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Envisioning the Future of Mathematics Education in
Uncertain Times



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**Envisioning the Future of Mathematics Education in
Uncertain Times**

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AN ELABORATION ON MASTER NARRATIVES IN MATHEMATICS AND HOW UNDERGRADUATES RELATE TO COUNTERNARRATIVES

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Because the master narratives about mathematics in the US often play an exclusionary role in students' educational experiences, educators have sought to integrate counternarratives into instruction that might disrupt these effects. As part of a larger project to develop a research-informed curriculum for undergraduate introduction to proof courses, we gathered author stories from a diverse set of mathematicians for students to read and reflect upon. To study student responses to these author stories, we synthesized a framework of the master narrative of mathematics in the US and identified how the author stories countered elements of this narrative. We then analyzed 80 student reflections from one introduction to proof course to identify whether and how students either endorsed or countered the elements of the master narrative. Our findings point to a positive, yet modest capacity for these stories as counternarratives.

Keywords: Undergraduate Education, Equity, Inclusion, and Diversity

In recent years, counternarratives have become not just a means for research, but a potentially transformative tool to incorporate into instruction. Stories both about ourselves and society provide a means through which to organize our understanding of the world. Culturally shared narratives, or dominant/master narratives, provide a framing to compare or integrate personal experiences. These master narratives often disadvantage marginalized groups, such as women and people of color, in fields like mathematics (Berry III et al., 2011; Leyva, 2017; Adiredja, 2019). Narratives portraying mathematics as neutral, individualistic, and meritocratic reinforce hegemonic norms, dismissing alternative ways of learning and working that align with diverse identities and cultures (McBride, 1994; Cobb & Russell, 2015; Cervia, 2019). Counternarratives (e.g., Solórzano, D. G. & Yosso, 2002) can serve to challenge dominant narratives by not only disrupting storylines about who can succeed in mathematics (e.g., Berry III et al., 2011; Langer-Osuna et al., 2016; Leyva, 2016; McGee, 2009) but also redefining what it means to engage with the subject. However, as cautioned by Cervia's (2019) exploration of scientists, simply showcasing successful individuals from minoritized groups can inadvertently reinforce existing master narratives, especially if these narratives align with traditional norms. Disrupting master narratives requires challenging not only demographic stereotypes but also the perceived traits and norms associated with mathematicians and mathematical activity.

In this study, we analyze student reflections on mathematician biographies paired with proofs in an introduction to proof course. These narratives, tailored for the intended audience of undergraduate mathematics students, aim to challenge dominant narratives about who can succeed in mathematics and how mathematics is practiced. By synthesizing literature on

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mathematics and mathematician storylines, we develop a framework to examine how counternarratives resonate with students and align with or challenge dominant narratives in the United States. Our research questions are twofold: What elements of mathematician counternarratives were salient to a group of undergraduate mathematics students? How do these elements align (or not) with dominant narratives of mathematics in the United States?

Theoretical Framing

Broadly, we adopt McLean and Syed's (2016) narrative distinctions. Master narratives are culturally shared stories that guide behavior and identity within a culture. They dictate who excels in math and define the essence of being a mathematician. Counternarratives, on the other hand, challenge these dominant storylines. Personal narratives involve negotiating between societal expectations and individual identity, influenced by both master and counternarratives.

Drawing from various research areas, we identified themes in master narratives about mathematics. These themes encompass beliefs about mathematicians, descriptions of mathematicians, countered narratives, and theoretical discourses. While these categories overlap, they collectively shape the perception of the American Mathematician. In Table 1, we present these narrative elements alongside quotes from key studies that inform our understanding.

Table 1: Mathematical Master Narrative Elements and Storylines

Element/Storyline	Reference
Mathematics is done by privileged white men.	"[P]opular discourses overwhelmingly construct mathematicians as white, heterosexual, middle-class men" (Moreau et al., 2008, p. 25).
Mathematics is done by those who are brilliant, but socially inept.	"Mathematicians were often portrayed as socially inept nerds" (Di Martino et al., 2023, p. 11).
Mathematics is done in isolation.	"Mathematicians always work alone in my mind. They're always like those, those hobbits that live in their own little room... Like this would be perfect, lined with grease boards and chalkboards" (Female Math Major, Piatek-Jimenez, 2008, p. 638).
Mathematics is dry and not fun.	"Mathematics is full of rules and formulas to be remembered. Mathematics is dry, it does not leave room to feelings. Mathematics does not make sense, the aim of learning certain things is not clear. In mathematics, there is no room to express one's own ideas" (Di Martino, & Zan, 2011, p. 477).
Mathematics ability is innate, and mathematics is easy for those with high ability.	"Instead of seeing learning math as an ongoing process, learning at my own pace, it became "either you get it or you don't." I put math in the, 'it's just not for me' category" (College student, John et al., 2022, p. 9).
Mathematics is colorblind and neutral.	"The mathematical model of equality constructed intentionally perpetuates the myth of mathematics as neutral and objective to maintain white institutional spaces" (Gómez Marchant et al., 2023 p. 12).
Mathematics is individualistic and a meritocracy.	"A prominent feature of education in the United States is the widespread endorsement of an achievement narrative, which links individual motivation and effort to academic achievement." (Zavala & Hand, 2019)

We emphasize that these storylines together support greater myths such as the existence of a racial hierarchy of ability (Battey & Leyva, 2016). All of these elements serve a hegemonic role in preserving exclusionary standards and the white patriarchal space of mathematics (Battey & Leyva, 2016; Battey & Marshall, 2023; Leyva, 2017; Martin, 2013; McGee, 2020).

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Methods

We present data from one implementation of this curriculum in an introduction to proof course at a large research university in the United States. As part of this curriculum, interesting proofs are paired with author stories from modern mathematicians. In this study, students wrote reflections on six author stories (authors included two Black men, one Latinx woman, one Pacific Islander one, one white-nonbinary person, and one Latino) The authors told their stories both as mathematicians and outside of mathematics, obstacles and struggles, and images of what doing mathematics looked like (See Melhuish et al., in press). Twenty-one students were enrolled in the class and were listed in university documentation as having the following ethnicities: 11 White, 2 African-American, 6 Hispanic, 1 Asian, 1 Unknown. There were 7 women and 14 men.

The focus of this submission is on the written reflections of sixteen student participants on the assigned author stories. Students submitted a mean of 5 reflections, for a total of 80 student reflections. Student reflections varied in length from three sentences to two handwritten pages. Prompts for the reflections included questions such as: “What stuck out to you about Dr. ____’s story?” “How did Dr. ____’s story resonate with your own story? How did it differ?”

For the purpose of this study, we identified passages of the reflections where students noted components of the master mathematical narrative were either countered or endorsed in the author stories. Two authors independently coded each of the 80 reflections for counters and endorsements, resolving discrepancies through discussion. Overall, we identified 127 instances of countering the master narrative elements and 15 instances of endorsing them.

Results

Student reflections revealed how they internalized the author stories. Some students endorsed master narrative elements by highlighting them in the stories or by opposing counter elements. Others recognized counternarrative elements, emphasizing their significance. We present Table 2 to summarize the narrative elements reported by students. Additionally, we introduce two new categories: linear trajectory in becoming a mathematician and family and cultural expectations. Students expressed surprise at the non-linear career paths of mathematicians, echoing narratives of academia's linear progression. Similarly, they were surprised by authors facing family discouragement from pursuing mathematics rather than a more lucrative career.

Table 2: Mathematical Master Narrative Elements Found in Student Reflections

Master Narrative Element/Storyline	# Countering	# Endorsing
Mathematics is done by privileged white men.	6	1
Mathematics is done by those who are brilliant, but socially inept.	2	0
Mathematics is done in isolation.	5	2
Mathematics is dry and not fun.	13	0
Becoming a mathematician is a linear trajectory.	13	0
Mathematics ability is innate, and mathematics is easy for those with high ability.	15	4
Mathematics is colorblind and neutral.	5	0
Mathematics is individualistic and a meritocracy.	0	3
Family and culture would hold positive views on choosing mathematics as a career	5	0

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A Look at How Students Reflected on Elements of Master Narratives

Mathematics is done by privileged white men. None of the author stories were written by white men. We found that some students explicitly referenced this master narrative. Students further identified themselves in the stories with one woman explaining, “being a Latinx woman is personally inspiring, as I too am a Latinx woman.” Such comments also extended to economic and educational privilege with several students noting things like relating to coming from a “rural” or “blue collar” town without great public schooling. We see each of these comments implicitly showing awareness of the master narrative about white, privileged men as mathematicians, but focusing on the counter to it and the ways the counter aligns with their personal narratives.

Mathematics ability is innate, and mathematics is easy for those with high ability. Every author stories included times of struggling with mathematics, in the academia, or in school. This was the most commonly attended to element in the student reflections. Several students reflected that they related to these stories because their own “identity of being ‘good’ at school” had been challenged. One student explained, “even people who have earned their degree in mathematics have struggled with math. Even though I struggle on some topics, it doesn’t mean I’m not geared for math.” These comments reflect a negotiation of their personal narratives where students seemed to take the counter story elements and expand their idea of who can be a mathematician and whether it is necessary to always have things come easy.

Becoming a mathematician is a linear trajectory. A number of the author stories represented atypical paths to mathematics including nearly failing out of school, leaving the academy and returning, and cycling through many majors before arriving at mathematics. Students often reflected on these elements with some noting elements such as “detours.” One student reflected, “I had a pre-conceived notion that mathematicians must be persistently passionate about math. Dr. [W] proved that notion incorrect.” These elements served to expand out who can do mathematics (not just those who are always passionate about math) and how one can arrive at being a mathematician.

Mathematics is dry and not fun. The author stories also contained ways that the authors loved mathematics and how they went about doing mathematics. Some students contrasted the standard approach to school mathematics such as one student noting the importance of the idea of “learn[ing] in a way you are changed and not in a way that you memorize.” Students further linked ideas of mathematics being fun with the challenge.

Other Story Elements. A major theme in author stories was the collaborative nature of mathematics. However, students rarely mentioned this in their reflections. Some noted the need to connect with others, but most focused on professors and mentoring rather than peer collaboration. Ideas of individualism and meritocracy were mixed. One student countered the idea of innate ability but endorsed meritocracy by stating that effort leads to success. Others recognized the support from people in their lives, challenging individualism.

Discussion

In this report, we provided two fundamental contributions. First, we stitched together a dispersed literature base to create a master narrative of mathematics with attention to: who does mathematics (mathematicians), how one becomes a mathematician, how one does mathematics, and what mathematics is. Second, we explored how author stories that challenge these narrative Kosko, K. W., Caniglia, J., Courtney, S., Zolfaghari, M., & Morris, G. A., (2024). *Proceedings of the forty-sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Kent State University.

elements were perceived by students. The student reflections provided strong evidence that the author stories were successful at challenging several elements of the master narrative around mathematics: mathematics being dry and not fun, the path to a career as a mathematician being linear, and mathematics ability as being innate and mathematics being easy for those with high ability. The master narrative that white men dominate math was less disrupted. Only a few students, particularly women of color, mentioned race. Meritocracy and individualism were either not addressed or reinforced by students' reflections. Stories often highlighted overcoming barriers, emphasizing individual effort. Further research should explore which stories can disrupt which narratives and how to effectively engage students in reflecting on their personal narratives.

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ADVISOR PERSPECTIVES: SERVICES AND PROGRAMS FOR AFRICAN INTERNATIONAL STUDENTS IN HIGHER EDUCATION INSTITUTIONS IN THE UNITED STATES

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The globalization of higher education in the United States has led to a significant increase in the enrollment of international students, particularly from Africa, thereby enhancing the cultural diversity of academic institutions (Hendrickson et al., 2011; Lee & Rice, 2017). African international students face unique challenges due to their diverse academic backgrounds and specific cultural and social needs (Hendrickson et al., 2011; Lee & Rice, 2017; Irungu, 2013). While these students enrich the academic environment and contribute financially to the U.S. economy, their academic journey, especially in mathematics education, is fraught with difficulties such as language barriers, cultural adjustments, social integration issues, and academic pressures (Irungu, 2013). Existing orientation programs and support services often fail to address the specific needs of African students, hindering their academic success (Smith & Khawaja, 2011).

Higher learning institutions have developed support systems and programs to assist international students, including academic advising, tutoring, mentorship programs, and mental health services. However, African international students encounter difficulties accessing these services due to cultural, language, and financial barriers (Smith & Khawaja, 2011). Tailored support structures are essential to effectively address these challenges and ensure the academic success and well-being of African international students in U.S. higher education institutions (Jin, 2019).

A multiple-case study approach was employed to explore the experiences of African international students in mathematics education in U.S. institutions, focusing on the perspectives of international student advisors (Altbach & Knight, 2018; Poyrazli & Grahame, 2007). The study aims to assess the effectiveness of existing support services and programs for African students and understand how advisors perceive these services (Olson & Banjong, 2016). Preliminary findings indicate that while resources are available, there are significant challenges and gaps in the support systems, emphasizing the need for culturally responsive approaches and tailored support for African international students (Irungu, 2013; Poyrazli & Grahame, 2007).

This study underscores the significance of addressing the unique challenges faced by African international students in U.S. higher education institutions and calls for refined strategies to create a more inclusive and supportive environment (Mwangi et al., 2019; Smith & Khawaja, 2011). By investing in culturally relevant programming, fostering collaboration among stakeholders, and continuously evaluating support strategies, institutions can enhance the

academic success and well-being of African international students, contributing to a more equitable and enriching educational experience (Smith & Khawaja, 2011).

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