Math Anxiety Data Sources: Capturing Individual Differences Through Diverse Lenses

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This multiple case study explores the affordances and limitations of four data sources: a validated math anxiety (MA) scale, written narratives about one's relationship with mathematics, semi-structured interviews, and recorded classroom observations. Analysis of three preservice elementary teachers revealed that each data source provides a unique and valuable perspective. Our findings demonstrate the need for researchers to leverage a diverse range of data sources to develop a more robust understanding of each individual's MA experiences, their MA triggers, responses to these triggers, and how these things may change over time.

Keywords: math anxiety, preservice teacher education, observational data

Identifying ways to reduce the math anxiety (MA) experienced by preservice elementary teachers (PSTs) is a persistent concern in education. Defined as "a feeling of tension, worry, and/or fear in situations involving math-related activities" (Bjälkebring, 2019, p. 1), MA is particularly prevalent among PSTs (Hembree, 1990), and is linked to a variety of negative outcomes for their future students (e.g., Mizala et al., 2015). Although relatively well studied, the vast majority of what is known about PST MA has been established through research conducted primarily using self-reported data sources. We aimed to investigate the affordances and constraints of three such data sources (a validated MA scale, written narratives about each PST's relationship with mathematics, and semi-structured interviews), as well as a fourth data source that does not rely on PST self-report, namely classroom observations.

Literature Review

Research on PST MA is primarily conducted using four data sources: validated survey scales, written narratives, interviews, and classroom observations. Validated survey scales are, by far, the most widely used data source, and therefore underpin most of what is known about PST MA. These surveys ask individuals to rate the amount of anxiety they associate with various mathematical settings, such as "listening to another student explain a math formula" (Alexander & Martray, 1989, p. 147). These surveys are easy to administer, take little time to complete, and can be helpful in identifying broadscale shifts in MA experienced over the course of a semester (e.g., Barrett, 2013). Despite their usefulness, these scales are limited to the situations referenced in the scale items, which tend to emphasize testing scenarios (Pizzie & Kraemer, 2019).

In contrast to surveys, written narratives give respondents the freedom to share about their MA experiences in their own words and to highlight the mathematical situations that are most relevant to them. Such narratives can help identify classroom aspects that either exacerbate or reduce individual PSTs' MA (e.g., Lipscomb & Lorenzen, 2023). Similarly, interviewing PSTs enables respondents to share about aspects of their MA that they believe are important and allows researchers to ask clarifying questions. This increases the chances that the researcher will build a nuanced understanding of PST's MA experiences and the kinds of scenarios that trigger their MA (e.g., Stoehr, 2017). The fourth data source, observational data, is rarely leveraged in published research; however, this data source has the potential to yield unique insights because it does not rely on PST self-report. That is, observational data can provide researchers with access to aspects of PSTs' MA that they are unaware of themselves (e.g., Daniel & Bailey, 2024).

Theoretical Perspective

We drew on Ramirez et al.'s (2018) *interpretation account* of MA because it acknowledges the individualized nature of MA by asserting that "students' development of MA is largely determined by how they interpret … previous math experiences and outcomes (rather than the outcomes themselves)" (p. 151). This perspective explains why certain situations, such as receiving a failing exam grade, might give rise to MA for some students and not for others. If a student interprets the failing grade as evidence that they have a fundamental inability to succeed in mathematics, that interpretation may provoke MA in future mathematical settings. In contrast, if the student interprets the failing grade as the product of their instructor's strict grading policies, this interpretation may give rise to anger instead of MA. We selected interpretation account because it centers the ways in which PSTs make sense of their own MA, the unique situations that elicit it, and the kinds of experiences that might help to alleviate it.

Leveraging the individualized focus of interpretation account, we define *MA triggers* as the unique mathematical situations and/or interactions that elicit tension, fear, or worry for an individual PST. Interpretation account suggests that MA triggers are unique to each PST because such situations and/or interactions will be interpreted differently by individuals. Although PSTs will write and speak about their MA triggers in a variety of ways, researchers have identified some MA aligned language commonly used by math anxious individuals. For example, Stoehr and Olson (2023) found that math anxious PSTs described their mathematical experiences using words or phrases such as *embarrassed*, *math is not my thing*, and *dreaded math class*. PSTs will not necessarily write or talk about all of their MA triggers (or even be aware of them); however, noting the commonly used MA-aligned language can help researchers to identify such triggers, thereby gaining a fuller understanding of each PST's unique MA experiences.

Because interpretation account asserts that the development and experience of MA is dependent on individualized interpretations of events, it also implies that MA experiences depend on a complicated tangle of factors, such as past experiences, personality, and culture. This suggests that multiple data sources are necessary in order to develop a robust understanding of the various ways in which MA is experienced by different PSTs within a single class. The primary aim of this work is therefore to explore what can be learned using four different data sources in characterizing the MA experiences of PSTs over the course of a single semester.

Methodology

The purpose of this multiple case study (Yin, 2018) is to understand the strengths and limitations of four different MA data sources: a validated MA scale (sMARS; Alexander & Martray, 1989), written narratives about each PST's relationship with mathematics, semi-structured interviews, and classroom observations. The three cases each consisted of a single PST enrolled in a terminal mathematics content course. Of 25 study participants, we selected three PSTs with high sMARS scores and different classroom dispositions; Mari was reticent, Eva confidently participated in class, and Velma was loquacious but appeared to lack confidence in class (all pseudonyms). We aimed to answer the research question: What do we learn about PSTs' MA using the sMARS, written narratives, interviews, and classroom observations?

Data was collected in Spring 2024 and included the sMARS (pre/post; Alexander & Martray, 1989), short written narratives about each PST's relationship with mathematics (pre/post), semi-structured interviews (pre/mid/post), and recorded classroom observations (pre/post). To characterize each PSTs' baseline MA, we used a priori theoretical coding for MA-aligned language (e.g., Stoehr & Olson, 2023) on the pre-narratives and interviews. We coded the pre-observation for evidence of their MA triggers and trigger responses and open coded the same

data for any additional MA triggers and trigger responses beyond the MA-aligned language. To track any MA changes, we performed descriptive statistics on the sMARS data and open coded the post-semester narratives, interviews, and observations for any changes in PSTs' MA triggers, responses, and potential rationale for those changes. After writing up case descriptions, we performed a cross-case analysis to answer our research question.

Findings

Our sMARS data showed that Mari and Eva reported notable decreases in their MA levels at the end of the semester (3.7 to 2.0 out of 5 and 3.6 to 2.9 out of 5, respectively). Velma's pre- and post-sMARS scores were nearly identical, with average item scores of 4.1 and 4.0, respectively. Considering these scores alone, it appeared that Mari and Eva had experienced a marked reduction in their MA levels, while Velma did not. However, considering the PSTs' written narratives, their interview responses, and our classroom observations revealed that all three PSTs' MA experiences had changed substantially over the course of the semester. Further, we observed that these changes were unique for each PST—not just in magnitude, but in nature.

Mari: "I can't figure it out on my own"

As identified in her pre-narrative and interview, Mari's baseline MA triggers were shaped by a belief that her peers were more mathematically capable than her: *working without support* and *peer comparison*. With respect to her first trigger, Mari expressed a desire to avoid working alone, writing in her pre-narrative that "I work better with a partner or in groups." In her pre-interview, she indicated that she not only felt more comfortable learning mathematics with her peers but believed that she *could not* do so without them. For example, Mari said, "I don't like doing stuff on my own. … I can't figure it out on my own." Despite her affinity for group work, Mari indicated that comparing her mathematical capabilities to theirs was also a source of MA. In her pre-interview, Mari was asked to clarify why she had scored the sMARS item *listening to another student explain a math formula* as eliciting more MA than *watching a teacher work on an algebraic equation on the board* (5 and 3 out of 5, respectively). Mari explained:

> When I hear another student, like, "oh, I did all of this to get this answer," I would just think, "I didn't even do it that way. I didn't even think the way she thought." … I get anxious thinking about that. But when I see a teacher doing it, it makes me feel better.

This explanation made it clear that, in addition to working alone without support from her peers, comparing herself to them mathematically was also a prominent MA trigger for Mari.

In the pre-interview, Mari described remaining inconspicuous as her primary response to an MA trigger. She stated that "I rather just sit quiet in math since I don't understand at all," and, when asked about sharing her thinking with the class, Mari said "I'd be deadly afraid to go up to that board and write everything down." Mari's pre-classroom observation was consistent with this characterization, as we saw her stay silent the entire class period, often engaging in behaviors that may have indicated anxiety (e.g., arms crossed, staring off, chewing her lip).

By Mari's mid-interview, we found emerging evidence that her levels of MA (connected to both MA triggers) were decreasing. This was most apparent when Mari discussed her experiences during the midterm exam and a subsequent email she received from her professor. Although the professor made it clear that students would have ample opportunities to correct any mistakes they made on the midterm, Mari reported that taking the exam was a stressful experience because she spent most of the exam comparing her experience to that of her peers:

> I heard everyone going, "Oooh!" like they under-, they said, "Oh!" out loud. I was like, what do you mean, "Oh?" I don't know what they're "oh"-ing about. … I was like, …

> maybe I'm not getting this. I was doing it … and I kept moving on. But then they're like, "Oh, I get it." And I was like, I'm not getting this … because I was not "oh"-ing.

Although her lack of having an "oh" moment made her fear that she had performed poorly, Mari reported that the professor sent her an email that had helped change her perspective:

> She sent me an email saying that I did really good in the midterm and that she was proud of me. And I was like, I did good on the midterm? … I just hoped that I passed, … but she was like, "You did really well. I'm so proud of you." … I was like, that means I should not think low of myself. I can actually learn this. So, next time … I could be like, hey, Mari, you can do this. You did well, … you can do it again now.

This suggests that this interaction with the professor helped Mari to make progress with respect to both of her MA triggers, as she seemed to recognize that she was capable of doing mathematics on her own, and that she had done so without "oh-ing" like her peers.

Mari's progress in overcoming her MA triggers appeared to continue throughout the semester. In her post-narrative, she wrote that her relationship with mathematics was "completely different now than it was before." She identified her realization that mathematical problems can be solved in multiple ways as a source of this change, which seemed to free her from her peer-related MA triggers. In her post-interview, she said, "Now that I know there's multiple other ways to do it, … if I can't do it one certain way, I could try another way to do it, because maybe that way works better for me than the other person."

Although Mari reported feeling much more comfortable in class during her post-interview, this change was only marginally observable. Mari was still mostly silent in her post-observation, and she did not share her mathematical thinking with her group or during whole-class discussions. However, we did observe her smiling and sharing a brief high school math experience with the whole class. For Mari, the observational data indicated some change in how she responded to her MA triggers but did not reveal the same profound MA transformation evident in her sMARS scores, written narratives, and interviews.

Eva: "It really was more dependent on the teacher"

Unlike Mari, Eva's MA experiences seemed unrelated to peer comparison or beliefs about her capabilities. Eva said early on that her MA was almost solely triggered by *teachers requiring particular solution methods* and *inadequate teacher support*. Eva wrote about her first trigger in her pre-narrative by describing a high school class: "I didn't like that I couldn't argue my point or think creatively in any sense. … I was frequently told I was wrong, even though I had gotten the correct answer, simply because of the method I chose to solve the problem." Similarly, in the pre-interview she described asking for mathematical explanations and being rebuffed: "No one could explain to me why things were the way that they were. … Like, two plus two equals four, just because two plus two equals four. There was no rhyme or reason." When asked whether the content of her high school math classes influenced how she felt about the class, she replied, "I think it's not so much the content that affects the math course … it really was more dependent on the teacher." Therefore, Eva's baseline data revealed that her MA was almost entirely dependent upon the classroom environment created by the course instructor.

Eva's pre-interview indicated that, in the past, she had responded to her MA triggers with disengagement. For example, she described disengaging after a teacher dismissed her question: "It was like, well, if you're gonna ignore me, then I'm gonna ignore you right back." However, such behavior was never witnessed during Eva's pre-observation. This was perhaps due to a lack of Eva's MA triggers in class; the course was specifically designed to emphasize the use of multiple solution strategies and the professor was attentive to students' questions.

Although Eva reported a decrease in her MA over the course of the semester, it was clear that this decrease was almost entirely instructor dependent. In her mid-interview, she indicated that the format of the course had improved how she felt about mathematics:

> The discussion element of [the course] really helps me out. And I think that is what the missing piece was when it came to my high school experience with math. So, I'm definitely feeling a lot better about it now.

Eva also stated that she felt supported by the instructor and her extensive assignment feedback: "She tells you what you're doing right and not just what you're doing wrong. Like, 'I love this thinking, can you just expand on this?' … At least I know I'm on the right track." In her post-narrative and interview, Eva suggested that her increased comfort with mathematics may not follow her into other mathematical environments. For example, she wrote, "I am not fully confident in my abilities, but I do have courage I could succeed given the right circumstances." When asked in her post-interview if her course experience changed the way she felt about mathematics more generally, she responded, "I have a better relationship with math, even though it doesn't really have to do with math, it has to do with the class."

All of Eva's observations showcased a mathematically confident student with no evidence of her identified baseline MA response of disengagement. Although this observational data appears to conflict with the MA decrease in her sMARS scores, Eva's narratives and interviews resolve this apparent incongruity. These data sources revealed that for Eva, MA was situational and dependent on the instructor's pedagogical practices. It is reasonable to assume that Eva's pre-semester sMARS responses were made referencing high school experiences, while her post semester responses likely referenced the current course environment. Eva's comfort with this environment perhaps meant that she rarely experienced MA in class during the study, fully explaining both her sMARS score decrease and the lack of observable disengagement.

Velma: "I'm just the lost person"

In her pre-narrative and interview, Velma repeatedly stated her belief that she was incapable of doing mathematics, a belief that permeated both of her primary MA triggers: *perceived mathematical inadequacy* (by self or others) and *having a wrong answer*. With respect to her first trigger, she stated in the pre-interview: "I'm not good at math. I still struggle to this day with my math. I constantly count on my fingers. … I can't do math." When asked to describe herself in her favorite class, history, she referred to her brain as a "sponge"; when asked to describe herself in math class, however, she described her brain as a "big blob."

While Velma did not self-identify a specific response to her first trigger, we observed a pattern of disengagement in class. When one of her groupmates expressed confusion, she quickly whispered "I'm confused too." When this groupmate later made progress and was praised by the teacher, Velma declared: "I'm just the lost person." After this exchange, Velma did not watch as her classmates shared their thinking in the whole group discussion and spent the rest of the class engaging in behaviors such as playing on her phone, ripping up paper, and doodling.

Her second trigger, *having a wrong answer*, emerged in the pre-interview: "I'm afraid of being wrong and being shunned for being wrong. I'm scared to be wrong. I'm embarrassed to be wrong." She then described responding to this trigger with silence: "I don't answer the questions. I don't like to answer the question in front of the class." Our pre-observation of Velma corroborated this response; she did not verbally contribute to either her group's collaborative thinking or to the whole group discussion.

Later in the semester, we found evidence of a shift with respect to Velma's second MA trigger (*having a wrong answer*), but not with respect to her first (*perceived mathematical*

inadequacy). We observed an increase in Velma's group participation, a change she identified herself in the mid-interview: "If it's not about something I like, I'm like, I can't do this. … I think [my group has] really helped get me out of that. They're like, 'Come on, you got the answer.'" Velma went as far as to say that "My group's really helped me just be less nervous and anxious." In the post-interview, Velma indicated that she had made further progress with respect to this trigger: "Now I'm like, okay, if I'm wrong, just tell me. I get it. I'm dumb sometimes, and I can't think. … Don't be afraid to tell me it's wrong. Like, teach me how I can fix it."

Despite this progress, her self-description as "dumb" and unable to think indicated that her first MA trigger, *perceived mathematical inadequacy*, remained consistent. In the mid-interview, Velma described her midterm exam experience: "I only got one and a half problems done. I got to the second page and … I couldn't get my brain around it." These self-disparaging descriptions persisted throughout the semester, with her post-interview rife with statements such as "I suck at math." Her post-narrative similarly contained statements such as "Basic math is simple but anything past that is too hard. My relationship [with math] remains the same."

Our post-observational data, however, painted a very different picture of Velma. We saw evidence of confident mathematical engagement that did not align with her own self-descriptions. As an example, consider Velma's contribution to a group discussion about the problem ⅓ divided by ⅙. Her groupmates arrived at different answers and were expressing confusion and frustration. Unprompted, Velma interjected: "It's 2. Because if you look, one sixth takes up half of the one third, and if you add another one it makes one whole, so [the answer is] 2." Velma did several things in this response that demonstrated confident mathematical engagement. First, she participated actively, sharing her thinking with her group without their encouragement. Second, she asserted her answer in a way that demonstrated certainty in her response. Finally, when sharing her thinking, she did so succinctly and in a way that made sense to her peers, starkly contrasting her representation of herself as "dumb" or unable to think.

Initially, Velma expressed confusion and frustration when working on fraction addition (e.g., "I'm just the lost person"), and rarely shared her thinking with her group mates or the whole class. By the end of the semester, and despite her expressed lack of confidence (e.g., "I'm dumb sometimes"), she participated in meaningful ways. Her contributions, both in small and whole groups, indicated that Velma was making progress with respect to *both* MA triggers, yet she only recognized improvement with respect to *having a wrong answer*. Consistent with the continued narrative that she believed herself incapable of math, she reported the highest sMARS score of the three PSTs both at the start and at the end of the semester, and her decrease was the smallest in magnitude. It was clear that Velma continued to view herself as incapable and was unaware of the shifts in confidence that we observed in her end of semester classroom observation.

Cross-Case Findings

As we looked across the three PSTs' MA journeys, the theme that emerged from comparing the data sources was that there was no single most insightful data source. In fact, the most insightful data source varied across cases. The sMARS provided insight into the existence of self-reported MA but failed to reveal how each PST's MA had changed. For example, the sMARS data showed a decrease in MA for both Mari and Eva but not the differing nature of their changes in MA; the sMARS missed that Mari's MA decrease was tied to a fundamental shift in how she viewed herself as a mathematical thinker, while Eva's was tied to a comfortable classroom context. These insights were revealed through their interviews and written narratives, through which we were able to characterize how they made sense of their MA triggers, responses, and the changes they experienced in these over the semester. Yet, the classroom

observations did not reveal any meaningful changes in behavior for either Mari or Eva. Observational data, however, was critical in understanding Velma's MA journey. The sMARS did not identify a change in Velma's MA, failing to register the shifts in how she responded to her MA triggers that were clearly evident in her interviews and second classroom observation. In fact, Velma's shifts in MA with respect to her first trigger would have gone undetected without the observational data. In conclusion, the cross-case analysis revealed that, consistent with the individualized nature of MA, each data source holds potential to reveal unique insights, though the nature of these insights will vary from person to person.

Discussion

We aimed to answer the research question: What do we learn about PSTs' MA using the sMARS, written narratives, interviews, and classroom observations? Our analysis revealed that each data source provided a unique and valuable perspective for each individual PST and presented its own affordances and limitations. For example, the validated survey scale helped us quickly identify high MA study participants and revealed some MA decreases. However, this data source could not identify the stark differences in the nature of these PSTs' MA decreases; it also did not identify the change in Velma's MA evident in other data sources.

Although our study was limited in size, each case illustrates how conclusions drawn in extant research may be enriched by analysis of additional data sources. Consider Barrett (2013), who used validated surveys (pre/post) to conclude that teaching PSTs to reason with manipulatives reduced their MA (a finding consistent with other studies, e.g., Gresham, 2018). If Eva was a participant reporting an MA decrease in this study, an interview may have yielded insight into whether this drop resulted from—or in spite of—the manipulative use. Without such data, it would be unclear if using manipulatives served as an instantiation of Eva's first MA trigger (*teachers requiring particular solution methods*) or if she viewed their use as a means to explore her own strategies.

Velma, in particular, illustrates how even the most robust data collection can fail to detect MA shifts if the study only employs self-reported data. Stoehr's (2017) study exemplified robust longitudinal MA data collection, showcasing the power of written narratives and interviews to reveal individualized aspects of PST MA. With three PSTs, Stoehr found that their unique MA coping mechanisms employed in learning mathematics carried over to teaching mathematics (e.g., working to conceal knowledge gaps). Despite Stoehr's extensive self-reported data and analysis, it is possible that a participant like Velma (who was sometimes unaware of how her MA manifested) may have presented a unique challenge to Stoehr's analysis. For participants like Velma, the absence of observational data likely translates into an absence of insight.

Beyond the value of varied data sources in MA research, the most commonly used data sources are often not utilized to their full potential, including in our own study. For example, the sMARS measures three dimensions of MA, *math test anxiety*, *numerical task anxiety*, and *math course anxiety* (Alexander & Martray, 1989). Though most validated MA surveys measure more than one MA dimension, few researchers utilizing these scales disaggregate their results by MA dimension, potentially ignoring readily available insights. Although we failed to consider disaggregated sMARS scores, our analysis suggests that, in addition to having a distinctive set of MA triggers and responses, each PST will also likely have a particular data source where changes in their MA are most evident. Because such evidence is not visible until data is analyzed, it is vital for MA researchers to utilize multiple data sources, including both self-reported and non-self-reported measures. This will honor the individualized nature of MA and ensure that MA research findings benefit a broad range of PSTs who struggle with MA.

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