How to Combat Math Anxiety and Build Confidence in the Classroom

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Abstract

In an age of STEM (Science, Technology, Engineering, and Mathematics), the relevance of mathematical understanding and skill continues to increase across the country. It is becoming more apparent that a large majority of students have developed anxiety that stems from doing math in both academic settings and ordinary life. Despite the increasing awareness of math anxiety, the overall negative feelings towards mathematics demonstrated by students of all ages has stayed significant and is continuing to worsen. In collaboration with the education department at the State University of New York at New Paltz, a group of preservice elementary school teachers contributed accounts of their personal experiences with math anxiety during and after their enrollment in two required math courses for those pursuing elementary education. Surrey and interview data was collected from eight students attending the university, which offer qualitative evidence of several causes of math anxiety that stemmed from past experience as well as teaching methods used in the courses taught at SUNY New Paltz that lessened students' math anxiety and increased their mathematical confidence.

Key words: Mathematics, math anxiety

1. Introduction

In relatively recent years, a nation-wide phenomenon known as math anxiety has firmly grasped the attention of mathematicians and educators. Math researchers have defined math anxiety as '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' (Finlayson, 2014). The concept of math anxiety was originally introduced in 1957 as the term 'number anxiety' by Dreger and Aiken, but has received escalating amounts of attention in recent academic studies.

Although the subject of math anxiety has become increasingly relevant in academic discussions, inquiries, and research, it continues to plague schools and student minds across America. Due to this affliction, there exists a plethora of academically capable students that continuously struggle in the field of mathematics (Stuart, 2000). It has been consistently concluded that methods used to teach mathematics skills largely affect whether a student experiences math anxiety or develops mathematical self-confidence (Stuart, 2000). Therefore, the responsibility of combating this hardship has fallen on the shoulders of American teachers.

Math anxiety has ignited a societal pandemic in which many students and adults have negative feelings and poor past experiences with mathematics (Furner, 2017). If the perceived difficulty and hatred felt towards math can be eliminated in classrooms across the country, it can be replaced with creativity, intrigue, and a love for mathematics. This paper aims to explore the ways math anxiety is cultivated among students and how math teachers can alter their teaching strategies in order to lessen the impact of math anxiety on students.

2. Literature Review

The relevance of math in everyday life is astounding. Most mathematical thinking is so intricately intertwined with daily life, it often goes unnoticed. From the time we are children, mathematics influences our thinking and decisions in both subtle and obvious ways. "Everything can be thought of as a math problem" (Stuart, 2000). Why is it then, that such a large majority of people across America cringe at the thought of performing math? Why does the mere discussion of the subject cause uncomfort, frustration, and distress? This paper aims to examine a phenomenon known as "math anxiety." Several causes and effects of math anxiety will be identified and analyzed. Methods to combat math anxiety will also be explored. After reviewing this paper, readers will have a better understanding of math anxiety and be equipped with strategies to lessen it. To accomplish this, it's important that readers discard any preconceived notions they have about mathematics. It is crucial to have an open mind when attempting to rid oneself of math anxiety and instead consider the plethora of possibilities that come with exploring the field of math.

Math researchers define math anxiety as "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" (Finlayson, 2014). In more candid language, math anxiety is described as "a feeling of sudden death" (Stuart, 2000). Regardless of which description is considered, it's evident that math anxiety has the potential to greatly affect one's ability to interact with math. This enervating phenomenon affects a large number of people throughout the United States. "It

is possible that only about 7 percent of Americans have positive experiences with mathematics from kindergarten through college study." (Furner, 2017). In another study, it was found that "two-thirds of American adults fear and loathe math" (Burns, 1998). In her book, *Math: Facing an American Phobia*, Marilyn Burns recalls, "Scores of people have told me of an aversion to math, about their fear, dismay, anxiety, avoidance, dislike, inadequacy, incapability, and more. I've heard it all, a heap of personal descriptions that add up to a national phobia." The exact percentage of Americans who have had negative experiences with math is not particularly significant. However, it is worth noting that in all surveys that inform this paper, it was found that more than half of participants had poor feelings towards math. This statistic begs the question, if a majority of people struggle with math anxiety, why aren't we doing more to help?

A common phrase expressed by those struggling with math is, "I'm just not a math person." Expressions such as this one are detrimental to one's mathematical self-confidence. They insinuate that the ability to successfully do math is an innate skill (Boaler, 2020). This belief is horribly incorrect. In fact, "that singular belief- that math is a "gift" that some people have and others don't- is responsible for much of the widespread math failure in the world" (Boaler, 2020). When students are under the impression that their ability to learn math is based on whether or not they are a "math person," they will assume they fall into the latter category when faced with mathematical adversity that requires them to struggle before achieving an understanding. There is no such thing as a "math person," just like there is no such thing as a "reading person." It is a widespread belief that with the right resources, all children are capable of achieving literacy. As a society, we must expand our perspective on academia to include math in this assumption. That way, students can practice math with more confidence and less fear of its perceived difficulty. It's also important to note that "gender and ethnic backgrounds are not determining factors in mathematical competence, but peers' and teachers' attitudes toward gender and ethnicity may increase or decrease one's confidence in mathematical skills" (Stuart, 2000). All students, regardless of the differences that exist between them, have the potential to be successful in the field of mathematics.

"Math anxiety is caused primarily by the way the student learns math: the type of authority the teacher uses, an emphasis on right answers and fear or getting wrong answers, requirements that the student respond with an answer sooner than they might be ready, and… potential condemnation of a student who responds poorly, in short the traditional way of teaching math" (Furner, 2017). In several studies, traditional teaching methods were observed in correspondence to levels of math anxiety in students. It was concluded that math anxiety is typically most present when traditional methods of teaching math were practiced (Finlayson, 2014; Furner, 2017).

One of the most destructive elements of traditional teaching in math classrooms was the requirement for students to work entirely independently from one another (Furner, 2017). This lack of student collaboration typically caused students to feel isolated from their peers and pressured to problem solve without assistance from others. Oftentimes, this caused students to feel as though their misunderstandings were unique among their classmates and prevented them from voicing instances of confusion, which typically resulted in the worsening of their mathematical understanding. When experiencing math anxiety, it was common for students to develop an obsession with the idea that "everyone knows that I don't understand. I'd better not

draw attention to myself …" (Stuart, 2000). Without reinforcement from classmates, it was difficult for students to feel confident about math.

Traditional classrooms tend to emphasize producing correct answers using the exact methods modeled by the curriculum. "The subject is often taught as if there were a right way to solve problems and any other approaches would be wrong, even if students got the right answer. When learning, understanding the concepts should be paramount, but with a right/wrong approach to teaching math, students are encouraged not to try, not to experiment, and not to take risks" (Finlayson, 2014). With so much emphasis placed on completing math problems in a step-by-step manner, students were unable to indulge in any sort of creative interactions with the content. In simpler terms, math ceased to be fun. When obtaining correct answers was prioritized over mathematical understanding, students felt an immense pressure to act robotically and feared straying from the mathematical routine provided by their teacher. This teaching method cultivated math anxiety among many students.

Math anxiety was also caused by a general misunderstanding of mathematical content. When students were unsure of content, it made it more difficult for them to confidently problem solve, further contributing to their math anxiety. There were several aspects of traditional teaching that restricted students from completely understanding mathematical concepts and tended to significantly increase their math anxiety. In traditional math classrooms, "there is a focus on success and getting results, instead of on understanding" (Finlayson, 2014). In other words, procedural knowledge that is necessary to pass standardized tests was prioritized over developing a deeper conceptual understanding. Oftentimes, this unbalanced prioritization went hand-in-hand with a lack of student engagement. Instead of using manipulatives to demonstrate and investigate concepts, traditional methods of teaching math emphasized "following the steps," leaving students to their own devices to understand the inner workings of math problems. This didn't allow students to thoroughly grasp math concepts and significantly contributed to their misunderstanding of math. As stated in an ancient Chinese proverb, "Tell me math and I forget; show me mathematics and I may remember; involve me… and I will understand" (Stuart, 2000).

To promote the growth of students' passion towards and understanding of mathematics, it was helpful when teachers emphasized conceptual understanding. One study found that

> *"Undergraduates had chosen mathematics as their university pathway because they had always been good at math. But when they arrived at university they found they were surrounded by other students just as good at math as they were. At that point, they experienced a crisis in confidence and in their identities as people. The students had not learned to love math or appreciate the beauty of mathematics; rather, they chose it because they could do it and they had been made to feel they were special. Surrounded by other people apparently as "special" as they were, they lost their purpose and decided to abandon mathematics, realizing they had never developed an interest in the subject itself" (Boaler, 2020).*

To ease the anxiety that has intruded the minds of so many math students, teachers must first and foremost increase students' mathematical confidence. One study concluded that "people like to

do something if they think they are good at it, and to feel good about mathematics, you have to believe that you are good at it" (Stuart, 2000). In another survey, "many students spoke of the importance of having teachers believe in them, tell them that they could do the mathematics, and celebrate the small successes of students. They indicated that teachers who were approachable and who took an interest in their students played an important part in relieving math anxiety" (Finlayson, 2014). In short, it's extraordinarily important for teachers to provide their students with encouraging words and positive feedback. "Anxious individuals tend to focus on negative stimuli more than positive stimuli, essentially making themselves more anxious" (Furner, 2017). Therefore, creating a positive and productive environment for students is incredibly important. After all, "mathematics is like a sport: 90 percent mental- one's mathematical confidence- and 10 percent physical- one's mathematics competence in performing mathematical skills" (Stuart, 2000).

Several studies have found that when math teachers collaborated with school counselors, math anxiety was lessened among students. Systematic desensitization was proposed as an effective tool when attempting to ease students' math anxiety. "Systematic desensitization in the context of math anxiety may be defined as a gradual exposure to the mathematical concepts that are causing students to become distressed and teaching them how to cope with that fear" (Furner, 2017). It was also concluded that granting students consistent opportunities to verbalize their anxieties regarding math and providing them with tools and strategies to overcome their fear significantly aided the lessening of their anxiety. "Through counseling… students come to understand that their anxiety was a learned behavior, they were not born with this feeling, and they can be taught to overcome it by consistently implementing their self-monitoring strategies to become less anxious" (Furner, 2017).

In general, constructivist classrooms offered teaching and learning strategies that differed from the rigid methods practiced in traditional classrooms. Constructivist classrooms typically consisted of elements that emphasized conceptual and interactive learning, group work, and the pursuit of student questions and interests (Finlayson, 2014; Furner, 2017). In one study, it was observed that when students were provided with the opportunity to collaborate, they found more mathematical success and experienced less math anxiety. While collaborating in a constructivist classroom, "students learned to share and accept more than one correct solution or strategy. They began to trust one another and take risks in their problem-solving endeavors, thus increasing their mathematics confidence" (Stuart, 2000). Student collaboration allowed for more consistent acknowledgement and discussion of student misconceptions. In general, "the constructivist style is much less intimidating and does not emphasize… correct answers; instead, it focuses on the process of doing mathematics" (Furner, 2017).

Constructivist classrooms also prioritized developing a personal connection between students and the academic content. Mathematical situations were often compared to real life experiences. In *Math: Facing an American Phobia*, Marilyn Burns claims, "The solution is not to make math easier or simpler… the change we need to make is to broaden the notion of what basic arithmetic is so that it includes the complexity of real-life arithmetic, so that it promotes the thinking and reasoning that are essential life skills." This idea is practiced in constructivist classrooms in order to adhere to student needs as much as possible, while also decreasing their math anxiety. As Finlayson eloquently states, "Children are not blank slates to be filled." Instead, students

learn best when they are "allowed to construct a personal understanding based on experiencing things and reflecting on those experiences" (Finlayson, 2014).

The National Council of Teachers of Mathematics (NCTM) has made several recommendations for teachers to lesson and prevent math anxiety. These recommendations include, but are not limited to: "design positive experiences in math classes… emphasize that everyone makes mistakes in mathematics… emphasize the importance of original quality thinking rather than rote manipulation of formulas… and characterize math as a human endeavor" (Furner, 2017). These strategies allow students to take ownership of their learning and develop a full understanding of mathematics, ergo lessening their math anxiety.

In one study, students were taught how to address the physical and emotional symptoms of their math anxiety, confront frustration and fear of failure, and become engaged in their mathematical learning (Finlayson, 2014). When surveyed regarding their coping mechanisms, there were several commonalities between student responses.

> *"Thirteen students had developed ways to relax, either by breathing exercises, by listening to music, or by simply convincing themselves to calm down. Sixteen students had developed ways to build self-confidence. These included: making connections to previous knowledge… building upon small successes; and telling themselves that they could be successful at math… Twenty-eight students identified the importance of getting help: from teachers, from peers, and from family members" (Finlayson, 2014).*

Some critics of the constructivist approach may think it's unnecessary to make such radical changes to traditional math classrooms. Many Americans are under the wrongful impression that the overall goal of mathematics is to provide students with the procedural knowledge required to pass standardized tests and that class time should not be wasted on addressing math anxiety. However, it has been found that reducing math anxiety goes hand-in-hand with the improvement of standardized test scores. After implementing strategies to lessen math anxiety, one study showed that "100 percent of students passed the test… and 49 percent achieved more than a year's growth… Students who had seemed to have the most math anxiety made the most dramatic improvements, with learning indexes increasing 10 to 30 percentage points" (Furner, 2017). From this data, it can be gathered that strategies that reduce math anxiety only serve to benefit students.

Moving forward, it is crucial that teachers recognize the effect of math anxiety and aim to ease and eventually eliminate its harmful influence in math classrooms. If administrators, teachers, parents, and students collaborate on the journey to eradicate math anxiety in schools across the country, it will soon be realized that mathematics is not a subject to be feared. Instead, the subject of math will be recognized as the creative, fluid, and playful academic field that it is.

3. Methods

The data used in this study was collected from preservice elementary school teachers attending the State University of New York at New Paltz. The participants of this study contributed data

while they were enrolled in the courses MAT140 and MAT240. MAT140 and MAT240 are the only required courses for students pursuing elementary education that focus on mathematical content. They are typically taken in consecutive semesters. In this case, both courses were taught by the same professor. Throughout this course, the professor aimed to implement teaching strategies that lessened math anxiety among students.

Data consisted of weekly reflections and a post-course interview collected from each student. All student reflections were written independently and electronically submitted. All interviews were independently conducted between each student and the MAT140/240 instructor. The post-course interviews aimed to identify ways in which the course had either increased or eased students' math anxiety. During the interview, students reflected upon the course as a whole and indicated the teaching methods that either contributed to their math anxiety or built their math confidence. Additionally, students tended to reflect upon their past experiences with math in order to make comparisons with MAT140/240. At the start of MAT140, a self-reported survey was administered to measure the severity of students' math anxiety in relation to doing and teaching math. The exact data collected from these self-reported surveys wasn't directly used in this study, but was mentioned during several student interviews.

A method known as open coding was used to analyze this data (Corbin & Strauss, 1990). As recurring themes were identified throughout student responses, each theme was paired with a specific color. Student submissions or quotes that reflected a recurring theme were coded with its corresponding color. Each theme either indicated a cause of students' math anxiety or a teaching method that built students' mathematical confidence.

4. Results

In this section, recurring themes that either indicated causes of math anxiety or math confidence will be identified and explored. In total, 4 themes established causes of math anxiety and 5 themes recognized teaching methods that eased math anxiety and contributed to the improvement of students' math confidence. Overall, the teaching methods used by the instructor of MAT140/240 yielded the desired results and significantly lessened students' math anxiety. Typically, the recurring themes that indicated causes of math anxiety were supplied by quotes that stemmed from students recalling their past negative experiences with math. Recurring themes that identified teaching methods that could be used to combat math anxiety typically drew from the experiences students had in MAT140/240.

4.1 - Causes of Math Anxiety

Theme 1: Academic Isolation

The recurring theme of academic isolation was made immediately evident upon analyzing student interviews. Academic isolation occurred when students were forced to problem solve completely independently, without collaboration or help from others. One student expressed the defensiveness and lack of support they felt when experiencing academic isolation.

> *"Usually when working alone… it felt like it was me against everyone else."*

Generally, students felt anxious when required to problem-solve independently. Several students indicated that their anxiety was heightened when instructors requested them to demonstrate their understanding in front of the class. One student expressed that regardless of their comfortability with the mathematical content, they felt nervous to write on the board in front of the class. This uncomfort could stem from a lack of positive reinforcement that occurs when students collaborate with one another. Rather than agreeing or disagreeing with another student, working independently caused students to constantly be unaware of whether or not they were on the same page as their classmates.

> *"One thing that I was nervous about in math [class], even though I knew I was good at doing the problems, was when the teacher would call you up to write on the board by yourself."*

> *"When I was in school, I hated being called on. I hated attention being on me because it made me so anxious."*

Academic isolation also contributed to students' hesitation to admit to confusion and ask clarifying questions in front of the class. Without the validation that typically stems from the confirmation of other students having the same questions and uncertainties, a lot of interviewees admitted that they prefered to remain silent, rather than voice their misunderstandings in front of the class.

> *"A lot of math anxiety, especially for me, comes from not knowing when to ask a question, if it's a right question to ask, if it's a wrong question to ask."*

> *"Nobody else is thinking what I'm thinking. I don't want to seem dumb."*

In one interview, a student recalled a traumatizing experience they had in their fifth grade math classroom. This instance is especially isolating because the student was not only isolated from their peers while learning; they were also isolated from their own body parts and forced to rely solely on their ability to do mental math. To diminish students' math anxiety as much as possible, it's crucial that teachers allow them to use every resource that is available to them. This includes their classmates and it includes their body parts.

> *"I had a very bad experience in 5th grade with minute math and in particular with this one teacher… She fostered a lot of anxiety in the class, especially around math… I used to count, you know, like the 9th table trick [when finding multiples of 9]... She would tell me don't use your fingers… You should be able to use your fingers. You can have those on a test."*

<u>Theme 2: Mistakes Are Viewed in a Negative Light</u>

When math teachers fostered a classroom environment in which mistakes were viewed negatively and often associated with ignorance and failure, students tended to experience a

significant amount of math anxiety. When obtaining correct answers was regarded with much importance, many students feared getting answers wrong and panicked at the thought of looking unintelligent in front of their peers. Several students claimed that making errors in class was equivalent to "the end of the world."

> *"You have to get it or it's the end of the world."*
>
> *"If I don't get… something right the first time, I feel stupid… A lot of the time when I do have errors, I feel like it's the end of the world."*

Typically, when mistakes were viewed in a negative light, students were reluctant to voice their uncertainties, and instead remained silent when faced with difficulties. Several students indicated that their math anxiety stemmed from pressure to get answers correct. Interviewees consistently noted that admitting to misunderstanding was anxiety-inducing when mistakes were regarded with negativity.

> *"I feel like there's an additional layer of stress… just because I don't know whether or not I'm doing it correctly."*
>
> *"In my first couple of semesters, I was very nervous about saying things that I didn't understand."*

Theme 3: A Lack of Mathematical Understanding

In general, when students suffered from a lack of mathematical understanding, they experienced an increased amount of math anxiety. Typically, a lack of mathematical understanding stems from a lack of foundational knowledge. Oftentimes, students are taught to memorize tricks, formulas, and procedures to obtain correct answers, rather than being challenged to understand the inner workings of math problems. In simpler terms, procedural knowledge is usually valued more than conceptual understanding in math classrooms that foster anxiety.

Interviewees indicated that this lack of understanding contributed to their math anxiety because they weren't able to form a connection with their academic endeavors.

> *"There were things that I didn't realize I only knew by rote memory… we talked about it in class and I felt like the connection wasn't there."*
>
> *"I would say one thing that comes to mind in terms of increasing anxiety for math was definitely when we took quizzes or tests and we had to show your work on every single question, just because if there were steps I forgot or something like that then, I didn't do as well."*

When extreme emphasis was placed on procedural execution, students tended to develop "mathematical muscle memory." In other words, they were able to successfully solve math problems in class after being instructed on what steps to follow, but struggled to remember how to solve problems when attempting to complete homework without step-by-step guidance.

Students also tended to struggle when solving variations of the problems presented in class because they weren't equipped with the conceptual knowledge to adjust to the mathematical alterations. This is because the student didn't develop a conceptual understanding of the content presented in class. Instead, they only exercised their short term memory and failed to form an intellectual connection with the material.

> *"In high school… I'd have to go back to the step-by-step directions… and then I kind of got dependent on that… I wouldn't have my notes and I wouldn't know what to do."*

> *"When I forget what I've learned, that's when it becomes hard for me."*

Theme 4: Teachers' Math Anxiety Can Be Passed on to Students

In many instances, classroom environments that fostered math anxiety were led by teachers who experienced math anxiety themselves. In classrooms where the instructor felt insecure about making mistakes, they typically fostered an environment in which students were also shamed and made to feel embarrassed for making mistakes.

> *"A lot of times since professors are a pro at the course they're teaching, when they're teaching it to students and students aren't getting it, they're like 'why aren't you getting it?' They kind of don't understand that there's a lot of error that goes into making something perfect."*

> *"A professor that's flexible emotionally with their own work won't feel offended if you're not getting it right… or offended if you're asking a lot of questions because it's just not clicking for you."*

Several student interviewees indicated that they felt anxious about teaching math in their own future classrooms. It's worrisome that unless these students overcome their math anxiety and become more comfortable making mistakes and confident in their own mathematical abilities, they could also foster a classroom environment that causes students to develop math anxiety.

> *"The idea of [teaching math] scares me because I don't want to teach anything wrong. I don't wanna go through a whole question and end up being wrong. I wanna crawl under the covers and just cry."*

> *"Obviously I need to teach math, and if I'm not comfortable with the material, it would be weird if I had to say 'Okay, learn this,' when I don't even feel comfortable with it."*

4.2 - Causes of Math Confidence

Theme 1: Student Collaboration/Discussion

Among student interviewees, there was a tremendous decrease in math anxiety when students were permitted and encouraged to collaborate with one another. Classrooms that facilitated class discussion and collaboration among students usually implemented a considerable amount of

small group work. Students often indicated that participating in front of a small group of peers was less intimidating than speaking in front of the entire class. Therefore, the use of small groups created a low-stakes opportunity for students to speak their minds and potentially admit to misunderstandings and confusion.

> *"There was a decrease [in anxiety] when [the class] was more discussion based… You look around the classroom and see everyone kind of has the same look in their eyes… [The professor] made it more open for all of us to look at each other and say, 'I have the same question as you, maybe we should ask it instead of holding back.'"*

> *"[The class] was conversational… there was a lot less pressure."*

Facilitating a discussion-based classroom did more than help students who were unsure of content. It also helped students who had a better understanding of the content to become more confident in their abilities to do and teach math while explaining concepts to their classmates.

> *"The girl that was sitting next to me in class, she would often be confused in our class. So I was kind of teaching as well… I got a little more confident in my math abilities and was able to teach it to my friend."*

<u>Theme 2: Mistakes Are Viewed in a Positive Light</u>

When mistakes were viewed in a positive light, students typically felt considerably less math anxiety. Several students indicated that they felt more comfortable asking questions in class when they knew they weren't going to be made to feel embarrassed or ignorant.

> *"I felt a lot more comfortable in that class being able to advocate, 'Hey, I'm confused.'"*

> *"I didn't feel pressured to constantly automatically know everything."*

> *"When [the professor] was teaching… I didn't feel a lot of pressure to get everything right and to have everything done correctly."*

> *"I like the fact that it wasn't laid back to the point where we weren't learning anything; it was laid back to the point where I felt comfortable."*

> *"[The professor] took more time with students to explain where they went wrong and fix that… It benefits students, instead of just being told 'You're wrong.'"*

> *"We were able to be open in the classroom… it just made it easier to learn multiple different ways how to complete our problem."*

Student responses indicated that instructors typically play a significant role in establishing the classroom norm regarding mistakes and whether or not it's acceptable to make them. Several students recalled an instance during which their professor admitted that they did not explain the content of the lesson adequately and that they would reteach the information during the next

class period. This demonstration had a tremendously positive impact on students. It contributed to the establishment of a classroom environment in which mistakes weren't a sign of weakness or failure. Students witnessed their teacher, the authoritative figure in the classroom, make a mistake, admit to their error, and make another attempt in hopes of improving their work. In other words, students gathered that no one, including their teacher, could flawlessly do or teach mathematics.

> *"One class I remember… you said that you were going to redo [the lesson] the next class… I appreciated that because you didn't feel confident with how you taught it… It's okay not to feel confident in what you're teaching and to try a different approach… That helps both as somebody going into the education field and as a student in math class."*

> *"A lot of professionals wouldn't do that because they feel that... 'I want to maintain my reputation and authority. I shouldn't show vulnerability in any way."*

> *"The way that you had the classroom environment, I felt like if you made a mistake on the board all of us students would easily point it out without being like, "Oh can we tell him that something went wrong?" I felt like that also gave the classroom a culture of correcting each other."*

One student demonstrated incredible growth over the course of the semester. At the start of the class, this student indicated that they felt a tremendous amount of math anxiety and that they were fearful of making any mistakes whatsoever. By the conclusion of the course this student was comfortable making a mistake on one of the final exams due to the teaching methods that were implemented by the professor in hopes of easing math anxiety. The student stated that even though they made an error in a portion of one of the problems on the exam, they still very much enjoyed the process of solving the problem as a whole.

> *"I don't know if it was our final or if it was one of the other exams… I actually think I messed up in one part, but I really liked doing it."*

<u>Theme 3: Improving Mathematical Understanding</u>

Improving mathematical thinking and understanding played a critical role in building students' mathematical confidence and easing math anxiety. Student responses indicated that there were two key factors that greatly contributed to the betterment of their mathematical skills.

One teaching strategy that seemed to greatly benefit students' mathematical understanding was the use of technology in the classroom. This method is known as Technology-Based Learning (TBL). Utilizing technology in math classrooms provided students with opportunities to interact with visual representations of mathematical ideas and allowed them to further develop their conceptual understanding. Many students conveyed that hands-on, technology-based activities aided their understanding of math in a very significant way.

> *"Having all that visual representation helped a lot… because you are seeing a lot of numbers on the page. It's a lot of anxiety."*

"It made it [math] less textbook and numbers and stuff… We were able to see the visual aspect of that versus all of us doing the same problem, getting the same answer."

"I liked the visual aspect of it, because not everything is just numbers in math."

"Being able to see the shapes and being able to use graphs online will definitely help me later on in life when teaching math because technology has become such a big part of our lives."

"The visual drawing stuff helped me, since I am a visual learner."

Oftentimes, using technology in the classroom allows students to participate anonymously. Several students indicated that this aspect of technological resources greatly eased their math anxiety.

"I liked how everything was anonymous because I felt like when we were playing with the tools… I was able to make mistakes and see that my name was covered up."

"Sometimes we put in numbers that didn't work, like we had some slope graphs where we would end up in a different quadrant than the rest of the class… It was anonymous… That was helpful."

"I liked that it was anonymous… It helped a lot with anxiety."

Students also expressed that their professor's use of open-ended probing questions contributed to the improvement of their mathematical understanding. This technique is known as inquiry-based learning (IBL). When students were challenged to inquire about the content, rather than passively receiving information, their mathematical understanding exponentially improved. Consequently, students' math anxiety tended to decrease.

"There are times you asked, 'What did this do?', 'What did this change?' so that we definitely had to use our brains."

"You never gave us a formula first. You always talked about a concept and you got us there and then you go 'Oh, by the way, we just did this formula.'"

"I think [IBL] lessened my anxiety because I was able to explore my options before I learned exactly what I was doing."

"Very, very effective… it should be the way [math] is taught all along. I think a lot of anxiety would go away if it was always taught this way… because you're giving us an opportunity to figure it out on our own terms."

"I think that inquiry based learning is better for students in a way that makes them like things and not just follow a set list… Also I think it helps them remember a lot more when

they understand it, rather than just follow."

Theme 4: Allowing Students to Take Ownership of Their Learning

When students were able to take ownership of their learning, they seemed to develop a deeper connection to the academic material. Essentially, allowing students to take ownership of their learning meant that students were able to play a more active role in the learning process, rather than solely being receptive to lectures. This method tended to contribute to the improvement of their mathematical understanding as well as the lessening of students' math anxiety.

> *"I think I would love to implement this in my own teaching because I really like the way… we're not just being told what to do. We get to figure it out… I feel like that stays in my brain more because I'll remember, 'Oh, I did this.'"*
>
> *"Instead of just copying down everything and memorizing what's on the page, you're putting it into practice with you and your peers, which is a better way."*
>
> *"From a student's perspective, you are in charge of what you're learning, which is really cool and for a student, that's one of the best things, instead of just having someone talk at you."*

Theme 5: Fostering a Positive Classroom Environment

Students consistently indicated that they felt more comfortable in classrooms run by professors that demonstrated their support for students' learning. Typically, when academic instructors expressed confidence in their students, students were more easily able to feel confident in themselves. Several students noted that they felt inspired by the positive classroom environment and aimed to facilitate a similar environment in their future classrooms.

> *"You constantly asked how we felt with certain subject matters and that made me feel like no matter how far lost I was, I could easily just be like, 'I need help.'"*
>
> *"I want to make sure that my students feel comfortable and safe in the classroom."*
>
> *"You had us do weekly reflections. I like those because I think there were times where I didn't really talk about math… It made me feel better in general."*
>
> *"[The professor] talked to us like we're humans… A lot of the time I feel like professors talk to us like we're just robot students and we don't have our own personal lives and things going on… When you showed your kid that one time that was super cute… I felt like there was actual human interaction and not just teacher-student interaction."*

5. Conclusions

This paper identified and analyzed some of the causes and effects of math anxiety using data collected from preservice elementary school teachers enrolled at the State University of New York at New Paltz. Based on this data, recurring themes were highlighted and explored through the use of student quotations.

Most students were able to recall past experiences with math in order to identify the causes of their math anxiety. Then, when reflecting upon the teaching methods used in courses MAT140 and MAT240, students expressed which methods were helpful in lessening their math anxiety and building their mathematical confidence.

The goal of this study was to better understand the contributing factors of math anxiety and to identify the ways in which academic instructors can foster classroom environments that combat students' math anxiety. Limitation of the study includes the small sample size and the abrupt alteration of course setting due to the COVID-19 pandemic. Further data is necessary to construct a more comprehensive analysis of the causes of math anxiety and the methods that best combat it. Based on the findings of this study, more questions arose:

- *What resources can be made available to students outside of the classroom in order to combat math anxiety?*
- *What teaching strategies reinforce the lessening of academic anxiety across disciplines?*

More research is needed as we aim to develop the skills and practices to build mathematical confidence and lessen math anxiety among students.

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