

Attending to voices of women and racially/ethnically minoritized students: Conflicting perceptions of mathematical competence

Background and Purpose

Many scholars have researched the phenomenon of the secondary school-tertiary transition (STT), in mathematics considering cognitive, didactics, sociocultural (De Guzman et al., 1998), and affective dimensions. The nature of mathematics at university is different than secondary school mathematics, resulting in certain affect-related outcomes that prevent students from becoming competent mathematicians (Di Martino & Gregorio, 2019). Holding a positive attitude about ourselves is one of the key aspects of meaningful participation along with the ability to effectively communicate mathematically in becoming involved in a new community (Lave & Wenger, 1992). Women rate a lower mathematical self-conception than men even though mathematics has a slightly better gender representation in mathematics than other STEM domains (Sax et al., 2015). However, increased representation does not always provide women and racially/ethnically minoritized students with equal representation in public mathematical spaces, such as classrooms. It is documented that women in mathematics often experience challenges in a way that positions them at the periphery of mathematical participation (Solomon, 2007). Women have difficulties in acknowledging their potential in mathematics due to gendered stereotypes in many mathematical communities (Solomon, 2007). STT research is limited in its ability to address the intersectionality of identities such as race, gender, or ethnicity in the examination of affective dimensions of mathematics learning. Therefore, we examined the obstacles in the STT by using affective aspects such as perception of competence of women particularly from racially/ethnically minoritized populations in mathematics (Di Martino & Gregorio, 2019). We also highlighted perceived competence in mathematics with attention to emotional expressions, as well as the notion of belonging considering legitimate peripheral participation of women (Solomon, 2007). Accordingly, our guiding research question is: *How do women and racially/ethnically minoritized students in the mathematics major position themselves as mathematics learners considering their perceptions of mathematical competence?*

Theoretical Perspectives

We adopted the three-dimensional model for attitude (TMA) for our conceptualization of the relationship between beliefs and emotions as components of students' experiences with mathematics in university (Di Martino & Zan, 2010). The three dimensions are vision of mathematics, perceived competence in mathematics, and emotional dispositions towards mathematics. Students' vision of mathematics as being more relational or instrumental (Skemp, 1978) are linked to their beliefs of mathematics. Students' beliefs about themselves as mathematics learners, which are influenced by their vision of mathematics, can be thought of as perceived competence in mathematics (Di Martino & Gregorio, 2019). Finally, Di Martino and Gregorio (2019) identified associations between the vision of mathematics and perceived competence, which often manifested through emotional responses. We particularly addressed the component of perceived competence on students' mathematical experiences. We also discovered that the notion of belonging deserved more attention when it comes to the identity development of women and racially/ethnically minoritized mathematics students.

Method

Participants and Settings

We conducted a pilot study, the Women and Underrepresented Minorities in Mathematics (WURMM) study, from Spring 2019 to Spring 2020 in which 13 students participated. The pilot study focused on mathematics majors who were from racially/ethnically minoritized populations (e.g., students of color, women). The pilot study consisted of multiple data sources such as interviews, survey responses, students' reflection diaries, and seminar¹ artifacts. Considering our aim to address students' perceived competence, our paper focuses on the activity conducted in the second seminar which was held in Spring 2020 with four participants. We report data from three of the four participants (see appendix for Table 1) for whom we have complete data profiles. Two students were pure mathematics (PM) majors and one student was a secondary mathematics teaching (SMT) major. The goal of this seminar was to gain insights into students' STT experiences from affective perspectives. We prompted students to talk about the attributes of mathematicians by addressing perceived competence in mathematics and mathematical identity during the seminar activities. The data sources we focus on for this paper consist of video recordings from four seminar sessions (two hours each) conducted in Spring 2020. We also collected data through students' written artifacts from the fourth seminar session's activity and post-survey responses. Finally, we draw on interviews conducted in Spring 2019, which included information about demographic, secondary school experiences, perception of mathematics, and perceived competence in mathematics. We were able to analyze the affective components of STT experiences by comparing secondary school to university experiences related to perception of competence and vision of mathematics.

Session 4 activity: Exploring attributes of mathematicians

We designed an activity to capture the salient attributes of a mathematician's identity. The activity was useful in prompting students to articulate the attributes of a competent mathematician and accordingly to understand students' beliefs on their perceived competence in mathematics. Also, the activity enabled us to observe students' emotions while they talked about mathematical competence. We shared a Google document with students which was divided into four quadrants with a guiding question for each: (1) Who is a mathematician?, (2) What does a mathematician do?, (3) What does a mathematician say?, and 4) What do you consider a mathematician is not?

We asked participants to individually think about their responses to the questions and then each participant populated the Google document with their comments. Since participants were asked to use only short phrases or terms within the document, we also facilitated a discussion in which participants could more thoroughly share their perspectives. The activity helped elicit students' thoughts on mathematicians' identity attributes and how they relate to emergent characteristics. We asked the same questions in the post-survey to provide students with a chance to express their personal opinions, without being influenced by responses from other participants.

Preliminary Findings

Using aspects of the TMA, we highlight our findings related to perceived competence and concomitant emotions. We present excerpts that reflect students' views on the attributes of a

¹ We use the term "seminar" to describe the intervention we included during the pilot study. These seminars (one in Summer 2019 and one in Spring 2020) consisted of four sessions each (each session was 2- to 3-hours in duration), and included mathematical tasks, discussions, and short presentations.

competent mathematician, as well as the emotions evoked when they reflect their own mathematical competence.

Attributes of a mathematician

Participants reflected on the attributes of a competent mathematician (see appendix for Figure 1) including mathematician's identity, discourse, and actions. Sunny used the expressions of "creative and logical" by stating that a mathematician communicates by "clearly indicating logical processes and reasoning as well as the goal of the problem" (Post-survey 2020). Sunny valued logic and clarity as part of a competent mathematician's identity. Manuel similarly articulated that a mathematician is a "problem solver and logical" and asks "why?" Dana's reflection included: "The way in which they communicate automatically provokes thinking critically and stimulates conversation" (Post-survey 2020). Dana's response underlined the importance of communication aspects. That is, she valued a mathematician who contributes to the common discourse within a community of practice.

Next, students elaborated on the prompt which was related to how mathematicians can change their confidence. Sunny reflected on the prompt from a personal standpoint and responded with "expanding her course work and exploring more areas of mathematics" as a way to help her to improve her confidence. Interestingly, Manuel referred to the mathematician's identity as a "title" rather than an "action" (Post-survey 2020), which he thinks could help to improve how mathematicians do mathematics. We speculated that the basis of this idea of a mathematician might have its roots in the conventional view of a mathematician, which positions them as naturally capable in society regardless of their actions. Dana responded with: "by 'doing' more mathematics, and by surrounding themselves in a supportive environment that promotes intellectual conversation about mathematics without rejecting the ideas of others" (Post-survey 2020), which aligned with her earlier comment during the seminar. Dana's responses reflected her perceptions of a competent mathematician that were closely related to social participation in mathematical communities. Dana valued a mathematician who is also precise in communicating mathematical ideas and creates a dialogue. From her perspective, the latter also stressed the significance of discourse, which was aligned with social aspects of a mathematician's identity.

Perceived competence in mathematics

We asked further questions about students' perception of competence in mathematical communities. Dana's mathematical confidence was supported by her vision of mathematics. That is, she emphasized a key aspect of her mathematical confidence related to being able to develop relationships between abstract concepts and as she progressed through the course work.

I feel as if in a way... it has made me feel *more confident, but also less confident*² for different reasons. Like, *I feel more confident because of these higher-level math courses*. I'm learning about math as this abstract concept and the more I'm just learning about these different concepts and I'm able to connect different relationships that are allowing me to just form different connections. And so, in that way, *I begin to feel more confident*. (Seminar 2020)

We also noticed certain negotiations concerning perceived competence in mathematics in Dana's articulations. It appears that Dana's perceptions of a competent and confident mathematician that she described earlier was conflicted with how she felt about participating in mathematical spaces.

² Italics are used to indicate expressions which we considered aligned with the emotional dimension of TMA.

In the preceding excerpt, Dana outlined some perturbations in her perceived competence, including doubts when surrounded by “brilliant people” and questioning of her abilities in mathematics.

...But also [I’m] just *less confident*. The more I’m surrounded by people that are just really brilliant and I just, I tend to... I don’t know how to explain it. I feel as if, even though I am in the same classes as them and I do have a right to be there, I always just, *never built up enough confidence* to, like, for example, just ask a question or just be involved and I feel not to turn this into a whole gender thing, but I feel as if... Because like STEM and mathematics still are more of a male-based subject, *it’s hard for me to really voice my opinions and voice what I feel*. When I am in a group of all guys during a study group or like when I’m just doing partners, you know, I just *tend to get less confident*. (Seminar 2020)

Dana’s negotiations of her perceived competence in mathematics accompanied by emotional states and doubts about her belonging to her mathematics community. Affect was not only associated with vision of mathematics but also certain sociocultural factors in her experiences. When we raised the notion of societal norms that shape women’s perceived competence in mathematics, her responses reflected a feeling of underrepresentation in mathematics classes starting in high school and dealing with norms and stereotypes regarding women’s abilities attached to it. The next excerpt captures Dana’s sensemaking of her participation in mathematical spaces, in which she reflected on her experience in high school and her ongoing negotiation of a sense of belonging in a mathematics community.

...I think we all know our capabilities and we all know that we deserve to be where we are in the mathematics department, but I also think, you know, we hear all these things and we hear these societal standards that *it’s hard to just ignore those facts*, you know? And *it’s hard to just push that aside*... I don’t think as much in the university as it was in high school... in math classes where, at least for me, I would be one of the only few girls and sometimes the only girl in some of my math classes. And I know that just *inhibited my ability to ask questions* and to, you know, *participate as much as all the other people* in my class because I just felt as if *I ...wasn’t worthy enough* to ask these questions, but just *scared* and just that I don’t know, I just *felt like always out of place* because of that. (Seminar 2020)

Dana pointed out that gender-related factors hindered her participation in the mathematical discourse during high school mathematics classes. It is worth noting that Dana went to a small, private, and predominantly White high school in the southeastern United States. Her expression of discouragement to participate in such mathematical discourses focuses attention on the stereotypical positioning of women as dissociated from the mathematics discipline. Tensions surfaced during Dana’s negotiation of her mathematical identity, specifically in the case of taking part in mathematical spaces. Her experiences in high school mathematics classes, such as being one of few females, made her question her belonging to mathematics. Moreover, Dana articulated her challenges with rejecting societal norms against women, which could alter her participation in mathematics classes despite her achievement.

Sunny also expressed her perception of competence in mathematics in emotionally laden ways, which raised questions regarding the definition of competence for students in the major. Considering Sunny had grades of over 90% (out of 100%) in her major, it was remarkable to detect conflicting patterns in her beliefs about confidence in mathematics during the seminar. The following excerpt highlights how Sunny attributed aspects of her self-concept to both the nature of mathematics being broad and unknown as discipline as well as to the social comparison.

Sunny: *I don't think I'll ever be confident in mathematics*, to be honest, I feel like there's, it's just such a wide thing. And there's so much to learn. And there's so much that goes into it. I feel like I could like, have a Ph.D., and have like 10,000 awards and *still not feel confident* beyond it...

Interviewer: And there is nothing to change that?

Sunny: Oh, I don't think there is. I mean, in my case. I'm always going to feel like there's more to learn. And there are people who know more than I do.

Her negative statement about her confidence seemed to contrast with her previous view regarding improving her competence by expanding her course work. Though Sunny did not mention gendered discourses, her identity as a young woman in mathematics might have been shaped by the masculine nature of mathematics. Her reflections aligned with Dana's statement that being around smart people led to doubts about one's competence in mathematics. Finally, Manuel's reflection on the perceived competence in mathematics differed from those of Dana and Sunny regarding being surrounded by other smart people in the classroom. Manuel expressed that "I find more ... drive and competitiveness about the idea that they know more than I do. I understand more" (Manuel, Seminar 2020). Evidently, Manuel distanced himself from his peers in his perception of competence in mathematics.

Discussion, Conclusion, and Implications

We captured students' ideas of a competent mathematician and how those perceptions related to how they view themselves as competent in mathematics. We noticed that the nature of mathematics becoming an abstract and broad discipline had some favorable influences on how Dana and Sunny reflected on their competence. Talking about perceived competence in mathematics elicited some emotions for students such as being scared away from participation (Di Martino & Zan, 2011). Moreover, we explored perceived competence of women and minoritized students in mathematics while illustrating the negative influences of gendered discourse on their identity. We detected issues in the participatory nature of mathematical spaces, which seemed to exclude women from becoming full participants in it (Solomon, 2007).

We also explored how women are challenged emotionally, which led to identity negotiations regarding their capabilities. While Dana believed that she was a capable mathematician (as evidenced by other survey data) gendered stereotyping (Leyva, 2017) may have created barriers for her towards participation in mathematics. In fact, Dana and Sunny were both emerging women mathematicians who possess superb mathematical ability and were extremely enthusiastic. Our analysis also uncovered alternative forms of becoming successful in the discipline of mathematics (Solomon, 2007) including legitimate peripheral participation (Lave & Wenger, 1992). In our investigation of perceived competence and emotions, we also gained insights on the need for belonging, particularly for people from racially/ethnically underrepresented groups participating in mathematical communities (Lahdenperä & Nieminen, 2020). Belonging and perceived competence seem to be interrelated and are specific to women and minoritized groups' participation and persistence in mathematics (Good et al., 2012). Considering that small numbers of women and racially/ethnically minoritized students pursue mathematics related fields (NSF, 2019), mathematics environments should foster inclusion for these populations.

Acknowledgments

This research was funded in part by a Florida State University College of Education Dean's Circle Research Grant.

Appendix

Table 1: Demographic information of selected participants

Participants	Major/Year	Gender	Ethnicity
Dana	PM/Sophomore	Female	Hispanic/Latino
Manuel	SMT/Sophomore	Male	Hispanic/Latino
Sunny	PM/Sophomore	Female	Non-Hispanic/Latino

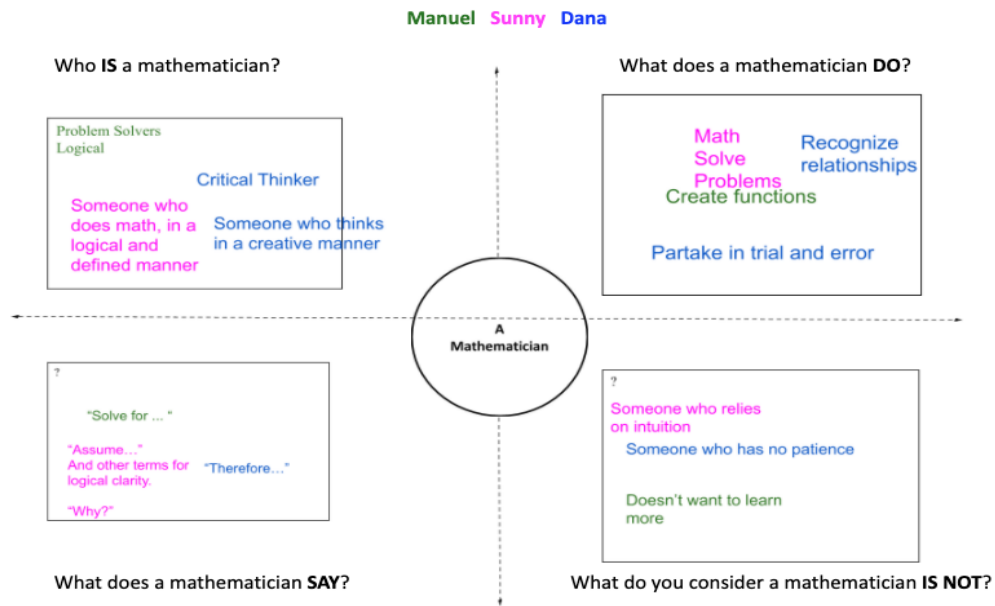


Figure 1. Students' artifact from the activity for exploration the attributes of mathematicians

References

- Di Martino, P., & Gregorio, F. (2019). The mathematical crisis in secondary-tertiary transition. *International Journal of Science and Mathematics Education*, 17(4), 825–843. <https://doi.org/https://doi.org/10.1007/s10763-018-9894-y>
- Di Martino, P., & Zan, R. (2010). “Me and maths”: Towards a definition of attitude grounded on students’ narratives. *Journal of Mathematics Teacher Education*, 13(1), 27–48. <https://doi.org/10.1007/s10857-009-9134-z>
- Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM Mathematics Education*, 43(4), 471–482. <https://doi.org/10.1007/s11858-011-0309-6>
- Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women’s representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700–717. <https://doi.org/10.1037/a0026659>
- Lahdenperä, J., & Nieminen, J. H. (2020). How does a mathematician fit in? A mixed-methods analysis of university students’ sense of belonging in mathematics. *International Journal of Research in Undergraduate Mathematics Education*, 6(3), 475–494. <https://doi.org/10.1007/s40753-020-00118-5>
- Lave, J., & Wenger, E. (1992). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
- Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics education. *Journal for Research in Mathematics Education*, 48(4), 397–433. <https://doi.org/10.5951/jresmetheduc.48.4.0397>
- Mendick, H. (2005). Mathematical stories: Why do more boys than girls choose to study mathematics at AS-level in England? *British Journal of Sociology of Education*, 26(2), 225–241. <https://www.jstor.org/stable/30036060>
- Mendick, H. (2006). *Masculinities in mathematics*. McGraw-Hill Education.
- NSF (2019). *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Arlington: National Science Foundation. <https://nces.nsf.gov/pubs/nsf19304/digest>
- Sax, L. J., Kanny, M. A., Riggers-Piehl, T. A., Whang, H., & Paulson, L. N. (2015). “But I’m not good at math”: The changing salience of mathematical self-concept in shaping women’s and men’s STEM aspirations. *Research in Higher Education*, 56(8), 813–842. <https://doi.org/10.1007/s11162-015-9375-x>
- Skemp, R. R. (1978). Relational understanding and instrumental understanding. *The Arithmetic Teacher*, 26(3), 9–15. <http://www.jstor.org/stable/41187667?origin=JSTOR-pdf>
- Solomon, Y. (2007). Not belonging? What makes a functional learner identity in undergraduate mathematics? *Studies in Higher Education*, 32(1), 79–96. <https://doi.org/10.1080/03075070601099473>
- Solomon, Y., Lawson, D., & Croft, T. (2011). Dealing with “fragile identities”: Resistance and refiguring in women mathematics students. *Gender and Education*, 23(5), 565–583. <https://doi.org/10.1080/09540253.2010.512270>