

“Dear Math...” Letters: Insights into Mathematics Graduate Students’ Mathematics Identities

T. Royce Olarte
University of California, Santa Barbara

Cierra Street
Cal Poly, San Luis Obispo

Rachel Tremaine
Colorado State University

Casey Griffin
University of Delaware

Tenchita Alzaga Elizondo
University of Texas,
Rio Grande Valley

Understanding mathematics identity development has yielded insights for undergraduate mathematics education. In this work, we build on existing conceptualizations of mathematics identity to explore this construct in the context of mathematics graduate students with academic career aspirations through analyses of “Dear Math...” letters. We identify and detail four dimensions of graduate students’ mathematics identity: Doer of mathematics, Sharer of mathematics, Feeler of mathematics, and Believer of mathematics. We conclude by discussing implications of these dimensions, as well as the unique opportunities of “Dear Math...” letters to provide valuable insight into graduate students’ mathematics identities.

Keywords: Graduate Students, Mathematics Identity, Methodology

Introduction

Mathematics identity development has emerged as a critical area of research, providing insight into students’ achievement (e.g., Gonzalez et al., 2020), persistence (e.g., Joseph et al., 2017), and career choices (e.g., Cribbs et al., 2021), and informing curriculum, pedagogy, and instruction that can better support students’ identity development (e.g., Clark et al., 2013, Fernández et al., 2022). Despite our increased understanding of mathematics identity in K-16 education, little is known about the mathematics identities of graduate students. Graduate education has historically served to socialize and develop graduate students’ professional identities as professors (Van Lankveld et al., 2017). However, within the mathematics discipline, this process may be more complex and nuanced. Scholars have explored graduate students’ professional identity formation as teachers (e.g., Beisiegel & Simmt, 2012) and as researchers (e.g., Hancock & Walsh, 2014). Still, we have yet to critically examine their sense of selves as mathematicians or attempt to understand how they make sense of and identify with the discipline in ways that do not conflate with their professional identities as mathematics professors. Mathematics graduate students have succeeded and persisted through years of rigorous mathematics studies, thus focusing on their identities allows us to both incorporate and extend beyond notions of competence, performance, and traditional markers of success to dive deeper into dimensions of mathematics identities that may not be as prevalent in K-16 students.

In this work, we also introduce the use of “Dear Math...” letters (e.g., Webb, 2020), or letters that students write to the mathematics discipline, and illustrate how this type of qualitative data provides new perspectives into graduate students’ mathematics identities. This can inform us about the formative and disruptive experiences in their mathematical journeys and we contend that a better understanding of graduate students’ mathematics identities can position departments and institutions to better support their transition to academic positions. The research question that guided this study was: How did mathematics graduate students reflect on their mathematics identities through writing letters to the discipline?

Conceptual Framing

Scholars generally describe mathematics identity as the ways students relate to mathematics and position themselves within or around mathematics. This identity is dynamic and transformative, changing depending on the context and the accumulation of mathematical experiences (Gardee & Brodie, 2021). However, the exactitudes within different definitions vary. Cribbs et al. (2015) divide the concept into three sub-categories: ways in which students perceive their competence in mathematics, their interest in mathematics, and their recognition as mathematically capable by themselves and others (e.g., instructors, peers). Crossley et al. (2018) present a similar three-part definition, including students' math self-concept about their ability, their interest in mathematics, and the value of mathematics in terms of its utility in their lives. These two conceptualizations describe mainly individual perceptions and traits. In contrast, Voigt (2020) posits a conceptualization that explicitly draws on social and contextual aspects of mathematics education. He describes mathematics identity as encompassing students' perceptions of their ability to effectively perform and participate in mathematical environments, the ways they position themselves within or outside mathematical communities, and how they negotiate their identity within institutional, individual, and societal contexts. These are just three examples of the numerous avenues scholars conceptualize mathematics identity. However, the majority of contemporary research focuses on the undergraduate level, with very limited work on graduate students' mathematics identity. Given the many ways undergraduate and graduate school differ, in this study we leverage the wide scope of research on mathematics identity and the multiple definitions presented to examine graduate students' mathematics identity.

Method

Context and Participants

This study was conducted at a Minority-Serving Institution in California with a mathematics department that offers graduate programs in mathematics at the masters and doctoral levels. We used convenience sampling (Miles et al., 2020) to recruit graduate students in the mathematics department. Sixteen doctoral students completed a survey that elicited self-identified/self-selected demographic information and requested their participation in a 90-minute qualitative interview. Six students participated in the interview and are identified in this study by their pseudonyms and pronouns: Connor and Landon (he/him); Kayla, Kendall, and Morgan (she/her); and Martin (they/them). All participants reported actively pursuing mathematics faculty positions.

Data Collection and Analysis

We utilized Zoom to conduct the 90-minute interviews. In the first hour, we used a semi-structured interview protocol (Rubin & Rubin, 2011) focused on students' experiences in graduate school, including the supports and barriers they encountered, their perceptions of the mathematics professoriate, and their understanding of mathematics teaching. Within the last 30 minutes, participants wrote the "Dear Math..." letter in which they personified the mathematics discipline and wrote correspondence to it. They were prompted to reflect on their experiences with mathematics, their career choices, and how mathematics has impacted their sense-of-selves and then tell the discipline how they really feel. Although the first author was present in the Zoom call, participants wrote the letters without any interaction or interference. For this study, we utilized these "Dear Math..." letters as the primary data source.

We consider self-reflective, narrative activities as mechanisms of identity development. Prior scholars have emphasized that narrative activities (e.g., writing self-reflections, telling stories, etc.) are identity constructing activities and can be methodological tools for researchers to examine identities (e.g., Beijaard et al., 2004). We posit that writing letters to the discipline is one avenue for students to share stories that illuminate dimensions of their mathematics identities. The use of letters is a facet of correspondence and arts-based methodology (Leavy, 2020), and is different from asking participants to narrate their experiences in an interview. Most notably, writing letters provides participants with an avenue to privately share experiences and emotions they might not comfortably share in an interview (Harris, 2002; Stamper, 2020). Webb (2020) found that letter-writing methodology allowed students to critically self-examine their experiences with mathematics past and present.

To analyze the data, the research team first individually read through the letters and wrote memos about what we noticed in how graduate students described themselves, others, and mathematics. Then, as a group, we open-coded (Miles et al., 2020) the letters and found three initial themes: (1) *Doers* of mathematics, (2) *Feelers* of mathematics, and (3) *Sharers* of mathematics. The research team verified the relevance of the codes by re-coding the letters and in this round, another theme emerged: *Believer* of mathematics. In our final round of coding, we re-coded all the letters using the four themes listed above, which we conceptualize as dimensions of graduate students' mathematics identity.

Findings

We now highlight how our analysis of graduate students' letters to the mathematics discipline revealed four key dimensions of their mathematics identities: *Doers*, *Sharers*, *Feelers*, and *Believers* of mathematics.

Doer of Mathematics

The first dimension that emerged from our analysis was students positioning themselves as *Doers* of mathematics. In these instances, our participants described how they make use of mathematics or see its function in the world (i.e., its utility). For two of our participants, the utility of math was mostly a form of play, whereas one of our participants saw it as a means to gain valuable life skills. Morgan and Kendall referred to doing mathematics as fun and playful. For example, Morgan described how she "loved playing with numbers and coming up with my own problems that I could subsequently solve." Similarly, Kendall stated how "you are extremely fun to explore and play with." These two students viewed themselves as *Doers* of mathematics for the purpose of playing, exploring, and having fun.

Landon described a more practical application of what it means to do mathematics. For example, he wrote that "most importantly, I love how you have taught me how to think. Doing math has clearly changed the way my internal world model interprets and analyzes sensory data ...equivalent to upgrading from an old computer to a new one." We see that Landon viewed himself as a *Doer* of mathematics for the purpose of developing cognitive skills like logical thinking and sensemaking. Further, he placed value on skills that he has acquired through doing mathematics. Interestingly, he explicitly specified that the act of doing mathematics was not as a requirement to fulfill in school or necessary to enter a mathematical career, but rather "these things all feel secondary to doing math as a way to learn how to think clearly about things and apply this clear thinking to every aspect of my life." Again, whereas Morgan and Kendall viewed themselves as *Doers* of mathematics for enjoyment, Landon viewed himself as a *Doer* of mathematics for the purpose of developing valuable and widely applicable skills for life.

Sharer of Mathematics

The second dimension that emerged pertained to how students positioned themselves as *Sharers* of mathematics. In their letters, the participants discussed mathematics both in terms of their role in sharing mathematics with others and their sense of mathematics as a community. This dimension frequently appeared as students assuming the responsibility to share the positive side of mathematics with others. An awareness of common negative perceptions associated with mathematics prompted many students to write about how they see themselves as advocates for the discipline. Kendall noted in her letter that she hopes she “can help more people see you [mathematics] as a friend.” Many participants, like Kendall, identified teaching as a way they could take on this advocate role. Martin wrote, “I see [my students] grapple with your theorems and symbols, but I want to show them who you truly are – what you can really do.” Similarly, Connor wrote, “I’m thankful for...the moments of teaching I remember when I finally showed someone something very cool about you.” These participants saw teaching as a prime opportunity to share their love and admiration for the discipline with others.

Affiliation with a mathematics community and awareness of how mathematics is shared within that community also revealed how participants identified as *Sharers* of mathematics. For instance, Connor wrote how “you’ve led to the creation of some of my most treasured communities, you’ve led me to some of my best friends”. Kendall wrote of a similar experience, writing “I appreciate how much I have learned from you and the people you’ve brought into my life. You really have the best friends.” For these two participants, mathematics fostered community and friendships. For Landon, mathematics could be used to bring people together through a universal language, writing “I can communicate perfectly with someone that doesn’t speak a word of english.” For some, the notion of a mathematics community did not always come with positive experiences or connotations. Morgan wrote explicitly about how she felt excluded as a result of being a woman in a male-dominated field, writing “I learned, through thousands of little words and actions, that I wasn’t welcome in the boys’ club that is the world of math.” She later wrote about persevering and finding her place within the community, but acknowledged how exclusionary it can be. Overall, we saw both positive and negative experiences in how graduate students described being *Sharers* of mathematics.

Feeler of Mathematics

We also found that participants described themselves as *Feelers* of mathematics. This dimension of their mathematics identities refers to affective factors relating to their experiences with mathematics, relationships with members of the mathematics community, and overall feelings toward the discipline. Participants described experiencing a range of positive and negative feelings towards mathematics over the course of their educational experiences. These feelings were not static and were often influenced by their graduate education experience. Some students revealed that early experiences with mathematics fostered curiosity, excitement, and interest, and this often came from being positioned as successful by their teachers and peers. However, positive early experiences were not always shared by the participants. For example, Martin wrote, “When we first met, we didn’t get along – at least, I didn’t understand you and wanted you to go. Multiplication was hard, and those timed worksheets made me anxious...Honestly, you scared me, or so I thought.” Here, Martin expressed how their early feelings surrounding mathematics were marked by anxiety and fear, illustrating that graduate students can have widely different early emotions with mathematics that shape their identities.

Additionally, students detailed how graduate school marked a period of time when they contested with negative feelings about themselves and the discipline. This detrimentally

impacted their mathematics identities and made them question their place within the discipline. A frequently cited area of dissent was when graduate students compared themselves to their peers and were made to feel like their mathematical abilities were not adequate for this space. For example, Kayla noted that entering graduate school involved confronting the idea that “there were other people that were just as good at you as I was,” which made her feel “threatened” and “jealous.” Kayla was faced with reconciling her mathematics identity, mainly related to her competence, in comparison to how she perceived her peers. Similarly, Morgan described feelings of exclusion due to gendered mathematics spaces, leading to feeling that “every success was handed to me for the sake of diversity, or so I was told, until I believed it.” These feelings of exclusion constitute an affective component of Morgan’s positioning within mathematics.

The most common sentiment across the letters was gratitude. The participants reflected on the experiences that mathematics afforded – including the connections and community that they developed. Kayla expressed gratitude to mathematics for “bringing [her] joy all through [her] school years” and for “your friendship.” Similarly, Morgan wrote, “I wanted to take a moment to...express gratitude for the profound impact you made on my life.” Despite the varying feelings expressed about themselves and mathematics, the participants described being drawn to mathematics and feeling motivated to continue their studies and pursue faculty positions.

Believer of Mathematics

The final dimension of mathematics identity which emerged was the *Believer* of mathematics. This theme echoes the work of scholars who investigate the notion of mathematical study and religion as conjuring parallel experiences, both in their embodiment and in their rejection (Jonker, 2012; Krajewski, 2021; Kurniawan & Hidayati, 2020). Kurniawan and Hidayati (2020) define religion in part as a way one “seeks the meaning of life, the value of truth, and the meaning of the world.” Many of our participants described ways that mathematics provides universal meaning and truth. In the same way that understanding one’s religious identity yields insight into their worldview, we view understanding the ways in which an individual “believes” in mathematics and its power as something which yields insight into a student’s mathematics identity.

One way in which this theme appeared was through the participants’ frequent assignment of powerful qualities to mathematics. In her letter, Kayla contrasted her initial negative feelings towards mathematics with her present feelings of “appreciating your beauty and mystery.” Similarly, Morgan noted her passion for “studying the beauty of your theory”, and Martin noted the “utility and richness of your subjects.” Landon described mathematics as “foundational to understanding the world”, and cited this as a reason he was drawn to the field. In some instances, participants expanded on these qualities in ways that went beyond ascribing a quality and characterized mathematics in a more holistic way. Connor made two such potent characterizations: that “the spirit of discovery resides in you”, and that “we will unlock the secrets of the universe with your help.” Both of these characterizations are not out of line with a religious profession of exalt; Connor is expressing his exaltation of mathematics through the ascription of spiritual characterizations to the subject.

The participants also described mathematics in ways that reflect omnipresent and omniscient properties often ascribed to religious deities. Connor explained how mathematics “is the hope I have for a brighter future..., because humanity has hope through you and the insights you hold.” Regarding mathematics’ far-reaching power, Martin further wrote that “you are everything, everywhere, all at once, and I think nothing else can explain the universe in a better way.” Landon and Martin also positioned mathematics as a determinant of universal truth. For

example, Martin noted that mathematics “offer[s] exactness in a time and place where everything is changing, and... keep[s] me grounded to this existence.” In these ways, the participants’ descriptions reflect a higher “belief” in the power and truth of mathematics.

Discussion and Implications

The participants’ letters revealed four main themes that suggest important dimensions in mathematics graduate students’ expressions of their mathematics identities. These themes both connect and diverge from literature focused on undergraduate students’ mathematics identity.

The *Doer* dimension reflects mathematics identity conceptualizations that include utility, or the “degree to which a student thinks that math is or will be useful to their life” (Crossley et al., 2018, p. 13). Landon’s letter, for example, reflects this, discussing how mathematics supported the development of critical thinking skills useful in numerous aspects of his life. The *Feeler* dimension relates to affective components within students’ mathematics identity but expands on the usual limitation to students’ level of mathematical interest. Cribbs et al. (2015) define mathematical interest as “a student’s desire or curiosity to think about and learn mathematics” (p. 1052). The participants described feelings of curiosity, such as when Kayla wrote how “ever since I was of a young age, I always knew that I wanted to learn more about you.” However, they also expressed numerous other emotions including excitement, inspiration, enjoyment, and appreciation around mathematics, as well as anxiety, fear, and annoyance. For example, Connor described how he is “annoyed with you so very often.” Thus, while interest and curiosity appeared in some of the letters, participants described additional feelings that relate to their mathematics identity such as perceptions of ability and mathematical self-efficacy.

The *Feeler* dimension also demonstrates connections to perceptions of ability. Martin described not “getting along with” mathematics initially, implying that a lack of perceived ability hindered their relationship with mathematics. Kayla also describes changes in her perceived ability, reflecting back on grade school when “you made me stand out as a very smart and exceptional student,” whereby in graduate school, “there were other people that were just as good at you as I was, and I became threatened and jealous.” As a result of her lower self-efficacy, she questioned that mathematics “maybe... [was] never my friend to begin with.” Thus, perceptions of ability still appear in graduate students’ construction of their mathematics identity, whether as a consequence of earlier experiences or within graduate school itself.

The *Sharer* dimension exhibits similarities and differences with existing literature on undergraduate students’ mathematics identity. Echoing existing literature, the participants frequently referenced their positioning within or outside of a mathematical community. Connor and Kendall described the friends they have gained through mathematics. However, Morgan cited gender-based exclusion within the “boys’ club” of mathematics and Connor noted his dislike toward competition within mathematical spaces. These notions of community reflect conceptualizations of mathematics identity focused on belonging and recognition (Cribbs et al., 2015; Voigt, 2020). However, the *Sharer* dimension also included a unique component of graduate students’ mathematics identity, namely their role in sharing mathematics as a teacher. Multiple participants described teaching as a way to change negative perceptions around mathematics and communicate their love for the discipline. For these participants, the co-construction of professional and mathematics identity was an important component of their graduate school experience. Beisiegel and Simmt (2012) note that “it is through the formative experiences of graduate school that mathematics graduate students’ identities are shaped as mathematicians, researchers, teachers, or more generally as professors of math” (p. 35). The dimensions of *Doer* and *Sharer* are particularly relevant to Beisiegel and Simmt’s assertion;

understanding how graduate students see themselves as doing and sharing mathematics in relation to their mathematics identity can illuminate their professional identity development.

The identity dimension that most diverges from existing literature on undergraduate students' mathematics identity is the *Believer* of mathematics. This appears to be a unique facet of mathematics graduate students' mathematics identity. The salience of this theme across all of the participants' letters suggests that a belief in the power of mathematics is a significant factor in their mathematics identity. The participants expressed this dimension in various ways, from admiration of mathematics' beauty and spirit to its bringing hope to humanity and grounding one to this existence. These statements do not align well with previously established mathematics identity components such as perceptions of ability, interest, utility, sense of belonging, participation, etc. Given the novelty of this theme, further investigation is needed to determine how fundamental or universal this dimension is among graduate students, whether undergraduate students who resonate with this aspect of mathematics identity are more likely to pursue graduate education, and if and how instructors could instill this within their undergraduate students.

The letters also reinforced how mathematics identity is a fluid construct, subject to change across time and experience. We see past mathematics identities present in Kayla's narrative, as she reflected on mathematics as bringing her her "greatest joys" and "lowest places" in a temporal way. She associated a shift with the beginning of graduate school, in which she began feeling "threatened and jealous" – something she identified as a "false narrative" that resulted in "ill feelings." In addition to considering previously held mathematics identities through descriptions of feelings and experiences, there was one instance of consideration of a future mathematics identity present in Kendall's letter in which she writes she "[has] no doubt we will be lifelong friends." These elements of both a past and a projected future mathematics identity are integral to how students position themselves with respect to mathematics as a discipline, and thus serve as informants of their mathematics identity. We see this as a possible area of application for Markus and Nurius's (1986) *possible selves* in which identities are given temporal dimensions, and past or possible considerations of identity are conceptualized as irrevocably intertwined with the current self. In the same way that possible selves have been leveraged to provide insight into professional development in other realms on education (e.g., Blaney et al., 2022; Park & Shallert, 2020; Quaisley et al., under review), so too could they provide insight in the developing mathematics identities of graduate students.

Conclusion

Overall, our work suggests that graduate students' mathematics identity development reflects and extends beyond traditional notions of identity. We recognize the salience of social identities (e.g., gender, race, etc.) in the shaping of mathematical experiences (e.g., Leyva et al., 2020; Voigt, 2020); future work is needed to more carefully examine the connections between these identities and the mathematics identity development of graduate students. We view examining letters as a novel and insightful approach to making sense of mathematics identities as they afforded students opportunities to articulate self-perceptions, stories, feelings, etc. that may have been difficult to convey through other data collection efforts. We posit that writing "Dear Math..." letters is one avenue that professional development efforts can take up to gain insight into the experiences that graduate students consider supportive or hindering in their progression through graduate school and their pursuit of academic positions. A continued examination of graduate students' mathematics identities can inform mathematics departments and higher education institutions on how to better support their transition to the mathematics professoriate.

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