghari, M., & Morris, G. A., (2024). *Proceedings of the forty-sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Kent State University.

Superpower, Math Anxiety Writing, Introduction to Self-Compassion, Self-Compassion (Part 2), and Reflection. This research is part of a larger study (Leppma & Darrah 2022; Darrah et al., 2023) and in this paper, we focus on the Math Anxiety Writing assignments and the last module Reflection. We were interested in how student engagement with these modules influenced how students felt about their ability to learn mathematics. Our research questions for this paper were as follows:

1. How did student perceptions of themselves as learners of mathematics change over the course of the semester?
2. What was the students' reaction to the Math Anxiety Modules?

Background

Math anxiety not only interferes with academic performance, but may contribute to STEM attrition (Ahmed et al., 2017; Ramirez et al., 2018). Students who earn lower grades in STEM courses in their first year of college are more likely to switch to non-STEM majors or drop out of college altogether (Chen & Soldner, 2013). Recent research (Daker et al., 2021) suggests that math anxiety is a better predictor of students' participation and perseverance in STEM majors, as well as performance in math classes, than actual math ability. Results indicated that higher math anxiety was associated with avoidance of STEM courses and lower grades in STEM courses when tracking students over a four-year period.

Research demonstrates that mindfulness-related practices are effective in cultivating internal resources as protective factors against the distress associated with math anxiety, which may help attract more students to pursue and persist in STEM-related majors (Ahmed et al., 2017). Mindfulness – the intentional and nonjudgmental awareness and observation of the present moment, including thoughts, feelings, and physical sensations one is experiencing – is positively associated with improved emotional regulation (Meyer, et al., 2019) and inversely related to depression, anxiety, and severity of anxiety symptoms (Tubbs et al., 2019).

A related construct, self-compassion, is the ability to show kindness and caring toward oneself in the face of discomfort, failure, or suffering. Self-compassion encompasses three components: self-kindness, common humanity, and mindfulness. Rather than being critical and judgmental toward oneself when making mistakes, self-compassionate people recognize that personal failures are part of the human experience and recognize their negative internal states without judgment or overidentification (Neff, 2003).

Students who develop internal resources, such as perseverance, grit, hope, emotion regulation, and motivation can overcome math anxiety and persist in math classes (Beilock & Maloney, 2015; Duckworth, et al., 2007; Snyder et al., 2002). Mindfulness and related self-compassion practices have been shown to alleviate anxiety, including math anxiety, and improve resilience, grit, hope, well-being, and emotional and cognitive functioning (Beilock & Maloney, 2015; Doorley et al., 2022; Leppma & Darrah, 2022; Weed et al., 2021). Mindfulness and self-compassion practices help to develop valued skills in academic achievement, such as concentration, memory, focus, and test performance. They also cultivate skills associated with occupational success and wellbeing, such as resilience, emotion regulation, interpersonal skills, grit, and hope for goal attainment (Chiesi et al., 2022; Leland, 2015; Shapiro et al., 2015; Strohmaier et al., 2022). Moreover, mindfulness diminishes the experience of stress and fear

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(Tubbs et al., 2019), and self-compassion increases intrinsic motivation to learn and improve (Akin, 2008; Manavipour & Saeedian, 2016; Neff et al., 2005). Thus, higher levels of mindfulness and self-compassion are associated with higher levels of grit and hope, and lower levels of math anxiety.

Methods

The research took place at a large public research university upon institutional review board approval. The participants in the project were a convenience sample of 59 students who were enrolled in an entry-level college algebra course and a college algebra co-requisite support course in the spring semester of 2022. Student placement into college algebra courses (with or without co-requisite support) is based on their SAT/ACT Math scores or how they performed on a Math Placement Exam (ALEKS). The co-requisite course focused on prerequisite skills including operations on real numbers and simplifying algebraic expressions, and metacognitive skills such as mindfulness, coping with math and test anxiety, and self-compassion. The co-requisite course was mainly taught by graduate assistants under the supervision of the course coordinator. The coordinator provided training on how to implement the modules mentioned in the Introduction.

For this paper, we focused on the Math Anxiety/Mindfulness pre-exam writings and the last student module titled Reflection. The purpose of the Math Anxiety/Mindfulness pre-exam writings was to help students acknowledge their thoughts as they prepared to take an exam. These writings were designed to help students practice mindful writing to bring awareness and clarity to their thoughts prior to taking an exam. These writing assignments took place before a practice exam given in the co-requisite support course but coincided with three exams taken in their 3-credit algebra course. Data collected were student responses on these three writing assignments. The prompt students were given was “Please take the next 7 minutes to write as openly as possible about your thoughts and feelings regarding the math problems you are about to perform.” These writings were completed in February, March and April (before algebra exams 2, 3, and 4).

The researchers used the Content Analysis method to look for common ideas and themes in the student response data. Analyses began with the preliminary reading of the responses, followed by the development of preliminary codes based on ideas and themes that emerged within the responses to the writing prompt. The development of codes was also guided by the overarching research ideas of the student’ perceptions of their ability in math and feelings of anxiety. The codes were grouped into three major categories: (1) confidence or lack of confidence in mathematical knowledge or ability to succeed on the pre-assessment, (2) specific feelings of anxiety or stress, and (3) positive feelings. The writing was not mandatory, so 97 students completed at least one of the writings, with 45 students completing all three writings. These 45 students were used as the analysis group, since we could compare across all three writings for changes.

Additionally, to determine students’ perceptions of the modules themselves, we presented the student responses from the last module, Reflection. This module asked students to reflect on the experience of learning about these ideas and practices (mindfulness and self-compassion) throughout the semester. Forty-seven students completed the final Reflection module at the end of the semester. Questions included “Will you continue to utilize some of the practices discussed

in the modules in the future? If not, why not?”, “What is your reaction to the series of modules?” The researchers used descriptive statistics to determine the percentage of students who found the modules useful and considered the open-ended responses for information about student perceptions and to extract ways to improve the modules or make them more useful to the students.

Discussion

We summarize the findings based on our two research questions.

Research Question 1: How did student perceptions of themselves as learners of mathematics change over the course of the semester?

For the 45 students who completed all three Math Anxiety/Mindfulness pre-exam writings we looked for change from February to April. Figure 1 below shows a summary of the analysis of the coding. We found that the number of students who made statements of confidence in their ability had a 75 percent increase. The number of students who made statements about positive feelings more than doubled, showing a 110 percent increase over the semester. On the flipside, the number of students expressing specific feelings of anxiety had a 34 percent decrease. For these 45 students, by April, they were making as many positive statements as negative statements about their feelings and more of them had statements of confidence than had statements of lack of confidence.

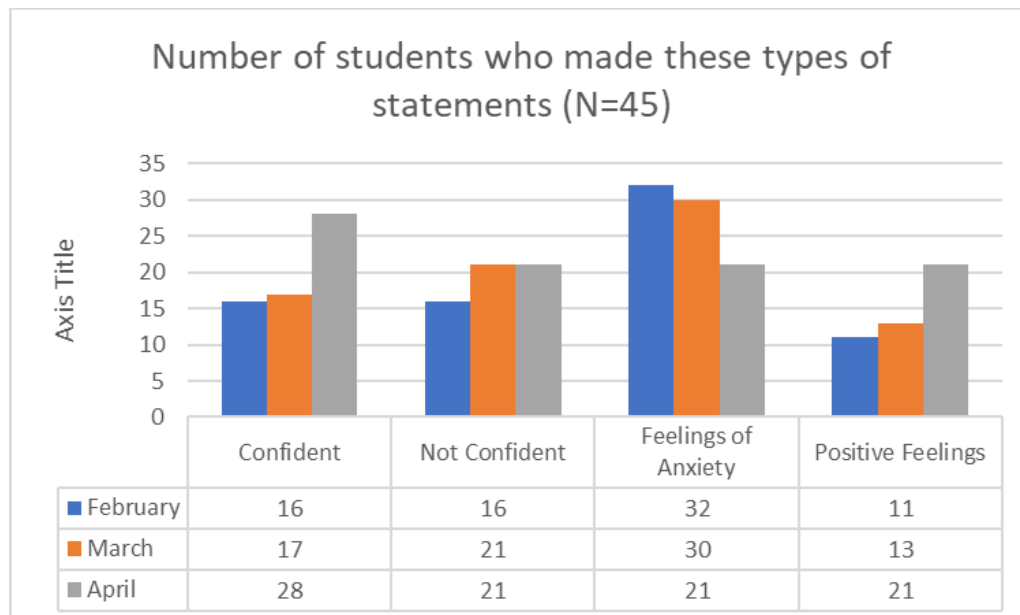


Figure 1: Summary of Coding of Math Anxiety/Mindfulness Pre-Exam Writing

Table 1 below is a sample of a few student responses that show the changes in the students’ perceptions of themselves as learners. From the matched responses in the table, it can be seen that students took these few minutes before the exam to really think through what they were feeling. They talked about what was going on in their lives, sometimes mentioning other situations not related to math that were troubling them. This activity gave them a mechanism to

let go of these thoughts and then to focus on the task at hand: taking the math test. Note the “VL” in the comments in the table stands for Video Lectures.

Table 1: Example Student Responses to Math Anxiety/Mindfulness Pre-Exam Writing

PROMPT: “Please take the next 7 minutes to write as openly as possible about your thoughts and feelings regarding the math problems you are about to perform.”		
February	March	April
I feel like I am struggling because I don't really know what is going on. The word problems confuse me. And the VL are not anything like what the problems are, they do not help me when I do homework. They are completely different. Most of it does make sense to me at all and I am really not good at math or understand it.	I am struggling so bad in math. I do not like it because it is hard. I don't understand anything we are doing I literally do not comprehend it. The VL do not help me at all and I feel like it is not the same as the stuff we learn in class.	I feel confident because when I did the VL I actually understood what I was doing. I thought I understood though and then in math 126 I was so confused because he taught it a different way. I am not nervous because I felt comfortable and now I am not really sure.
I do not feel as prepared as I would like to for this upcoming assessment. I don't feel very confident in my knowledge on the current problems and material we are working on in Math 126. Though I am beginning to pick up how to do partial aspects of current material, I don't think I know enough to perform as well as I could on this diagnostic.	I definitely feel more confident going into this next diagnostic test than the previous ones. Before others I felt certain I would not do well at all and was very worried about how it would affect my grade. I am hopeful that this one will have a better outcome and relieve some of that stress regarding my grade.	I feel prepared and good about the math diagnostic that I am about to complete. Other times I have been quite anxious for the diagnostics because I didn't feel that I would score well on them and was worried about the effect that it would have on my grade in the class.
I am kind of confident but also nervous at the same time to do the math problems because there are parts that I am super familiar	I am a bit nervous but also a bit confident as I kinda know how to do the problems but I also am just am unsure of them. I think	I feel okay about it as I am going to be able to know the majority of what is on this.
I honestly have no idea what is going on , the second you get one second behind with a specific topic regarding the material we have went over thus far, you are just SOL. You just get behind so fast, if you struggle with one little thing it is honestly	I barely understand what's going on with anything we are going over in 126 right now, and honestly 106 doesn't help whatsoever. 106 is repetitive and we get lil to no help in either class. Feels	I feel better about this module than I have any other , it still scary because were getting close to the end of the semester. I feel like I should have felt better about this math a lot sooner.

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impossible to continue with anything else. ...	very pointless
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Research Question 2: What was the students' reaction to the Math Anxiety Modules?

Forty-seven students completed the final reflection module at the end of the semester. When students were asked if they will continue to utilize some of the practices discussed in the modules, 81% of students said “yes”. When asked, “What was your reaction to the modules?” students elaborated on their thoughts and feelings regarding the modules. Some example quotes included:

- “I felt like I learned a lot from these modules this year whether it was my least favorite or my absolute favorite. I felt like learning all these unique ideas and lessons, I can use them to make myself a better student, etc.”
- “These modules made me improve my math scores throughout the semester. I kept improving as a student, and I will continue to do these practices.”
- “I found the information in the modules more useful than expected. Learning not only about anxiety, mindfulness, and self-compassion, but how to apply them to real life made a huge difference. While one would not think the modules would not have a huge impact when coming to learning math, it created a difference mentally, and how one begins to think.”
- “I loved them, I actually tried to apply what they were teaching me into my life.”

Student responses from those who said that they would not continue to utilize these practices included:

“Probably not as I'm confident in my ability to work out math problems and I'm confident in my abilities already and don't need self-help.”

“They all felt the same as they seem to just be about how I feel about math even though I enjoy math.”

“Self-compassion felt silly, but I enjoyed the ted talk like videos.”

Student feedback will be used to redesign modules or better explain their purpose to students. This feedback will also help inform professional development for instructors who will be implementing the modules.

Conclusion

Math anxiety is a problem for many students in our college courses (Tobias, 1976; Beilock & Maloney, 2015; Brunyé et al., 2013; Henslee & Klein, 2017; Samuel & Warner, 2019) and is causing a problem in our STEM pipeline (Ahmed et al., 2017; Ramirez et al., 2018). While the authors understand that these modules are not a silver bullet that will eradicate math anxiety in all students, we were pleasantly surprised by the number of students who took them seriously and who said they benefited from them. Over the years, we have not seen many resources that address the idea of anxiety in the math classroom and feel we have developed something to offer instructors who are faced with the student who suffers from math or test anxiety. We have also found through this research and reviewing the comments from the writing modules that the overwhelming majority of students in the co-requisite course started out with negative feelings, even though it may not have shown on their faces. We also note that these feelings, if addressed, can change throughout the course of the semester. The introduction of mindfulness techniques and self-compassion can make a difference in their perceptions of themselves as a learner.

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We are continuing to redesign and improve the modules based on student feedback. Another aspect of the work is to create and provide professional development for faculty who would like to use the modules as part of their course. These modules can help instructors learn more about math anxiety and equip them with tools they can use to help their math anxious students persist in their studies. Lastly, we will continue the process of testing all the modules with students to determine their effectiveness at reducing math anxiety and increasing student persistence and performance. Future research will explore mechanisms, interventions, and effectiveness in a broader population.

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