“Don’t Call on Me!”
Mediating Preservice Elementary Teachers’ Mathematics Anxiety in a Problem-Based Classroom

Christina Koehne¹, WenYen Huang¹, Nataly Chesky ¹

Abstract
This study aims to understand the ways in which problem-based teaching in a mathematics content course can alleviate pre-service elementary school teachers’ mathematics anxiety. The significance of this work is to help increase the content and pedagogical knowledge of mathematics education, as outlined in STEM policies. Using a mixed method approach, the teachers-researchers explore what methods, procedures, and other perhaps unknown variables helped pre-service elementary teachers decrease their mathematics anxiety during two mathematics content courses. The findings illuminate five major themes the authors discuss, which are illustrated by rich descriptions of students’ narratives and interviews. Given the importance of mathematics education, particularly the need for strengthening it at the childhood level, this work contributes to a growing body of research that can help future elementary education teachers become exemplary educators.

Keywords
Mathematics education, mathematics anxiety, problem-based pedagogy, pre-service teacher education

Quality teacher education programs are paramount to the success of reform efforts concentrating on the importance of bridging conceptual understanding with procedural knowledge in mathematics education (National Council of Teachers of Mathematics Principles to Action, 2014; National Governors Association Common Core Standards, 2010). Over the last few years, increased attention has been focused on early/childhood education and how best to prepare teachers to meet the needs of the future technological world. Understanding how to train future elementary school teachers to meet the needs of STEM reforms has garnered research attention (Chiu et al., 2015). It can be assumed that STEM education reform, and more specifically, mathematics high-quality teaching and learning, must be concerned with teacher education since it is here that quality instruction in the classroom is modeled and

¹ SUNY New Paltz

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hopefully learned in order to be implemented in future classrooms. However, since elementary teachers are trained to teach all subjects, they often possess deficiencies in their mathematics and/or science content knowledge. Additionally, they are more likely to have developed anxiety or phobia related to these subject areas.

Preservice teachers’ mathematical beliefs have been found to affect their teaching practices. Students who hold stronger beliefs and are less anxious tend to be more confident in their ability to teach mathematics effectively (Haciomeroglu, 2013). Therefore, it seems that pedagogical or content knowledge may not be enough to alleviate deep-seated emotional, psychological, and social responses to mathematics teaching and learning. Accredited teacher training institutions across the country have been revising their programs to meet this concern. As STEM educators in such an institution, we feel strongly that our work has an impact on future STEM educational goals and the students they are, of course, geared to serve. The purpose of this research study is to understand how and if problem-based mathematics educational experiences and learning practices in a teacher education program can help to resolve the level of math anxiety preservice elementary school teachers have before they enter the workforce. We focus on the following two research questions: (1) How does problem-based instruction influence preservice teachers' anxiety in a university mathematics classroom? (2) What do preservice teachers report as impactful to their mathematical learning in problem-based instruction?

**Theoretical Background**

**A Framework of Mathematics Anxiety**

Math anxiety can be defined as “a general fear of contact with mathematics, including classes, homework, and tests (Hembree, 1990, p. 34). Math anxiety is more than simply a dislike of mathematics content. Gresham (2007) refers to it as a feeling of tension, panic, or helplessness experienced when someone is asked to perform math operations or problems, referring to it as an “I can’t syndrome” (p. 182). Hence, math anxiety doesn’t necessarily mean one is poor at math, but that one believes they are. This self-fulfilling prophecy can cause a severe roadblock to learning mathematics, especially in early elementary grades where the necessary fluency skills and critical problem-solving abilities are paramount to learning and critically important to future mathematics achievement.

Mathematics anxiety does not derive from the mathematics content itself. Instead, it is from the way math was presented (Suárez-Pellicioni et al., 2016). Researchers have found that math anxiety is transferable from anxious teachers to their students by influencing their views about mathematics (Fiore, 1999; Jiang et al., 2021; Wood, 1988). Thus, traumatic experiences associated with mathematics that occur during elementary school often lead to mathematics avoidance by the time students are in secondary school (Harper & Daane, 1998).

Disproportionally, elementary school teachers have reported a higher frequency of math anxiety than teachers at other educational levels (Buhhman & Young, 1982), and preservice elementary teachers are found to have poorer attitudes about mathematics than the rest of their peers majoring in other subjects (Trujillo & Hadfield, 1999). This is cause for alarm since it is precisely in elementary school that children start to establish their relationship with
mathematics. Some researchers believe part of the solution may be to change the education of teachers before they enter the workforce. Higher education institutions with teacher certification programs have been conducting research to try and understand how to alter math anxiety in preservice teachers. For instance, Plaisance (2009) found that indeed preservice elementary teachers gained a more positive view of mathematics after experiencing a problem-based pedagogy course as part of their undergraduate course requirements. Researchers have found that the use of concrete manipulatives, engagement in non-traditional pedagogical practices during a methods course, cooperative group settings, and reflective journal writing all help to alleviate math anxiety (Gresham, 2007; Harper & Daane, 1998; Plaisance, 2009). Other interventions that have shown evidence to reduce anxiety include individual tutoring programs, narrative and mindset processes, physiological appraisal, games, and interactive technology (Ramirez et al., 2018).

While the above studies are a good start, there is no clear correlation between learning more pedagogical approaches and a decrease in math anxiety. More research needs to be done to offer a solid recommendation for decreasing math anxiety in higher education institutions’ teacher preparation programs, particularly in elementary education courses that are geared toward specific pedagogical approaches to teaching mathematics (Superfine & Martinez, 2013). It is towards this goal that this study hopes to contribute.

The Potential of Problem & Inquiry-Based Instruction

Student-centered approaches like inquiry-based learning (IBL) and problem-based learning (PBL) are based on the constructivist theoretical model, which is predicated on the understanding that students learn best through actively engaging in the lesson/content. PBL is “an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery, 2015, p. 12).” Problem-based learning asks students to apply theory into practice (Savery, 2006), and focuses on problem-solving and conceptual understanding in the mathematics classroom (Mustaffa, et al., 2016). Furthermore, Hmelo-Silver and colleagues (2007) further described PBL as an approach where “students learn content, strategies, and self-directed learning skills through collaboratively solving problems, reflecting on their experiences, and engaging in self-directed inquiry” (p, 100). In agreement with Hmelo-Silver and the mathematics education community, we view inquiry-based learning and problem-based learning as instructional methods that provide substantial guidance to students, which foster considerable student learning and achievement.

Several studies on PBL have found effectiveness in reinforcing students to develop the ability to think critically, solve complex problems, work collaboratively, and communicate effectively (Duch et al., 2001; Hmelo-Silver, 2004; Savery, 2015). PBL was also found to be more effective than traditional lecture-based instruction style in regard to students’ long-term knowledge retention and skill development (Merritt et al., 2017). Researchers have suggested that IBL and PBL approaches may reduce math anxiety (Lorenzen, 2017; Van der Sandt & O’Brien, 2017). Lorenzen (2017) found that math anxiety, determined through a MARS-S survey, significantly increased for traditional students, and significantly decreased for IBL students over the course of a semester. However, outside of Lorenzen’s (2017) common themes which included “course content, teaching methods, assessment, and student
behaviors” (p. 110), little is known about how these attributes affect the prevalent yet urgent issue of mathematics anxiety. Building on the insights of prior literature, the present study aims to address some of these unknowns.

Current Study
In this study, we employed a mixed method approach relying on survey data to provide an overarching picture of our students' mathematics anxiety. Using the *Mathematics Anxiety Rating Scale (MARS)* survey instrument (Richardson & Suinn, 1972) we administered at the beginning and the end of the courses, we were able to examine changes in self-reported math anxiety and understand the categories that this might encompass within our literature review. This only gives a very broad picture of our students’ experience in our classes. To get a more nuanced understanding, we then turned to reflection journals and interviews utilizing a grounded theory approach.

Participants
The participants in this study included 23 preservice Early Childhood and Childhood (B-6) elementary teachers in a combined Bachelor's Degree and teacher credential program at a large, public East-Coast university. As part of the program requirement, all participants enrolled in and completed two-semester sequential university mathematics courses. Participants include three cohorts of elementary preservice teachers (7 from the first cohort, 8 from the second, and 8 from the third) who took the sequential courses and were enrolled in the concentrations listed in Table 1 below.

Table 1
*Participant Concentrations.*

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Participant</th>
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<tbody>
<tr>
<td>Black Studies</td>
<td>1</td>
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<tr>
<td>Earth Science</td>
<td>1</td>
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<tr>
<td>English</td>
<td>10</td>
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<td>Geography</td>
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<tr>
<td>History</td>
<td>3</td>
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<tr>
<td>Spanish</td>
<td>4</td>
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<tr>
<td>Undeclared</td>
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Participants were selected through convenience sampling, who registered with the same instructor for both mathematics courses. Participants in the first cohort were abruptly interrupted by the COVID-19 pandemic in the first semester and were completely remote in the second semester, whereas the second cohort began the first semester in a remote modality but were then moved to in-person instruction in the second semester. The third cohort had both semesters in-person but were masked and socially distanced for part of the course.

Course Description
These courses are part of the undergraduate elementary teacher preparation program,
developed by the mathematics department, in cooperation with the college of education, in a public institution in the east coast. The courses are the only two mathematics courses required to complete the program for non-mathematics concentration students. The curriculum is composed of topics commonly taught in an elementary mathematics classroom, aligning with the State’s content specialty teacher certification exam.

The university mathematics course met twice a week for 14 weeks each semester, taught by the teacher-researchers. Based on the literature, we identify our pedagogy in this course and study as a problem-based approach (Savery, 2015), with elements of guided inquiry (Banchi & Bell, 2008; Wenning, 2005), and student-driven instruction (Strobel & Barneveld, 2009). The instructional approach had an emphasis involving the search, recognition, and evaluation of patterns, creating a transparent way for students to look and make sure of the mathematical structure (CCSSI 2010, SMP 7; Wilkie & Clarke, 2016). The instructors made maintaining a positive and safe discussion atmosphere the priority of the classroom. Student ownership was encouraged, where students felt that they were contributing, and their idea, regardless of correctness, was being valued and respected (Weening et al.2006). While there were occasional lectures, a typical 75-minute class session was oriented with a hands-on activity where students engaged collaboratively to formulate explanations. In a small group setting, the instructor regularly prompted students to build on peers’ ideas and connect with prior understandings through questioning techniques. Individual group findings were then brought to a class-level discussion, where students were encouraged to present, justify and build on existing ideas, question peer ideas, and generate a narrative summary of their mathematical thinking as a class.

An exemplary problem-based task in our sequential mathematics course was *The Mystery Number Project*. Traditionally, the concept of Greatest Common Factor (GCF) and Least Common Multiple (LCM) are introduced with heavy procedural emphasis; students are often asked to compute a solution given a set of numbers, through methods such as set intersection, product of primes, Venn diagram or short division. Our project reverse-engineered the process by providing students with a solution, or a GCF of 6 and LCM of 180. Students were then asked to generate as many pairs of possible integer solutions that satisfy the parameter and justify their reasoning with their group mates, both orally and in text. Student exploration was guided by probing questions, including “How do you know you have all the possible solutions?” Students were also encouraged to investigate different pathways to the same solution. Rather than learning the concept through rote memorization of procedures, the project offers students the opportunity to collaboratively explore the underlying mathematical structure and investigate the mathematical relationship between GCF and LCM.

**Data Collection**

A Mathematics Anxiety Rating Scale (MARS) survey was administered both pre and post to the sequential mathematics classes on all students. The questionnaire consisted of several questions and was evaluated based on a 1-5 Likert-scale ranging from 1: “no anxiety” to 5: “always anxious” (Richardson & Suinn, 1972).

We also collected student journal reflections, which was required weekly as part of the course assignment for 14 weeks each semester. The data collection of Cohort 1 (n=7) began from the second semester of the course sequence, whereas Cohort 2 (n=8) and 3 (n=8) covers
both semesters. We collected 471 journal entries among all participants, with an average of 20.48 entries per participant across the two semesters. The length of entries ranges from a single sentence to half of a page. The journal was designed to promote communication and build relationships, particularly while the course was in a remote modality, with the instructor. Students were encouraged to reflect and share their feelings in or outside their class experience. Thus, the direction of the journal was mostly open-ended, except for the following four prompts provided at the beginning of each respective month of the semester:

1. What are your hopes for this course towards your feeling of mathematics?
2. How does the project relate to your feeling toward mathematics?
3. How does this course (and the instructor’s teaching approach) relate to your feeling toward mathematics?
4. How do you think your feelings towards mathematics affect your ability to teach math?

In addition, a post-course interview was conducted remotely for each participant in Cohorts 1 and 2 with standardized interview methods (Berg, 2007). The interview protocols prompted participants to elaborate on their appreciation or challenges with their problem-based learning experience, focusing on the lens of mathematics anxiety. This information may not have been captured in the journal data, which were open-ended and collected weekly. The length of interview was approximately 20 minutes. The interview protocols were strategically designed in terms of wording and sequencing in order to effectively invite information from the interviewee (Merriam, 2009). All interviews were transcribed for further analysis.

Findings

Survey Results

Table 2 displays the pre and post count of participants response per question, followed by the corresponding mean. All 23 participants responded to each question. Table 3 displays the percentage of students with a change in anxiety between the pre and post survey results, whether decrease (green), same (yellow), or increase (red) in their Likert-scale for the respective questions. The results show that for nearly half of the students, the problem-based approach effectively reduces students’ math anxiety among all questionnaires in this study.

| Survey Questions | Score (Pre count | Post count) | Mean (Pre | Post) |
|------------------|-------------------|--------------|---------|
| I am anxious when I go into a math class | 1 | 0 | 7 | 1 | 3 | 5 | 2 | 2 | 10 | 15 | 2.43 | 1.65 |
| I am anxious when I open a math book | 3 | 1 | 5 | 1 | 3 | 4 | 3 | 6 | 9 | 11 | 2.57 | 1.91 |
When entering a mathematics classroom (Q1), and opening a math book (Q2), approximately half (47.80% & 55.00%, respectively) of the students decreased in anxiety, with no or minimal (0% & 10%) increase. In addition, around two-thirds (65.20%) of students shared a decrease in anxiety when they studied math alone (Q3). These results reveal that students had become more comfortable and developed confidence in mathematics.

As a course designed to prepare future teacher educators, we are pleased to discover that the students decreased anxiety (56.50%) when doing math with others watching (Q4). Specifically, when the teacher is watching (Q5), a decrease in anxiety (47.80%) accounted for slightly less and three times as an increase in anxiety (17.40%).

We are particularly fascinated in finding that while “doing” (Q6) and “teaching” math (Q7) shared a similar percentage on the decrease of anxiety (47.80% & 43.50%, respectively),
the latter questions revealed a much higher percentage in the increase of anxiety (21.70%) than the former (8.70%). Thus, overall, we see that student’s math anxiety decreased or did not change after taking the PBL content course sequence. Further discussion and explanations will be examined in the discussion.

**Emerged Themes**

While the survey results indicate that the problem-based approach has a positive influence on students’ math anxiety, it does not describe how the characteristics of problem-based instruction relate to students’ anxiety on teaching and learning mathematics. Thus, we further examined the students’ relations towards teaching and learning mathematics by looking at written reflections from students throughout the courses.

Many students would often comment on prior math experiences as negative while revealing that they had the opposite experience in their current course. Thus, before we dive into the emerged themes, we first begin by highlighting the students’ experiences prior to the course. Prior to taking the course sequence, students reported feeling anxious toward mathematics. Their anxiety stemmed from various sources, such as previous teachers, high school courses, or family members. For example,

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

For me in high school I've always struggled with math and I've had anxiety when it came to math. So entering college I was definitely nervous...

My parents are both... were like, ‘No, I don't know how to do this. Like just listen to your teacher.’ ...my dad would just slam the table and like, ‘You don’t understand this, That’s your problem.’ ... So I was like, as a kid, that was so stressful for me.

Now that an idea of the students’ prior experiences and feelings have laid the foundation for how they entered the course sequence, we look at what they found helpful in our mathematics course sequence in remediating those negative feelings. Participants shared various aspects of the courses and how those related to their learning, feelings towards mathematics, or their future teaching. In Table 4, we have grouped the students' comments into five different themes and their prior experiences that were evident in the students' reflections and interviews.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Sub-themes</th>
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<td>1. Collaboration</td>
<td>● Community of learners</td>
</tr>
<tr>
<td></td>
<td>● Comfortable asking peers</td>
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<td></td>
<td>● Peer explanation</td>
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In a similar vein to the comments made about the people in our students' lives and their relation to their math experiences prior to the course, we look towards our first theme: collaboration.

**Theme 1: Collaboration**

Many students revealed the experience of academic isolation in their previous mathematics classes, both at the high school and university levels. They shared the experience of being asked to work independently or being assigned a group setting without an actual opportunity to collaborate. A student made the distinction between sitting versus working in a group:

> I've had like the teacher who like - Yeah, we did our work by ourselves. Like, she sat you 'in a group'[air quotes] but, you didn’t talk to your group members... So it was like a 'group' because we were like in the same part in the textbook, but not a group.

Students expressed defensiveness and loneliness when learning independently. They felt that working with a community of learners provided reassurance and a sense of companionship, which contributed to their confidence towards mathematics and reduced their anxiety:

> When you first look at something [a math problem], the stress and anxiety could be hard, especially if you're alone. So I think the group helped with the anxiety aspect.

You’re working together along with the class, and usually when you’re alone, at least for me, it felt like it was me against everyone else. And with this [class]..., It feels a lot more like you feel a camaraderie, I guess with your peers, which is really nice.

Students reported that asking and discussing mathematics with peers at a group-level
was less intimidating than directing the questions to the instructor at a class-level. They were also more likely to admit confusion or misunderstanding, and seek assistance in a small group setting with their group mates:

> just having us put in the groups definitely really helps with math anxiety already because I was able to talk to like, you know, kids my own age about it. I think when like the teacher it over you or you’re talking in the teacher, that has a little bit more anxiety, at least for me.

I really like working in the group because it lets me work through the answers with people without having to necessarily like, say, the answer in front of the whole class and stuff. So it gives me the opportunity to like, check my work with other people before having to like, fully commit to an answer, I guess, in front of everyone. Which definitely helps me become more confident in my answers and less anxious about it.

Beyond the sense of being mentally supported, students revealed that working in groups allows them to rely on peer explanation and identify mistakes in learning mathematics:

> I think that working in groups is fun and is helpful because I get to see someone else's way of thinking and if I'm confused they can explain a problem to me in a different way that I haven't even thought about before.

In fact, many described a reciprocation relationship that helping others will benefit them when they themselves need the help later. They saw peers as valued resources in their journey of mathematics learning. The students also shared that working with peers created opportunities to learn and grow from each other by reasoning, critiquing, and making a connection between different mathematics ideas. They found that investigating different peer approaches to the same solution furthered their mathematical understanding.

> I feel like it gives everyone a chance to bounce off each other and it just makes the lesson more fun. I don't normally look forward to doing math, but I'm surprisingly really excited about this first project.

Working in groups is helpful in this project so we can compare solutions with each other, whereas in the other project the group work was more talking and discussing different methods we used to come up with the solutions.

Here, we see the students reported that collaboration made the math learning process more engaging, creative and prompted their interest in the math content. While some students' responses focused on how group work benefited themselves, others suggested a motivation and obligation to contribute to peers’ understanding. As pre-service teachers, students also felt helping their peers mutually benefited them by 1) developing teaching skills and confidence in their teaching ability and 2) enhancing their knowledge and understanding of mathematics content.

> I studied with [student1] and [student2] on Tuesday and walking them through the steps when they’re confused really helps deepen my understanding [sic] too. It makes me think of new ways to explain it to them that actually make more sense to me than
how I thought about it before.

As seen from the findings so far, the students also saw value in working with their peers and preferred to avoid the feeling of academic isolation when working alone. Moreover, our next theme highlights the students' comments on learning as a class. Thus, we turn our eyes to our second theme: Classroom discussions.

**Theme 2: Classroom Discussion & Questions**

Most of our students experienced a lecture-based approach in their prior math classes, where the dominance of the teacher’s voice is at the expense of students’ opportunity to express, argue and develop their own thinking.

You had us talk to each other a lot, which is something that, at least in math class. You didn't do very often. It [other math class] was always like pretty silent work. Or you'd like just watch the teacher... When we were together you had us talk to each other about it, which was interesting, which I did like.

Many students also admitted that due to the fear of embarrassment from asking questions or participation in a discourse, they would choose to remain silent despite their lack of understanding of the content, creating a vicious cycle that must be disrupted. Rather, the students expressed their preferences to learn in a discussion-based classroom, where the instructor creates an expectation for students to ask questions, exchange ideas, and be involved in a mathematical debate. As a result, students felt openness in exploring mathematics topics with less pressure.

Your methods are. Uhm? I think there was a decrease in it [anxiety] when there was a... It was more discussion-based... you made it more open for all of us to kind of look at each other and say like, ‘oh I have the same question as you. Maybe we should just ask it instead of holding back.’

professor goes like ‘if you have a question, I bet there's one other student.’

In addition, students identified specific teacher moves by the instructors that cultivated participation in the mathematics discourse, including the normalization of asking questions in the class, and deliberately allocated time and structured opportunities for peer discussion.

We used to have like classroom like debates about like which was right and like. Yeah sometimes like both of the answers seemed right. Your method, I guess, was for like the class communication like, so we would figure out together and sometimes that like worked and we all came to agreement.

If I had a question you would also be like, ‘can anybody else help out’ and then other students would jump in, which is also really helpful.

You'd write on the board and you do, you talk about 'Anybody? Alright, try to figure it out and then discuss with your classmates next to you.'
Particularly, students revealed their dislike of the “cold-call” strategy from their prior experiences, which forced them into a vulnerable position and created an atmosphere of anxiety. They appreciate that, despite the instructor’s effort to promote participation in the class, the cold-call technique was not adopted.

It was never a cold call. It was always that you have time to prepare. Then you have the option.

I like that you didn't always, not always, I like that you didn't like try and get people to participate, like if they didn't want to answer in class, they didn't have to. That's not something that a lot of teachers do.

Being called on in class to present an idea or strategy was noteworthy to the students here. However, the students also emphasized why they did not like being called on or asked to share, prepared or not. We examine this emphasis in our third theme: View of mistakes.

**Theme 3: View of mistake**

Prior to our course sequence, students often held a negative view of mistakes and associated mistakes with shame, guilt or even failure, which lead to an undermining of students’ self-esteem.

In a lot of other in my classes, I feel like if I don’t get, you know something right the first time I feel stupid.

Rather than embracing the mistakes as part of their learning, students often felt punished for their attempts which deprived them of the pleasure or enjoyment of exploring mathematical concepts.

High school trigonometry is the last math class I took because my teacher ruined my math experience. Every single item was graded in that class. And like, if I made a mistake, that's it. That became my grade. So I was never, ever doing a question for pleasure or just to understand it.

Certain students also shared a fixed mindset when it comes to making mistakes in math, believing that they are not intelligent or capable of solving the math problem.

My anxiety for math had started at a young age... I thought I couldn’t succeed and excel in it.

Throughout our course sequence, the students started to embrace making mistakes as an inevitable part of learning mathematics and became comfortable with trial and error of their own.

I feel like I appreciated the fact that I could have error and what I was doing and that it wasn’t the end of the world.

... you actually supposed to be making mistakes, like. It's OK to try something.

Many students began to shift into a growth mindset, where they were no longer afraid
of asking questions despite the possibility of being wrong. With the instructor’s encouragement, some students felt the obligation to share their confusion and ask questions. When students felt safe and supported in the class environment, they were more willing to take risks with challenging questions.

I felt A lot more comfortable in that class to be able to advocate. Hey, I'm confused and you know when a professor goes like 'if you have a question, I bet there's one other student’... we were able to just be open in the classroom.

Students shared that the hands-on, problem-based approach encourages them to take ownership of their learning. They had more opportunities to actively “figure out” the problem instead of passively being told what to do. These experiences may have contributed to the students’ shift in embracing mistakes, particularly when making mistakes is naturally a part of investigating and exploring in a problem-based approach.

We’re not being told directly what to do. We get to figure it out... That stays in my brain more because I'll remember, ‘Oh, I did this.’

From a student’s perspective, you are in charge of what you’re learning. One of the best things instead of just having someone talk at you, [is that] you're figuring things out.

Consequently, students came to find mathematical learning enjoyable, despite the complexity of the math programs or the error associated. They were comfortable in attempting difficult problems that required thinking and exploration, and found the traditional drill and practice type of task boring. Specifically, they found the problem-based project to be both fun and challenging. In fact, many of the students’ growth mindset on their view of mistakes also extended to assessment. While frustrated with their test score, students began to respond positively to the idea of making mistakes while learning the content.

I think mistakes are part of learning everything. You have to make a mistake and you have to learn from it. So it helps in math because I'll make a mistake like on the first two tests and then on the final, I understood it. And I was like, OK, I'm not going to make the same mistake again.

We also found that students' anxiety toward making mistakes is not limited to the mathematics classroom. Many expressed significant fear when speaking about their future elementary math teacher role. Compared to the impact on their grades, students were more afraid that their lack of math content would prevent them from being effective math teachers and being a disservice to their future students.

The idea of it [teaching math] scares me because I don’t want to teach anything wrong like I don’t wanna [sic] like if I go through a whole question and I end up being wrong. I wanna [sic] crawl under covers and just cry, so that’s important. That’s why you have to go through it as important to make sure you do so. That definitely gives anxiety.

I am not confident in math myself unless it is the simple stuff, therefore I will be very apprehensive and cautious of teaching math. I don’t want to be a math teacher to be very honest. I do not want to teach my students wrong.
As seen in this section, the students saw mistakes as connected to understanding. However, the students' comments regarding their understanding did not only reference mistakes, but also on their way of learning. This leads us to our fourth theme: Conceptual Understanding.

**Theme 4: Conceptual Understanding**

Prior to the course sequence, students reported mathematics as a procedure or process. This idea reappeared in the reflections as a comparison but would also occasionally compete with their new ways of thinking about learning. Students noted their prior mathematical experiences as something they would do in steps or computed calculations.

> It's very interesting to think about how we were trained in school to view math as simply just calculations and not the deeper ways in which a problem could be solved if that makes sense.

> In high school... I’d have to go back to the step-by-step directions... You kind of get dependent on that... I wouldn’t have my notes and I wouldn’t know what to do.

> Although, sometimes these procedural habits would win-out and the students would memorize the process or procedure without understanding the concept.

> I just have to study the rules of divisibility a couple of times to memorize it for the chapter test.

> ..but the memorization with a square is a parallelogram but a parallelogram is not a square tends to trip me up.

However, most of the time, students' reflections reveal that their understanding of mathematics in this course was through exploration instead of memorization. The idea of exploring math instead of memorizing was new to the students, but many found it to be beneficial and engaging. Students shared that problem-based learning made them dive deeper into the concept and reinforced them to be reflective on the underlying structure and reasoning of the mathematics concept.

> There are times you asked, ‘What did this do?’ or ‘What did this change?’ so that we definitely had to use our brains.

> I think it is more effective to learn how we arrive at formulas first rather than being given the formula and solving. And the same goes for other topics, it is effective to learn the concepts first and then the vocabulary, even though sometimes it doesn't make sense in the beginning.

Students also acknowledge the importance of understanding the mathematics reasoning embedded in the “step-by-step” procedure, sharing that an understanding the underlying mathematical structure provides them with a more comprehensive understanding of the material, and ease their anxiety toward mathematics, especially during an assessment.
It will help lessen the anxiety on the tests if we fully understand why we're doing all the steps that we're doing... understand the steps better rather than just trying to memorize them.

When the teacher just gives me the steps, I just memorize the steps. Mm-Hmm. And then if you give me a question that's like not exactly like with the steps, I'm not gonna [sic] understand it. But the way you teach it, you could give me a bunch of different questions worded in different ways, and I'll figure it out because I get the actual concept of it.

The students especially appreciated when they could see mathematics fit into everyday applications and the world around them through the exploration experience. The connection made mathematical learning more relevant, which eased students’ math anxiety. When you would give a lot of examples completely applying it [the math concept] to real life... that helped lessen anxiety because I could understand the purpose of it more when you would explain it in a real-life setting.

I like the projects as they help me bring mathematics to my own lived experiences. It adds more depth and makes me think much differently than just a quiz would.

In addition, the students appreciated the opportunity to explore mathematics and learn it in more than one way. They heavily relied on multiple descriptions, drawings, visualizations, and solutions. Students noted their appreciation of learning mathematics concepts through multiple representations, especially ones that they previously found challenging, such as fractions.

I really enjoyed today's class with all the vast categories and visual representations to further [sic] illustrate how to solve fractions, and later when learning how to solve a decimal to a fraction. I believe the color coding and the shapes helped me understand the concept further.

It has changed my understanding [sic] of fractions because [sic] anytime I even thought of working with fractions I'd get very nervous. This is because I've never really enjoyed working with fractions because of lack of understanding the material. However, this project has shown me that fractions aren't as complicated as I thought they were because of the many different ways there are for you to understand them.

Some students shared that their learning through the problem-based approach via exploration and different approaches were vital. The experience not only enhanced their mathematical understanding but also shaped their role and identity as a future teacher. Looking at it from a different perspective it makes it fun to learn fractions. It also helps me as a future educator understand how the computational answers are related to the figures.
I loved the premise of the project. Finding shapes in the real world and proving it through their properties. This was designed to teach us properties of shapes and introduce new technology that we can use in the future as teachers.

In commenting on exploring the content, applications, and multiple descriptions, students remarked on making the connections and exploring the pedagogical pattern before being introduced to academic language. Thus, the students were focusing on teaching methods, which leads us to our final theme: Extra Teacher Effort.

**Theme 5: Extra Teacher Effort**

Our last theme has little to do with the content and everything to do with the teacher and the structure of the course. When reflecting on prior experiences, students mentioned how many instructors would speed through the material and would feel as if they were a failure if they did not learn the content immediately or on their own. Not only did this put tremendous pressure on the students; but it also raised concerns about the instructors' passion and professionalism in teaching the subject and made students uncomfortable asking questions or seeking help.

Most of my professors now here, they just go straight into the slides, don't care about students at all, like what they're doing. It's kind of sad like it is sad to see because they're just like, very like, like looking very depressed and just want to get the slides over with.

A lot of my prior teachers would just zoom into new material and not asking questions, That's - a lot of my math teachers were like that. 'There, I finished teaching this. Next section.' And like, in a way, the mindset is like, 'I don't care if you didn't understand it or not.'

In contrast, students frequently reported in our data that the instructor would often seek feedback from the class and slow down or re-cover the material the following day when students signaled a topic was gone over too quickly. Thus, the students appreciated the pacing in our sequential math courses.

I love your teaching style and how you adjust the pace as we go. I appreciate that you seem to have an organized plan for the semester, but if we, as a class, need a little extra time on one topic or if we caught on to another topic really quickly, you were flexible in your pacing.

Her priority isn't to get through the material, rather to make sure we all understand even if that means slightly pushing back deadlines.

Several students also recall a specific class incident that occurred during the early stage of the course, during which the instructor admitted that he did not explain the content adequately and would re-teach the information in the following class. Students felt the public confession and the effort to improve the teaching practice successfully modeled that mistakes are not a sign of failure and demonstrated the instructors’ courage and confidence. As a result, the gesture earned more student respect.
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.

Additionally, the students reported that they felt the instructors were very supportive both in and outside of the classroom. They acknowledged the instructor’s caring and passion for teaching the class. This willingness to provide extra assistance and compassion for students' needs transformed into incentive for students to seek help from the instructors themselves.

The fact that you were nice and you wanted us to ask questions and you told us straight forward that you want to be the best teacher you could be. Like, it broke down that barrier and as you were teaching me and I was learning from you, and like it didn't have such a — the power contract is gone.

Many students expressed appreciation on how the instructors set up the course with clear outlines and assignments. They noted and appreciated the organization of the course structure, and the variety and level of assessments given throughout the course as different ways to demonstrate their understanding and collaboratively explore the topics further. They reported that the course structure decreased their stress levels and anxieties.

I enjoy your class because we have projects, homework, quizzes and midterms that can all show how we are doing.

I love how organized this class is. From the very beginning I likes [sic] how this class wasnt feeling overwhelming with work and it was distriputed [sic].”

In summary, the students not only appreciated a well-organized and structured course, with varying learning opportunities and assessment types, but also the attitude and democratic nature of the instructors.

**Discussion**

We begin our discussion by calling attention to the connective characteristic of our findings. With respect to our first research question: *how does problem-based instruction influence preservice teachers’ anxiety in a university mathematics classroom?* Supported from anecdote stories from the students, the results could be interpreted by the following two explanations. First, the course reinforces the students to own their identity as a future teacher, and serves as a reality check on the type of math they will be responsible for teaching. Second, the instructor’s modeling contributed to the preservice teacher’s acknowledgment of the effort and skills needed to effectively adopt a problem-based teaching approach. Additionally, the results indicating that many students had developed a trust bond with the instructors and their teaching approach which could explain the decreased anxiety students reported regarding being watched while doing mathematics. We found that, overall, our students mostly felt a decrease, or no change, in their math anxieties after the PBL content course sequence. This finding was similar to Lorenzen’s (2017) findings regarding elementary preservice teachers’ math anxiety after an IBL content course. Furthermore, Lorenzen (2017) noted a few students
whose journal entries showed markers of high anxiety, we also had a few students note a slight increase in math anxiety for particular survey questions. Thus, our main goal for this study was in regard to our second research question: what do preservice teachers report as impactful to their mathematical learning in problem-based? Our study uncovered what the students found to be impactful to their mathematics learning in the PBL instruction. Certainly, given the nature of our research question, methodology, and setting, the five themes that emerged are intertwined and non-exclusive. However, understanding the significance of them separately allows us to gain an understanding of the specific ways in which our students’ experiences have helped them alleviate their mathematics anxiety. Thus, we will discuss each theme separately.

Our study found that students had negative prior math experience that made students compare themselves with their peers and work in isolation. However, as described by Hmelo-Silver and colleagues (2007), our PBL instructional environment sought to encourage student engagement, reflection, and collaboration in the lessons. Thus, in the math content courses, they found that working as a collaborative community was beneficial to their learning and not as anxiety-inducing as their previous math experiences. When students are familiar with and feel comfortable in sharing with peers, students’ learning increases and anxiety decreases (Hsu & Goldsmith, 2021; Theoblad et al., 2017). This finding agrees with previous researchers’ findings and suggestions that “cooperative groups provide students with opportunities to exchange ideas, ask questions freely, verbalize their thoughts, justify their answers, and debate processes” (Blazer, 2018, p. 3). Beyond remediation support from peer explanation when facing difficulty in learning the content, the opportunity to exchange and build upon peer ideas enriches students’ mathematical understanding and helps students to develop more confidence in their teaching ability while explaining the content to their peers. Thus, prompting collaboration is more than getting students to feel obligated to support each other, but also guiding the students to see the mutual benefits of a collaborative relationship. Steele et al. (2013) illuminates this important theme, concluding the collaboration is a powerful pedagogical framework for students to feel their own praxis and thereby alleviate their math anxiety by becoming more self-governed in their individual learning process.

Similarly, in that students prefer not to work in isolation, the findings also suggest that the teacher’s instructional approach and the established class norm significantly affect students’ comfort level and willingness to participate in a class-level discussion. Students prefer to participate in discussions and ask questions when they feel safe and supported. In considering Bush’s (1989) findings “that teacher math anxiety was positively related to time spent on whole-class discussion and negatively related to number of questions asked by students” (Ramirez et al., 2018, p. 151), it is valuable for anxious future teachers to see the value in student lead discussions through questioning. Additionally, Sanders et al. (2019) study contributes to our understanding of how discussions in class greatly influence students’ learning. Not only did discussions in their coursework help provide an engaging and enriching classroom environment, but they found it also helps ease students’ anxiety. Discussion is an important part of our teaching. It contributes to an overall social environment that emphasizes cooperation and discovery, rather than competition and performance. Students are not randomly called upon or singled out to contribute their ideas or answers. Rather, students themselves chose to participate as they felt motivated and interested in sharing their thoughts and findings. This can contrast with other university courses our students experience. No cold
calls were utilized, which has been identified to generate high anxiety in students (England et al., 2017), and hearing students focus on this aspect validates our assumptions and pedagogical knowledge of what makes good teaching. In fact, previous research suggests that teachers should “avoid forcing lower-performing students into intimidating circumstances, such as working problems on the board or being singled out to answer a question in class” (Blazer, 2018). This is particularly essential in STEM fields, where students often feel inadequate and anxious about the content. As indicated by our findings here and previous research, some of the anxiety towards this content is driven by mistakes.

In most mathematics classrooms, mistakes are considered poor performance and are often punished by grades. Suárez-Pellicioni and colleagues (2016) remark on the previous claims from Turner and collaborators (2002), that “teaching based on high demand for correctness but providing little cognitive or motivational support may lead to avoidance on the part of students” (p. 10). Our findings provide evidence that students appreciated the freedom to try, make mistakes, and revise their understanding without the pressure of being evaluated. This finding agrees with Blazer’s (2018), in that “teachers should provide encouragement to all students, emphasize that everyone makes mistakes, and refrain from tying self-esteem to success in math” (p. 4). We also found that the ownership of learning in a problem-based approach led to the students finding value in errors, which improved their confidence in asking questions and taking risks in learning mathematics. Students have shared that teacher modeling plays a significant role in creating a culture that is open to mistakes. It is paramount that aspiring teachers unlearn some of the practices and norms they experienced in their K-12 math classrooms that may have contributed to their current math anxiety. One of which was a view that making a mistake was bad and something to be embarrassed about. We know, through the work of Boaler (2014) and others, that mistakes are integral to the learning process. This is especially true in mathematics. As Hollingsworth & Knight-McKenna (2018) study depicts, where the dispositional shift from anxiety about making a mistake to building self-efficacy can be achieved through a classroom environment in which making mistakes is celebrated rather than shunned. We were surprised that the view on making mistakes was such a prevalent theme in our data. Although we did not analyze quantitatively, we feel the most dramatic change throughout our courses was our students' acceptance in making mistakes in class. This shift may be most significant in reducing anxiety for our students. Ramirez and colleagues (2018) propose a framework to reduce student anxiety by shifting from a failure-as-debilitating to a failure-as-enhancing mindset. We very much agree and wonder how we can further promote a growth mindset in mathematics rather than one that was based on a deficit, anti-risk model that leads to students' anxiety.

Conceptual understanding was the least surprising theme of our findings given the literature and our own anecdotal experience. This was also amongst Lorenzen’s (2017) thematic development for their IBL students journal responses. In this study, we were not interested in determining whether our students understood a concept better or will one day become better teachers in that concept. Rather, we focused on whether our teaching helped alleviate their anxiety and therefore their confidence in learning and teaching mathematics. Our study examines students' emotional responses and not evidence of students' cognitive learning. Research has shown that problem-based instruction has a decreasing impact on preservice teachers' math anxiety (Van der Sandt & O'Brien, 2017). We further the case for PBL
in content courses by noting what the students positively and negatively reacted to within this teaching model. In this study, our evidence suggests that teaching conceptual understanding through exploration helps alleviate math anxiety by helping students feel they can interact with the concepts better. A traditional mathematics classroom often focuses more on reaching the correct solution instead of student understanding (Finlayson, 2014), and overemphasizing rote learning or memory retrieval in place of conceptual activities contributes to learners’ math anxiety (Ramirez et al., 2018; Trujillo & Hadfield, 1999; Vinson, 2001). Sense-making through active learning in mathematics classroom significantly reduces students’ anxiety (Blazer, 2018). In this study, we found that students enjoyed the hands-on opportunity to actively examine, explore and develop their own understanding. They also appreciated the open-ended probing questions that helped them connect or extend mathematical ideas, which reinforced their exploration of mathematical meanings and relationships.

The students in our study focused on different aspects of the content in the course. Most of our students considered themselves to be visual learners who appreciated seeing ideas presented visually, whether that be in the form of a diagram, a sketch, or using physical/digital manipulatives. Using manipulatives in math classrooms could represent abstract concepts with visual and concrete material, allowing learners to better understand math ideas and reduce students’ anxiety effectively (Blazer, 2018; Plaisance, 2009). Students also reported that having or seeing multiple examples and different pathways ways of solving the problem by the teacher and/or their peers not only led to their appreciation of the specific mathematics concept and structure, but it also improved students’ confidence in their teaching skills. These learning opportunities to shift and adapt between different problem-solving strategies prompted mathematics flexibility (Star & Rittle-Johnson, 2008), and may contribute to the increase of students’ mathematical confidence and change students’ view of mathematics (Boaler, 2014). Additionally, students in our studies shared that they valued seeing how the mathematics related to their everyday lives or the world around them. This relation also reduces math anxiety by helping students understand that math is a useful tool (Blazer, 2018).

Students’ mathematics anxiety is significantly associated with their perceptions of teachers’ quality in the classroom. For example, students who view their teachers as supportive, responsive, responsible, and flexible all revealed a lower anxiety level (Lazarides & Buchholz, 2019; O’Hara et al., 2021). In alignment with the literature, we found that instructors who asked for feedback regarding their pacing and showed an effort to incorporate students’ feedback created a safe classroom environment where students felt less stressed and more comfortable in their learning. The students felt “seen”, “heard” and “cared” about as individuals, which in turn, allowed for them to advocate for themselves. Moreover, many students shared their recollection of a specific incident where an instructor publicly admitted his dissatisfaction with how the lesson was approached and allocated additional time in the following class to reteach the lesson. The mainstream belief in students’ experience is that teachers are expected to always be confident in mathematics without mistakes or are considered not to reveal the reservation of their mathematical ability or knowledge (Chen, 2022). The contracting experience “humanized” the instructor and conveyed the message that the instructor cares about students’ learning over the reputation of being correct.

Our findings confirm that building a relationship is essential in effective teaching. We found that an instructor’s willingness to consider the students as individuals, listen to their
concerns, accommodate when possible, and be flexible in their pacing of the course all contributed to the students feeling more comfortable advocating for themselves and asking questions. The students frequently noted attributes of caring or humbleness in relation to their comfort as a student. This suggests that the students found these attributes in their instructors as indicators of more personable and approachable people. These findings agree with literature, as a review on math anxiety factors found “a large body of narrative evidence supporting the idea that early negative experiences with teachers contribute to the development of math anxiety (Ramirez et al., 2018, p. 150). In addition, positive encouragement from teachers can serve as a motivation factor and stimulate students’ confidence in their math learning (Jamieson et al., 2016).

Thus, it is no surprise, and in alignment with the literature, that many of our students reported that various styles of assessment and ways to demonstrate their understanding had helped lessen their anxiety in mathematics class (Luttenberger et al., 2018). However, we are most surprised with our last finding, in that the organization and clear layout of the course, as well as the transparency of the scope and sequence, contributed to the students' reported feelings of not being overwhelmed. Goldman (unknown) stated, "when people don't have a routine or structure to their day it can cause increased stress and anxiety, as well as overwhelming feelings, lack of concentration, and focus" (as cited in Garber et al., 2022., p. 2). Thus, providing students with a clear course structure can help students in creating a new routine with clarity that will not add but potentially alleviate additional stress or anxiety towards mathematics and how they will be evaluated.

**Conclusion & Implications**

Based on our extensive teaching experience and review of the literature, several of our themes were not surprising, while others surely were. The finding that emerged that most surprised us was within the extra teacher effort theme. On reflection, this should not have been surprising, especially given the post-pandemic academic climate we were now operating from. Our study mainly occurred during the covid-19 pandemic and the semester afterward.

Certainly, the pandemic is one of many variables that could have influenced our students’ responses. Our students, like many across campus and perhaps throughout the country and the world, craved teachers with empathy. K-12 Mathematics instruction for many of them was characterized as sterile, lecture-based, emotionless and oppressive. Therefore, experiencing a problem-based, student-centered, growth-mindset classroom devoted to wonder and excitement for doing mathematics was a significant difference experience for many of our students. Adding to all this, a teacher that cares about their students, is organized, transparent, supportive, communicative, and models making mistakes must have surely gotten our students’ attention! It is impossible, given the parameters and methodology of our study, to conclude which of these variables were most influential in alleviating our students' mathematics anxiety. However, it is obvious that teacher effort played a significant role and ought to be further researched. Additionally, understanding the ways in which the pandemic affected university students should be understood in relation to teacher education and mathematics education.

Teachers’ attitude toward mathematics impacts their pedagogical approach and the way they engage students with mathematics in their classroom, which then impacts their own
students’ attitude toward math (Ramirez, 2018). This study validated that the teacher’s pedagogical impact is applicable to our participants, both as a student and as a future elementary teacher. The research to understand how to combat mathematics anxiety falls in the beginning and at the relative end of educational reforms efforts. While we are learning much about the causes of math anxiety and ways to combat it in schools, as well as learning the consequences and possible solutions for teachers with math anxiety, we know little about how teachers can come to alleviate their math anxiety prior to entering the classroom. To begin, we need to better understand the initial causes of anxiety, not only how they have stemmed through the K-12 education environment, but how they remain so entrenched through teacher education programs. While knowledge on this topic has already been generated (Superfine et al., 2013), more research needs to be conducted on inquiry/problem-based activities that solicit fun inspirational ideas, in ways that consider beyond performing procedures and focuses supporting students’ exploration of mathematics concepts. One such study is underway in a separate paper.

This study had several limitations we would like to highlight now. First, the MARS survey data did not consider majors/grades. A longitudinal study would be beneficial and something we will consider for future research endeavors. We recognize and emphasize that this was only a two-semester course sequence, which may not be enough time to completely alter a person's beliefs, attitudes, or anxieties towards mathematics. The students in our study mostly entered the course sequence with high levels of math anxiety and did not all entirely change their perspectives on mathematics or have lessened effects of math anxiety after the end of the two-semester course sequence. However, the students did report some positive math experiences from the course sequence that contradicted their initial experiences and views, which possibly caused their math anxiety to decrease. A student’s end-of-course reflection emphasized their increase in confidence as a mathematics student and a future mathematics teacher: “I had a super fun time, and I learned so much will be so beneficial to me as a future educator. You made me love math just a little more, and it doesn’t seem that scary.” These are the experiences and comments that we have reported on here as potentially influential and important for mathematics educators to consider when teaching these content courses. Another limitation of our research design is that we relied on retrospective self-reported data, which are naturally based on the participants’ perception and are prone to their bias.

Addressing students’ mathematical anxiety requires instructors to provide support for students to be comfortable with the content and see value in specific pedagogical practices involving inquiry. This process, as well as the teacher-student connection, develops over time. Thus, we believe it is important for content teachers to reflect on ways to challenge the students’ negative experiences and provide them with more positive views and experiences in math. Beginning teachers face a very difficult task; in collaboration with a national non-profit organization New Teacher Center (NTC), Haynes (2014) estimated that 40 to 50 percent of new teachers leave teaching after the first five years of their teaching career in the United States. Learning valuable pedagogical practices that can entice and create wonder and interest in their classroom, as well as elicit a high level of learning is the skills public school districts expect from new hires. Teachers possessing these skills will have a higher competitive edge in the job market and be on their way to becoming master teachers. Students will learn the highly valuable teaching disposition of being reflective about one’s own knowledge and past
experience, and learn how it can influence their future teaching habits. In turn, their own future
students may view mathematics as a more fun and non-threatening subject that they can learn
to excel at and even enjoy doing. We sincerely hope our study helps contribute to literature in
understanding how to alleviate elementary preservice mathematics anxiety and lead towards
teaching education programs that develop exemplary STEM teachers for the future.

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ORCID iD
Christina Koehne https://orcid.org/0000-0002-7224-1554
WenYen Huang https://orcid.org/0000-0003-1933-6295

References
Pearson/Allyn & Bacon.
Research Services, Miami-Dade County Public Schools.
Boaler, J. (2014). Research suggests that timed tests cause math anxiety. Teaching Children
Mathematics, 20(8), 469-474. https://doi.org/10.5951/teachchilmath.20.8.0469
Arithmetic Teacher, 30(3), 55-56. https://doi.org/10.5951/AT.30.3.0055
Atlantis Press. http://dx.doi.org/10.2991/assehr.k.220131.059
Mathematics. Washington, DC: National Governors Association Center for Best
/wp content/uploads/Math_Standards.pdf
STEM education at the whole school level: A review of the literature. In NARST 2015
Annual Conference.
classrooms: Perceptions about active learning and persistence in the major. PloS one,


Lazarides, R., & Buchholz, J. (2019). Student-perceived teaching quality: How is it related to
different achievement emotions in mathematics classrooms?. Learning and Instruction, 61, 45-59. https://doi.org/10.1016/j.learninstruc.2019.01.001


