DISSERTATION

EXPLORING WOMEN OF COLOR'S EXPRESSIONS OF MATHEMATICAL IDENTITY: THE ROLE OF INSTITUTIONAL RESOURCES AND MATHEMATICAL VALUES

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Ciera Street

Department of Mathematics

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Doctoral Committee:

Advisor: Jessica Ellis Hagman

Hortensia Soto
Elizabeth Arnold
David Most

ABSTRACT

EXPLORING WOMEN OF COLOR'S EXPRESSIONS OF MATHEMATICAL IDENTITY:
THE ROLE OF INSTITUTIONAL RESOURCES AND MATHEMATICAL VALUES

There is a persistent and growing global call to examine, challenge, and transform exclusionary structures and systems within mathematics education (Laursen & Austin, 2020; Reinholz et al., 2019; Thomas & Drake, 2016; Wagner et al., 2020). An important component of this call examines students' mathematical identity. While a growing body of work considers how students' social identities interplay with their mathematical identity (e.g., Akin et al., 2022; English-Clarke et al., 2012), few studies consider mathematical identity at the intersection of gender and race (Ibourk et al., 2022; Leyva, 2016; 2021). This dissertation study explores undergraduate women of color's expressions of mathematical identity and the institutional structures and ideologies that influence these expressions. Following a three-paper model, each paper utilizes critical theories and an intersectional lens to recognize the gendered and racialized context of higher education mathematical spaces and the ways these discourses influence women of color's mathematical identity.

The first paper employs large-scale quantitative and qualitative data from a national survey on students' undergraduate calculus experiences to explore women of color's expressions of mathematical identity. Informed by Data Feminism, I use a cluster analysis to group women of color survey respondents based on four subdomains of mathematical identity and contextualize each group using qualitative survey responses. The second paper draws from Nasir's (2011) material and relational identity resources to examine the institutional resources available and accessible to undergraduate women of color to support their mathematical identity. Results from participant interviews indicate various supportive identity resources, such as peer relationships and student support programs. The results also describe unavailable, inaccessible, or detrimental identity resources, such as the lack of representation within the mathematics faculty and an exclusionary mathematics community. Using a sociopolitical lens, the third paper discusses the sociohistorical background of white, patriarchal mathematical values and the ways these values create inequities in undergraduate mathematical spaces. Interviews with participants suggest a clear misalignment between these sociohistorical mathematical values and women of color's mathematical and mathematics education values.

Together, these three papers emphasize within-group differences among women of color's mathematical identity and the different ways material, relational, and ideological resources can support or hinder women of color's mathematical identities. I conclude this dissertation study by illustrating connections across the three papers. I also provide implications for teaching, policy, and research to challenge exclusionary mathematical systems and support women of color's mathematical identity.

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DEFINITION OF TERMS

P2C2	Precalculus to Calculus 2; refers to the mainstream sequence of introductory mathematics courses required for most undergraduate STEM majors.
STEM	Science, Technology, Engineering, and Mathematics
PtC	Progress through Calculus
SEMINAL	Student Engagement in Mathematics through an Institutional Network for Active Learning
Gender identity	A dynamic and performative response to societal expectations and constructions within the false gender binary system, it is "something that we do and are done by not something that we are" (Mendick, 2006, p. 10).
Racial identity	A classification which has strong social, historical, and political roots that means "although … [race] has dubious value as a scientific classification system" (Martin, 2006, p. 197) has instigated numerous consequences for people of color's lives and access to opportunities in the United States (Spring, 2012).
Discourses	"Socially organized frameworks of meaning that define categories and specify domains of what can be said and done" (Burman, 1994, p. 2) which manifest within power structures and inform what individuals can say or do based on their positioning within those structures (Leyva, 2016).
Intersectionality	The ways in which interactions between race, gender, class, and other social constructs accounted for overlapping discrimination imposed on people with multiple marginalized identities within societal systems (Crenshaw, 1989, 1991; Perlman, 2018).
Anti-deficit perspective	The viewpoint that the systems and structures informing mathematical discourses marginalize students rather than placing responsibility on any individual or group.
Mathematical identity	The ways students relate with mathematics and their mathematics education, including students' beliefs about their participation and abilities, their sense of belonging in class and the field, and the role of institutional and interpersonal supports (Voigt, 2020)

CHAPTER 1 – OVERVIEW OF THE STUDY

Scholarship within mathematics education continues to call for systemic changes that challenge exclusionary structures and systems within undergraduate mathematics (Laursen & Austin, 2020; Leyva et al., 2021 Reinholz et al., 2019). Several professional mathematics organizations in the United States have released position statements addressing issues of equity and diversity and the importance of supporting students with marginalized identities related to race, ethnicity, gender, class, language, culture, sexual orientation, religion, and/or physical ability (e.g., American Mathematical Society, n.d.; Association for Women in Mathematics, n.d.; Association of Mathematics Teacher Education, 2015; Mathematical Association of America, 2018; National Council of Supervisors of Mathematics and TODOS: Mathematics for All, 2016; National Council of Teachers of Mathematics, 2014). This call is gaining increasingly more global attention as well (Thomas & Drake, 2016; Wagner et al., 2020).

One approach in creating more equitable mathematics education is through supporting students' mathematical identity. Mathematical identity broadly considers the ways students connect with, relate to, and position themselves within mathematics. Scholars suggest that strengthening students' mathematical identity can help foster mathematical enjoyment, increase retention in a STEM field, and promote well-being (Seyranian et al., 2018; van Laar et al., 2010). While a growing body of work centers the relationship between gender and mathematical identity (e.g., Akin et al., 2022) or race and mathematical identity (e.g., English-Clarke et al., 2012), few articles consider how the intersection of gender and race interacts with mathematical identity (e.g., Young & Cunningham, 2021). However, multiple studies demonstrate how exclusionary structures and values often create challenges for women of color in undergraduate mathematical spaces (Leyva et al., 2020; McGee & Bentley, 2017; Rodriguez et al., 2019). Thus, more intersectional work is needed to explore undergraduate women of color's mathematical identity and the ways institutional resources support or hinder their mathematical identity construction.

This dissertation study explores the various ways undergraduate women of color STEM majors express and develop their mathematical identity and in what ways gendered and racialized components of mathematics inform and interact with this expression and development. Furthermore, I consider the ways institutional structures and ideologies support or hinder this development. This centering of women of color's experiences requires grounding in various works related to race, gender, and intersectionality. In particular, I rely on the concept of *discourses* to frame the gendered and racialized components of mathematics education. I borrow from Burman's (1994) definition of discourses as "socially organized frameworks of meaning that define categories and specify domains of what can be said and done" (p. 2). I expand this definition to recognize how discourses manifest within power structures and inform "what can be said and done" (Burman, 1994, p. 2) based on one's positioning within those structures (Leyva, 2016). Thus, dominant discourses of mathematics continue to privilege certain identities (e.g. white[1], man) and marginalize other identities (e.g. person of color, woman) (Adiredja & Andrews-Larson, 2017).

This relates to what is frequently defined as an *anti-deficit perspective*, which focuses on students' strengths and resources and recognizes how institutional, social, and political factors

[1] Diverging from APA style, I use lowercase white and capitalize all other racial/ethnic groups. Based on the Associated Press's extensive research in the matter, this choice recognizes that marginalized racial/ethnic groups in the United States often have "the shared experience of discrimination due solely to the color of one's skin" (Daniszewski, 2020, para. 2), while this is not equally true for white people. This decision also separates one's work from those who emphasize capitalizing white, such as white supremicists. Using lowercase white may imply "whiteness" as the default; however, the design of this study purposefully challenges that assumption.

shape inequitable opportunities and outcomes (Adiredja & Louie, 2020). This viewpoint persists throughout this work and strongly relates to how I frame the studies supporting this research. I view studies that compare students using demographic information to reflect patterned disparities based on historically inequitable mathematical systems rather than placing responsibility on individuals or groups. For example, Rainey et al.'s (2018) study considering students' sense of belonging in a STEM discipline found that women of color were least likely to report a sense of belonging when compared to white women and men regardless of race. These results do not suggest that women of color do not belong in STEM, but rather reflect exclusionary mathematical systems that create unwelcoming spaces for women of color. It is worth noting that based on the demographic makeup of undergraduate mathematics, studies focusing only on gender often include predominantly white women (e.g., Ernest et al., 2019) and studies focusing only on race often include predominantly men of color (e.g., Reinholz, 2022). The results stemming from these studies may reflect the experiences of *white* women or *men* of color more so than women of color. Thus, I frame such studies as related but incomplete representations of the experiences of women of color in mathematics. Given the limited research specifically on women of color's expression of mathematical identity, I expanded my scope to include STEM more generally and to consider studies that explore various other components of women of color's experiences in mathematics.

Throughout this dissertation study, I leverage Voigt's (2020) conceptualization of mathematical identity. He defines mathematical identity as

> the dispositions and deeply-held beliefs that individuals develop, within their overall self-concept, about their ability to participate and perform effectively in mathematical contexts. Accounting for how individuals position themselves within or outside the

community as potential creators of mathematics… [and] is constantly negotiated through social discourses that are shaped by institutions, individuals, society, and intersecting systems of oppression (p.32).

Supplementary to this definition are three categories that inform students' mathematical identity, (1) students' perceptions of their mathematical participation and ability, (2) students' connection to mathematical communities and their positioning as doers of math, and (3) the influence of identity resources, such as peers, instructors, and programs. Each of these categories are influenced by both local and broader mathematical discourses. Scholars argue that mathematical discourses are both gendered and racialized such that they privilege masculine and white characteristics and values (Leyva, 2017; Martin, 2006). Thus, those who are unable or unwilling to assimilate into the white, masculine culture of mathematics experience more tension navigating mathematical spaces, more often women and people of color (Fong et al., 2019; Leyva et al., 2021; McGee & Martin, 2011). Related to categories (1) and (2) above, these discourses can negatively influence women of color's mathematical identity through promoting a white, masculine description of mathematical ability, success, and belonging (Leyva, 2016; Rainey et al., 2018)

To establish category (3) above, Voigt (2020) borrows from Nasir's (2011) definitions of identity resources, which are resources that students utilize in the environment to construct practice-linked identities. She categorizes identity resources as material, relational, or ideational. Material resources are physical components, such as structures and organizations, that link students to the practice. Relational resources are interpersonal relationships that support or limit students' access to the practice. Ideational resources are shared values and norms within the practice. Within mathematics, engaging with certain resources may afford or limit a students' access to social labels that position them as good at math or a "math person". Nasir (2011) emphasizes that these resources are contextually and culturally based, meaning that institutional structures and disciplinary culture influence the existence of and access to resources. Thus, in this dissertation study, I consider how gendered and racialized discourses in mathematics mediate women of color's views on the availability of identity resources, who has access to these resources, and the appropriate way to utilize these resources.

The limited research that does consider mathematical identity using an intersectional approach suggests unique experiences for women of color in mathematics (Ibourk et al., 2022; Joseph et al., 2020; Leyva, 2016). In particular, various studies suggest that gendered and racialized mathematical discourses can mediate whether a woman of color develops a strong mathematical identity (Ibourk et al., 2022; Young & Cunningham, 2021). Thus, this work centers women of color's narratives around their mathematical identity to challenge exclusionary discourses and promote the restructuring of mathematical spaces. The overall goal of this study is to expand on the limited intersectional literature around mathematical identity by exploring the various expressions of mathematical identity for women of color in undergraduate mathematics and the institutional and interpersonal resources that support or hinder stronger identification in the field. Toward this goal, this dissertation study explores the overall research question:

> In what ways do the values of the mathematics discipline and organizational context of higher education interact with undergraduate women of color's mathematical identity?

Theoretical Considerations

Intersectionality

I utilize an intersectional lens to emphasize how gender, race, and other social identities are intertwined and constantly renegotiated in response to varying contexts and societal expectations. Originally coined by Kimberlé Crenshaw in 1989, the term intersectionality describes the ways in which interactions between race, gender, class, and other social constructs account for overlapping discrimination imposed on people with multiple marginalized identities within societal systems (Crenshaw, 1989, 1991; Perlman, 2018). In an interview with Columbia Law, Crenshaw explains:

> Intersectionality is a lens through which you can see where power comes and collides, where it interlocks and intersects. It's not simply that there's a race problem here, a gender problem here, and a class or LBGTQ problem there. Many times that framework erases what happens to people who are subject to all of these things. (Columbia Law, 2017, para. 4)

Using an intersectional lens in research provides a more holistic and complex understanding of how individuals navigate power-laden spaces, including the mathematics environment (Crenshaw, 1991; Leyva, 2016). For example, in Dortch and Patel's (2017) study exploring undergraduate Black women's sense of belonging in STEM, the authors found that their participants expressed exclusion not only from white men, but also from white women. Similarly, Leyva's (2016) study utilizing an intersectional lens while researching Latin@[2] college women's mathematical experiences suggests that the intersection of gender and ethnicity simultaneously influenced his participants' conflicting discourses. The participant's described navigating both the pressure to have children and start a family coupled with family-oriented motivations to go to college and excel in mathematics. Researching only either gender or race

[2] Throughout this dissertation study, I preserve the author's terminology to categorize those who identify with Latin American origins and/or descent when specified (e.g., Latin@, Latino/a). When not specified, I choose to use the gender-neutral term Latine. I chose this term over that of Latinx to preserve the historical origins of the term Latinx for gender non-conforming people from Latin America and to more naturally follow Spanish pronunciation and writing rules (Gamio Cuervo, 2016; Salinas & Lozano, 2019).

within these studies, and thus circumventing an intersectional approach to the analysis, would have limited the richness of these participants' narratives and experiences.

An important component of intersectional research recognizes the interactions between social markers as related and interconnected rather than additive (Bowleg, 2008; Leyva, 2017). It is insufficient to parse out the relationship of a single identity with some construct, such as the relationship purely between gender and mathematical identity. Furthermore, it is also insufficient to compare the relationship between various identities disjointedly within an individual, such as their relationship between gender and mathematical identity versus their relationship between race and mathematical identity. Additive approaches to oppression posit that social inequality is somehow measurable relative to the amount of marginalized identities with which one identifies (Bowleg, 2008). Instead, intersectionality research argues that "multiple factors uniquely combine to define an individual's experience. For instance, being Black and lesbian confers a unique experience, above and beyond being Black or lesbian" (Bowleg, 2008, p. 319). However, further research supports the idea of "dual marginalization" which recognizes the unique interconnected set of potential oppressions from identifying with more than one marginalized group (Young & Cunningham, 2021). In particular, both gendered and racialized discourses simultaneously affect women of color's experiences in mathematics (Mendick, 2006; Young & Cunningham, 2021).

An intersectional lens is especially important in mitigating monolithic narratives of marginalized groups within power-laden environments (Esmonde, 2011; Leyva, 2017). As previously discussed, masculine norms produce tensions for women in mathematics. These tensions emerge differently for each woman and can fluctuate with intersecting identities such as race, class, sexuality, and other social markers. Esmonde (2011) warns against essentializing identity by treating a group, such as women, “as if they were monolithic groups with little internal variation” (p. 28). Essentializing potentially erases group differences regarding individual negotiations of social identities with mathematical discourses by either treating everyone as equally advantaged or masking the disadvantages of certain individuals within the group (Esmonde, 2011; Leyva, 2017). Utilizing an intersectional lens helps illuminate varying mathematical experiences across intersecting subgroups of students and highlights the power relations within the gendered and racialized mathematical space (Leyva, 2017; Young & Cunningham, 2021). Showcasing intersectional narratives outside of dominant groups paints a broader picture of mathematics education to inform and support more equitable mathematics spaces.

As highly recommended by various scholars within education research (e.g. Durodoye, 2003; Damarin & Erchick, 2010), and in particular within identity research (e.g. Leyva, 2017; Esmonde, 2011), I aim to clearly define both gender and racial identity as framed in this work. While I give space for each description separately, the overall viewpoint in this work maintains the interconnectedness of both race and gender for women of color.

Gender Identity

I conceptualize gender primarily utilizing Butler’s (1990, 1993) work on gender and power and Mendick’s (2005, 2006) work on gender within mathematics education. Within this line of work, gender represents a dynamic and performative response to societal expectations and constructions within the false gender binary system. That is, gender is “something that we do and are done by not something that we are” (Mendick, 2006, p. 10). The false gender binary system sets up masculinity as solely performed by men while femininity is solely performed by women. Alongside these scholars, I reject this notion and frame gender as relational rather than oppositional. This means masculinity and femininity are not distinct, such that men can do femininity and women can do masculinity (Mendick, 2006). Gender as relational also implies that practicing one's gender varies based on numerous factors both temporal and environmental: age, location, with people, alone, at home, in public, etc. In particular, one can express their gender differently within the school environment, with differences emerging even between the classroom and the hallway (Esmonde, 2011). Given the masculinization of mathematics, doing mathematics is often perceived as doing masculinity (Mendick, 2006). Thus, there often exist challenges within mathematics environments for women as they navigate doing mathematics and representing their femininity. In this work, I include anyone who identifies with the category of "woman" as part of their gender identity, including cisgender women, transgender women, and subgroups of non-binary and transgender people.

Esmonde (2011) argues that not only does sexism emerge in mathematics spaces, but also genderism, a valuing of those who conform to their gender expectations versus those that transgress. For women, practicing mathematics can evoke what feels or looks like a gender transgression. Framing gender in the above way highlights the tensions that can arise for women and other students who do not conform to the dominant masculinities in mathematics and thus can impact their ability or willingness to identify with the field. It also provides a foundation to alter mathematical discourses by illuminating numerous ways students of different genders do mathematics.

Racial Identity

I conceptualize race based on work from Martin (2006, 2009) and Ladson-Billing and Tate (1995). Similar to gender, race is socially constructed within systems of power, dominance, and marginalization. Ladson-Billings and Tate (1995) highlight the important intersection of race and property rights affecting various systemic inequalities, particularly in education. Thus, although race has questionable biological foundations, racial classification has strong social, historical, and political roots that have instigated numerous consequences for people of color's lives and access to opportunities (Martin, 2006; Spring, 2012). Therefore, this work focuses not on how race interacts with mathematical identity, rather on how racial consequences such as racism, racialized experience, and racialized inequities interact with mathematical identity (Bowleg, 2008; Martin, 2006).

Given the valuing of whiteness within racialized discourses of mathematics, students of color often face tensions navigating mathematical spaces (Battey, 2013). These discourses promote "only a few [students of color] to enter through the gateway of assimilation into white institutional spaces instead of promoting equitable mathematics education" (Basile & Lopez, 2015, p. 523). This also enables colorism in mathematics education in which lighter skin tones are privileged over darker skin tones, often within the same racial group (Nittle, 2021). For example, within McGee et al.'s (2016) study exploring Asian and Asian American students' STEM experiences related to the 'model minority' stereotype, many women of color participants described skin tone discrimination in their academic lives. Shreela, an Indian woman, explained how "I was also beginning to be viewed much more suspiciously than my non-Indian Asian peers... I have always felt that because I'm dark that I would never be able to be seen as all good [by STEM instructors]" (McGee et al., 2016, p. 12). Thus, illuminating how students from diverse racial backgrounds, including within the same racial group, experience both challenges and supports in mathematics challenges the white discourses of mathematics and promotes restructuring mathematics education to reflect women of color's values instead of encouraging assimilation.

Data Feminism

In conjunction and in concert with an intersectional lens, Data Feminism inspired the overall structure and design of this dissertation study. Coined by D'Ignazio and Klein (2020), Data Feminism combines ideas from Feminist thought and intersectional theory to analyze the sociohistorical use and implications of data. In particular, this theory posits that data historically have maintained inequitable power hierarchies through an unequal valuing in who collects data and their choices about who and what gets counted. Data Feminism at its core examines the connection between data and power and believes that "because the power of data is wielded unjustly, it must be challenged and changed" (D'Ignazio & Klein, 2020, p. 14). Projects rooted in Data Feminism challenge unjust power differentials through subject matter, data communication techniques, and/or processes of data collection and analysis. Data Feminism aims to restructure how we conceptualize data, such that they are "informed by direct experience, by a commitment to action, and by intersectional feminist thought" (D'Ignazio & Klein, 2020, p. 8).

Data Feminism prioritizes research methods that integrate multiple perspectives. This includes dismantling the gender binary which constrains choices to man or woman, neglecting other gender expressions and thus excluding them from important data implications. D'Ignazio and Klein (2020) conceptualize gender as a social construct maintained through repeated performances of gendered actions. Through these repetitions emerged modern gender categories. That is to say that gender is neither innate nor essential, but strongly reinforced through repeated actions and activities and bear certain implications in our society. One major implication of gender is society's adherence to a patriarchal system, meaning "the combination of legal frameworks, social structures, and cultural values that contribute to the continued male domination of society" (D'Ignazio & Klein, 2020, p. 108). As discussed previously, mathematical spaces often reflect these patriarchal values in a specific way, valuing certain traits historically subsumed within dominant masculinity. Given the strong focus of intersectionality, Data Feminism emphasizes how the intersection of gender with other social identities additionally contributes to inequitable power structures. This includes deconstructing other binaries as well, such as the racial binary of Black/white and the sexuality binary of heterosexual/homosexual. Defying these binaries within our data processes helps challenge classification systems that minimize who is counted and thus perpetuate oppression of those uncounted groups.

In support of contextualizing data, Data Feminism firmly asserts that data are neither neutral nor objective and cannot speak for themselves. To conduct research that is both ethical and accurate, researchers must situate data based on social, cultural, historical, institutional, and material contexts. Ignoring context can lead to data misinterpretations or inaccurate results based on the erasure of inequitable underlying structures. For example, analyzing and interpreting data from women of color within mathematics education research cannot ignore the white, patriarchal context of higher education mathematical spaces (Battey et al., 2022). D'Ignazio and Klein (2020) argue that "placing numbers in context and naming racism or sexism when it is present in those numbers should be a requirement – not only for feminist data communication, but for data communication full stop" (pp. 166-167). Thus, Data Feminism is a critical lens by which to underpin this work exploring how undergraduate women of color express and develop their mathematical identity within the gendered and racialized mathematical space.

Data Feminism describes how powerful institutions, such as universities, have long utilized data to maintain power hierarchies that privilege the dominant group. A feminist perspective recognizes this history and aims to use data as a counternarrative. For example, Fennema and Sherman (1977) used data to counter the narrative that men were biologically superior to women in mathematics by utilizing additional context, such as mathematical background. The high cost in terms of both money and resources needed to work with large scale data sets means powerful institutions such as research universities hold a particular responsibility in prioritizing critical data analysis. As research produced within a university, utilizing a Data Feminist lens helps inform this dissertation study as a counternarrative to the dominant culture in mathematics. Discussing mathematics as a gendered and racialized space centers an often subjugated topic about how our education systems privileges certain groups while marginalizing others. Thus, a main focus of this study considers how institutions both support and hinder a strong mathematical identity for women of color. Furthermore, a mixed methods study values the power of both quantitative data and qualitative data to create a more holistic interpretation of the results and data context. In the sections below, I describe how Data Feminism conceptualizes both quantitative and qualitative data and the ways my study aligns with these principles.

Data Feminism rejects the notion that quantitative data are less biased and more objective than qualitative data. D'Ignazio and Klein (2020) argue that "before there are data, there are people" (p. 10) such that every component of a research study relies on people counting, analyzing, visualizing, utilizing, and overall making choices regarding the data. Given the complexities of the human experience, this "process of converting life experience into data always necessarily entails a reduction of that experience – along with the historical and conceptual burdens of the term" (p. 10). This necessitates contextualizing the data, as previously mentioned, and recognizing the limitations of using a purely quantitative data set.

To this point, Data Feminism also highly values qualitative data, such as words, stories, sounds, and any other "knowledge that comes from people as living, feeling bodies in the world"

(D’Ignazio & Klein, 2020, p. 18). Given the focus on situating data within Data Feminism, qualitative data can help provide rich information about the culture, context, and background of quantitative data. Thus, a mixed methods approach is well aligned with a Data feminist lens. I supplement the quantitative results with follow-up interviews with women of color from the original dataset for two main reasons: (1) to provide overall context related to the participants within the quantitative data components and (2) to more deeply examine similarities and differences between various universities within the dataset. As previously mentioned, universities represent an important context where Data Feminism recognizes sexism and racism ingrained within the structures and systems rather than individuals. Rather than trying to “fix” bias at the superficial level, Data Feminism supports understanding and redesigning the structural oppression underpinning these biases. Given the gendered and racialized discourses around mathematical spaces, I aim to explore in what ways the various institutions align with or transgress from discourses that maintain white, patriarchal values. This mixed method study was designed to leverage the strengths of both quantitative and qualitative data, recognizing that without quantitative research, “it is difficult to distinguish between personal experience and collective oppression,” (Oakley, 1999, p. 251) while qualitative research illuminates individual stories within the collective.

Researcher Identity and Positionality

As a white woman with an undergraduate degree in mathematics and experience with mathematics education as a student, researcher, and instructor, I consider the ways that my positionality permeates throughout this work. The theoretical underpinnings of Data Feminism assert that data are always biased because they are collected, analyzed, and presented by humans, and thus “disclosing your subject position(s) is an important feminist strategy for being transparent about the limits of your—or anyone's—knowledge claims" (D'Ignazio & Klein, 2020, p. 83). My gender identity allows me to relate to participants' feelings of community exclusion, underrepresentation, and discomfort they may have experienced because of gender while navigating undergraduate mathematics. This shared identity as a woman who had also pursued a STEM degree helps "build trust and rapport with participants" (Martin et al., 2022, p. v) and support them in sharing both positive and negative experiences with mathematics.

I simultaneously recognize my limited perspective on the gendered-racialized experiences ever present for women of color. My racial privilege imbues a social distance where I cannot directly relate to women of color's racialized experiences within mathematics. This also relates to the position of power that I hold in mathematical spaces given my race and my success in these dominant spaces evidenced by my undergraduate degree in mathematics, role as a graduate student, and instructor of undergraduate mathematics. These are all positions readily noticeable by my participants through study recruitment documents and video, which may influence their responses. Acknowledging the nuances within my own positionality and the influence of these identities within my work broadens opportunities for both moments of empathy with the participants' and an openness to learn from them and their experiences.

This positionality statement is only "one part of a larger process of reflexivity" (Martin et al., 2022, p. v). My background, including my identities and experiences, formed my perception of undergraduate mathematics as a socially exclusionary space. However, this gendered exclusion does not directly translate to exclusionary experiences based on various other identities, such as race, first-generation status, or sexuality. Throughout this dissertation study, I rely on the works of numerous scholars of color, women scholars of color, and activists both inside and outside of the academy to reflect on my perspectives and inform research decisions.

While not explicitly detailed in the papers, I frequently engaged in journaling through my research decisions, exploring differing viewpoints for analysis and discussion, and continued reading through the work of critical scholars to inform my perspectives (Idahosa & Vincent, 2019). This reflexive process enabled more ethical and authentic work, positive relationships with participants, and a consistent centering of the participants' voices and experiences.

Reliability and Trustworthiness

Accounting for my identity and positionality within this work is just one way I engaged in reliability and trustworthiness measures (Noble & Smith, 2015). I spent time before and during the research process critically reflecting on my methodology choices to capture sufficient depth and breadth within the data and connect to both my theoretical stances and the research questions. For example, the choice to use a cluster analysis method to analyze the quantitative data provided large-scale patterns related to women of color's mathematical identity without referencing dominant groups. The survey item I used to collect the quantitative data was also previously determined to be reliable by Walter et al. (2016). The processes to collect and analyze the qualitative data contained numerous other means to increase reliability and trustworthiness. The above description of my positionality and my reflexivity practice throughout this research supported more open interview conversations that built trust and encouraged genuine responses. During analysis, I constructed a detailed codebook which I refined through multiple iterations of going through the transcripts and keeping a clear record of the decisions I made to remove, add, or edit codes from previous iterations. When presenting the results, I prioritized rich and thick descriptions of participants' narratives, utilizing their verbatim quotations as much as possible. I also emphasized the experiences that emerged across numerous participants or were frequently reiterated in a single participant's account. These various reliability and trustworthiness measures helped support a more authentic presentation of the participants' experiences and feelings related to their mathematical identity and values (Noble & Smith, 2015).

Methods

This dissertation study follows a three paper model such that each paper contributes to the overall research goal through its own research question(s) and methods. I leverage transformative, sequential mixed methods across the three papers to support the overall research question (Creswell et al., 2003; Mertens, 2014). Defined by Donna Mertens, a transformative paradigm is an ethical, culturally responsive framework that helps develop mixed methods research through recognizing power differentials and building trusting relationships (Mertens, 2012, 2014). Summarized by Creswell et al. (2003), a transformative, sequential mixed methods design utilizes an explicit theoretical framework focused on the empowerment of a marginalized group, includes two distinct periods of data collection, one qualitative and one quantitative, and integrates both data components within the interpretation phase. In this study, Data Feminism informs my use of a sequential mixed methods approach such that the quantitative data collection provides an overarching view to communicate within-group differences of undergraduate women of color's mathematical identity, while follow-up qualitative data collection expands on the data context and illuminates the human aspects ingrained within the quantitative patterns (Almeida, 2018; D'Ignazio & Klein, 2020). This aligns with a transformative, sequential mixed methods approach by which "using two phases, [the researcher] may be able to give voice to diverse perspectives" and "better advocate for participants" (Creswell et al., 2003, p. 183). Furthermore, Mertens (2014) emphasizes that the goal of transformative research is to center the narratives of marginalized students to promote systemic change; I center women of color's voices to encourage department and institutional level changes to mathematics education.

Data Background

The data utilized for this study originate from the *Progress through Calculus* (PtC) project funded through the National Science Foundation with support from the Mathematical Association of America (Mathematical Association of America, n.d.). The PtC project used survey instruments over two phases to collect information about students' experiences in Precalculus, Calculus I, and Calculus II (P2C2) within university mathematics departments across the United States. Phase 1 aimed to survey all university mathematics departments in the United States to characterize program factors related to students' success in P2C2 courses. Phase 2 consisted of deeper investigations into twelve universities selected for their variation of responses within phase 1. The survey suite for phase 2, called the *X-PIPS-M* survey suite, was co-developed by members of the PtC project and the *Student Engagement in Mathematics through an Institutional Network for Active Learning* (SEMINAL) project (ww.aplu.org/SEMINAL). They developed this survey based on the *Postsecondary Instructional Practices Survey* (*PIPS*), originally created and confirmed as valid and reliable by Walter et al. (2016). The PtC and SEMINAL teams adjusted *PIPS* specifically for mathematics (the M), to address the surveyed population (the X), and to add questions related to context and attitudes. As part of phase 2, all instructors, student instructors, and students enrolled in mainstream P2C2 courses at each of the twelve institutions were administered an *X-PIPS-M* survey during each semester or quarter term of the 2017-2018 academic year and the Fall term of 2019.

This dissertation study utilizes participants from the student survey, *S-PIPS-M*. This survey asked P2C2 students from the twelve selected universities various questions regarding their course experiences, mathematical affect, and demographic information (see Street et al., (2021) for full details). The dataset includes 19192 total student responses. Given the distribution of the survey over numerous terms, some participants responded more than once in this dataset if they repeated courses or continued in the P2C2 sequence. Provided that perceptions may alter over time and different courses, I did not remove these repeated participant responses.

Participants

For this dissertation study, I utilized a subset of the above total responses that includes only women of color. Driven by a Data Feminist perspective, I categorized women to include any participant who selected at least "woman" for the survey statement "Do you consider yourself to be (Select all that apply)" given the options Man, Transgender, Woman, Not listed (please specify). Thus, women in this study include cisgender women, transgender women, and subsets of gender non-binary and transgender students who selected "woman" as part of their gender identity. I categorize a student of color as any participant who selected at least one of the following: Alaskan Native or Native American, Black or African American, Central Asian, Hispanic or Latinx, Middle Eastern or North African, Native Hawaiian or Pacific Islander, Southeast Asian, South Asian, for the statement "Do you consider yourself to be (Select all that apply)." Participants who selected one or more of Central Asian, East Asian, Southeast Asian, South Asian and did not select any other option are coded as Asian and participants who selected more than one option (aside from the previous) are coded as Multiple Race/Ethnicity. Women of color represent the intersection of the above categorizations. This resulted in 3650 responses from women of color. However, the statistical method I used within Paper 1 required removing participants who did not answer any one of a selected subset of survey questions. This resulted in a final count of 3293 responses from women of color utilized in this dissertation study. Tables 1 and 2 below provide the number of women of color in this study by gender and race/ethnicity.

Additional demographic information, including first-generation status and sexuality, can be found in Appendix A.

Table 1 Women of color by gender (n = 3293)

Gender	Frequency (Proportion)
Cisgender woman	3288 (0.998)
Gender non-binary	4 (0.001)
Transgender woman	1 (0.001)
Transgender	0 (0.000)

Table 2 Women of color by race/ethnicity (n = 3293)

Race/Ethnicity	Frequency (Proportion)
Alaska Native or Native American	27 (0.008)
Asian	575 (0.175)
Black or African American	689 (0.209)
Hispanic or Latinx	990 (0.300)
Middle Eastern or North African	134 (0.041)
Multiple Race/Ethnicity	858 (0.261)
Native Hawaiian or Pacific Islander	20 (0.006)

I recruited participants for follow-up interviews from those who consented to future contact within the above dataset of women of color survey respondents (n = 1121). I sent an interest survey by email describing the follow-up study as an exploration of women of color STEM majors' experiences in undergraduate mathematics. Thus, those that completed the interest survey self-selected as women of color. Using the interest surveys, I selected and interviewed 12 participants in total. I chose these 12 participants in particular based on the quantitative results from Paper 1 and to promote sample diversity in terms of gender, race/ethnicity, major, and university. Table 3 provides information about each participant, including pseudonyms for name and institution and their self-described major, gender, and race.

Table 3 Information about interview participants (n = 12)

Name (Pronouns)	**Institution**	**Major**	**Gender**	**Race**
Callie (she/her)	Pine Grove University	Biology	Female	Hispanic/Latino
Daisy (she/her)	Dunshire University	Biology/Pre-Med	Female	Latina/Mexican-American
Daria (she/her)	Alpine University	Biology	Female	Persian/Middle Eastern
Gabby (she/her)	Maple State University	Computational Mathematical Sciences	Female	Hispanic/Latinx
Janelle (she/her)	Pine Grove University	Psychology & Interdisciplinary Studies	Female	Black/African American
Lyka (she/her)	Alpine University	Biomedical Engineering & Multidisciplinary Studies	Female	Filipino, White
Michelle (she/her)	River Rock University	Biomedical Engineering	Female	Asian
Rhythm (she/her)	Desert Bloom University	Mathematics	Female	Indian
Rose (she/they)	Sandpiper University	Mechanical Engineering	Genderfluid	Latine
Sara (she/her)	Desert Bloom University	Mathematical Sciences	Female	Middle Eastern
Sky (she/her)	Desert Bloom University	Biology	Girl	Asian-American, Filipino-American
Sofia (she/her)	Maple State University	Biochemistry	Woman	Hispanic/Latina

Paper 2 focuses on three participants: Callie, Sara, and Sky. Paper 3 focuses on two participants: Callie and Lyka. Further descriptions of these participants will be provided within the papers.

Paper Outlines

Paper 1 utilizes quantitative methods to highlight the various and unique expressions of mathematical identity for undergraduate women of color. In particular, I use non-hierarchical, k-means cluster analysis to address the following research question:

1) What groups emerge based on attributes of mathematical identity for undergraduate women of color in introductory mathematics?
   a) With respect to which attributes do the groups differ?
   b) With respect to which attributes are the groups similar?

In general, cluster analysis methods group datasets into subgroups "where the elements of each subgroup are more similar to each other than they are to elements not in the subgroup" (Battaglia et al., 2015, p. 1). Thus, cluster analysis helps answer the above research question by grouping women of color within the dataset based on similarities and differences across measures of mathematical identity. I chose a non-hierarchical cluster analysis method to remove any ordering of the groups. I chose a k-means approach because it is a common clustering method that does not require previous knowledge about response distributions. Furthermore, cluster analysis methods align with a Data Feminist lens by centering the perspectives of a marginalized group without necessitating a comparison group, such as when using linear regression, which often defaults as white men.

To measure mathematical identity, I created four subdomains using factor analysis over 22 likert-style questions from the *S-PIPS-M* survey. Informed by Voigt's (2020) attributes of mathematical identity, I selected the 22 survey questions based on (1) perceptions of ability and participation, (2) positionality and sense of belonging, and (3) identity resources such as programs, peers, and instructors (Appendix B). I named the four subdomains *Classroom*

Experience, Inclusion/Positionality by Instructor, Self-efficacy, and Mathematical Peer Interaction based on similar themes between the survey questions (i.e., factor items) and their relationship to the attributes of mathematical identity (Appendix C). I then performed the non-hierarchical, k-means cluster analysis over 4-dimensions, one for each subdomain. This resulted in four cluster groups representing four discernable expressions of mathematical identity among women of color in introductory undergraduate mathematics. I submitted Paper 1 for publication in Educational Studies in Mathematics and am awaiting a response.

Paper 2 expands on the results of Paper 1 by utilizing follow-up interview data from three participants all within one of the above clusters: Callie, Sara, and Sky. With each participant, I conducted a virtual, 60-90 minute, semi-structured interview which included questions that covered numerous aspects of their undergraduate mathematics experiences (Appendix D). Paper 2 focuses on ways in which the third attribute of mathematical identity, identity resources, contributes to undergraduate women of color's mathematical identity. Paper 2's results help contextualize and describe the participants' cluster group and provide further details about the institutional and interpersonal resources available for undergraduate women of color's mathematical identity development. I utilize Nasir's (2011) definitions of material and relational resources to explore the research questions:

1. What material and relational identity resources do undergraduate women of color STEM majors utilize within their institutions?
2. In what ways do they describe these resources as supportive or hindering to their mathematical identity?

The results and discussion of Paper 2 identify several identity resources for women of color that afforded or limited access to a strong mathematical identity and the ways that gender, race, and other social identities intertwine with these resources.

Paper 3 is a chapter currently in the revision process for publication in the international book titled *Values and Valuing in Mathematics Education: Moving Forward Into Practice*. This paper utilizes the same interview data from a different set of participants, Callie and Lyka. I selected these participants for this analysis because of their differences in demographics, institutions, degrees, and experiences. This paper focuses on the third of Nasir's (2011) identity resources not presented in Paper 2, called ideational resources. I conceptualize ideational resources using Bishop et al.'s (1999) subcategories of values in mathematics education: general education values, mathematical values, and mathematics education values. Using this conceptualizing, Paper 3 examines:

1. What do two women of color STEM majors in the USA describe as valuable/important about mathematics and their undergraduate mathematics education?
2. To what extent do these values align with the values traditionally held in the discipline and in their undergraduate mathematics spaces?

Following the call for chapters, this paper includes substantial exposition describing the definition of values, values in mathematics education, white and patriarchal values in Western mathematics, and the lack of marginalized students' values within undergraduate mathematical spaces in the United States. The results point towards a major disconnect between sociohistorical mathematical values and women of color's values. This paper does not directly focus on mathematical identity, however, the results imply a hindering of women of color's mathematical identity based on Voigt's (2020) and Nasir's (2011) description of ideational resources.

CHAPTER 2 – EXPLORING UNDERGRADUATE WOMEN OF COLOR'S EXPRESSIONS OF MATHEMATICAL IDENTITY: A DATA FEMINIST APPROACH[3]

Introduction

Global scholarship within mathematics education continues to call for equitable and just learning environments to counter mathematical systems built to marginalize students with certain identities (Battey et al., 2022; Frade et al., 2013; Leyva, 2021). This call is particularly prevalent for mathematics education scholarship in the USA, but is gaining increasingly more global attention (Wagner et al., 2020). One area within this field of study explores students' mathematical identities, with connections to students' well-being, mathematical enjoyment, and continuation in a mathematical field (Seyranian et al., 2018; van Laar et al., 2010). Mathematical identity broadly considers the ways students relate to mathematics and their mathematics education. This includes students' beliefs about their participation and abilities, their sense of belonging in class and the field, and the role of institutional and interpersonal supports (Voigt, 2020). While a growing body of work centers the relationship between mathematical identity and gender *or* race, few studies consider mathematical identity at the intersection of gender *and* race. Considering only gender or only race often highlights the experiences of only white women or only men of color, respectively, which cannot fully encapsulate the experiences of women of color. In response, scholars voice a particular need to consider the intersection of gender and race moving forward in mathematics education (Esmonde, 2011; Leyva, 2017; Solórzano & Yosso, 2002). The limited research that does consider women of color's mathematical identity

[3] This paper has been submitted to Educational Studies in Mathematics. Citation: Street, C. (2023). *Exploring undergraduate women of color's expressions of mathematical identity: A Data Feminist approach*. [Manuscript submitted to Educational Studies in Mathematics]. Mathematics, Colorado State University.

highlights unique experiences. These studies suggest that gendered and racialized mathematical discourses can mediate whether a woman of color develops a strong mathematical identity (Rodriguez et al., 2019; Young & Cunningham, 2021). Thus, this work centers women of color's perspectives to explore the ways in which experiences in undergraduate mathematics connect with their mathematical identity. The goal of this work is to challenge homogenous views about women of color's experiences in undergraduate mathematics, illuminate women of color's varying expressions of mathematical identity, and promote ways in which to deconstruct exclusionary mathematics environments.

Mathematical Identity

Researchers around the world use mathematical identity in various ways to explore how students' experiences in mathematics influence their perceptions of themselves and the field (Black et al., 2010; Cobb & Hodge, 2011; Lutovac & Kaasila, 2014; Voigt, 2020). They describe mathematical identity as a dynamic, context-dependent, and transformative construct which varies across mathematical environments, including through interactions with instructors and peers (Carlone & Johnson, 2007; Gardee & Brodie, 2023; Hall et al., 2018). Many definitions of mathematical identity include both social influences and individual components (Gardee & Brodie, 2021; Graven & Heyd-Metzuyanim, 2019; Voigt, 2020). Social influences include aspects such as recognition as mathematically capable by instructors and peers, involvement with mathematics-related extracurriculars, and perceptions of classroom community. These influences help construct students' social identity, a "navigated position between personal identities and the way in which people believe they should be perceived in a social setting" (O'Mahoney & Marks, 2014, p. 72). Langer-Osuna and Esmonde (2017) consider how membership identities, such as race and gender, can inform and sometimes limit students' access to certain social identities and make it more difficult to identify with mathematics. In the USA, numerous studies continue to report the presence and impact of gender and racial stereotypes which position women and students of color as less mathematically capable (Dortch & Patel, 2017; Ernest et al., 2019; Jaremus et al., 2020; Master & Meltzoff, 2020). These stereotypes influence women of color's perceptions of their mathematical ability and whether they feel safe fully participating in class (Blosser, 2018; Ernest et al., 2019; Mendick, 2006).

Students' personal identities are "an understanding of self" (Gardee & Brodie, 2021, pp. 9), including their interests, emotions, memories, values, and other thoughts and preferences (O'Mahoney & Marks, 2014). Agency "involves learners making active choices to participate in certain ways" (Gardee & Brodie, 2021, pp. 11) regardless of whether they are aware of the reason for their action. Students' personal identities and agency interplay with their social identities, transforming and constructing each other while informing their mathematical identity. Studies suggest that women's lower sense of belonging in mathematics, a social influence, may act as a mediator of gendered differences in mathematical confidence and interest, impacting their persistence in mathematics (Tellhed et al., 2017; Good et al., 2012). Other studies suggest that personal components such as lower mathematical confidence or perceived misalignment of their career goals and the goals of STEM may be responsible for women's higher departure from STEM compared to men (Diekman et al., 2010; Ellis et al., 2016). Therefore, both social and personal components are critical when exploring women of color's expressions of mathematical identity.

To conceptualize mathematical identity in this work, I draw from Voigt's (2020) description built from Leyva (2016; 2017) and Martin's (2006) work highlighting marginalized students' mathematical experiences in the USA. Voigt (2020) outlines three components to investigate students' mathematical identities: "(1) their beliefs about participation and perceived ability, (2) their positionality within mathematical communities, and (3) how each of these are shaped by identity resources such as interpersonal and institutional structures" (p. 32). Participation includes various actions exhibited by students in mathematics environments, including interacting, negotiation, formulating, speaking, and listening. Perceived ability relates to the extent students feel capable of learning, understanding, and communicating mathematics (Voigt, 2020). Both of these concepts relate to the discursive notion of mathematical identity where broader societal mathematical discourses and those discourses supported in the local environment influence students' perceptions of what modes of participation are accessible to them and who is capable and can succeed in mathematics, often including both gendered and racialized narratives (Leyva, 2016, 2021; Mendick, 2006). Positionality within mathematical communities captures students' ability and willingness to "position themselves within or outside the community as potential creators of mathematics" (Voigt, 2020, p. 32). Identity resources are the material, relational, and ideational resources available to students to support their connection to the practice of mathematics (Nasir, 2011). I use these three categories to structure this analysis and explore the different expressions of undergraduate women of color's mathematical identity.

Mathematics as a Gendered and Racialized Space

Mathematical identity considers learner positionality in both local mathematics environments and in society more broadly (Voigt, 2020). This definition necessitates consideration of both gendered and racialized mathematical discourses (Leyva, 2017; Martin, 2006). As a gendered space, mathematical discourses often value and give power to dominant masculine characteristics, such as framing mathematical reasoning as ultimate rational thought, mathematical ability as innate, and mathematicians as culturally deviant (Hottinger, 2016;

Mendick, 2006). As a racialized space, Bullock (2019) argues that the rhetoric of mathematics for 'all' continues to define 'all' as those who "can embrace the whiteness that standardization represents" (p. 77). Race in the USA is a social identity constructed within systems of power, dominance, and marginalization that are historically tied to property rights (Ladson-Billings & Tate, 1995). Thus, race has strong social, historical, and political roots that means "although… [race] has dubious value as a scientific classification system, …[it] has had real consequences for the life experiences and life opportunities of African Americans" (Martin, 2006, p. 197) and other marginalized racial groups in the USA (Spring, 2012). Therefore, this work focuses not on how *race* interacts with mathematical identity, rather on how *racial consequences* such as racism, racialized experience, and racialized inequities interact with mathematical identity (Bowleg, 2008; Martin, 2006). While this work is situated in the USA context, these gendered and racialized ideologies have been documented in relation to mathematics education internationally, including New Zealand (Hunter, 2021), Great Britain (Mendick, 2006), Australia (Jaremus, 2020), Lebanon (Sarouphim & Chartouny, 2017), and other countries (Forgasz et al., 2014). These mathematical discourses uphold norms rooted in traditional masculinity and whiteness that create tensions for those unwilling or unable to assimilate into this culture, more often women and people of color.

For women of color, navigating both of these discourses simultaneously poses unique challenges in undergraduate mathematics. Various studies illustrate covert and overt instances of racism and sexism in the mathematics classroom (Ernest et al., 2019; Leyva et al., 2021). In their study exploring participation in an IBL geometry classroom, Ernest et al., (2019) observed sexist talk in both men and women during small-group interactions. Scholars also highlight how students of color use coping strategies and stereotype management in response to racism in mathematics (Jett, 2019; Leyva, 2021; McGee et al., 2016). These stereotypes range in their assumptions, from placing Asian students as 'model minorities' to presuming a lack of ability for Black, Latine, and Indigenous students (Abrams et al., 2013; McGee et al., 2016; McGee & Martin, 2011; Oppland-Cordell, 2014). In both cases, these experiences in mathematics often impart undue cognitive effort on marginalized students to navigate assumptions and define their own mathematical identity (Martin, 2006; Masten et al., 2011). Informed by this previous work, this study centers women of color's narratives around their mathematical identity to challenge these exclusionary discourses and promote the restructuring of mathematical spaces to better support marginalized students.

Women of Color's Mathematical Identity

Studies suggest that gendered and racialized mathematical discourses mediate the development of a strong mathematical identity for women of color in the USA. Rodriguez et al. (2019) found that multiple Latina undergraduate women described how a lack of peer and instructor recognition "left them doubting their abilities and questioning their place within the STEM community" (p. 267). Young and Cunningham (2021) also found that only half of their sample of Black girl students expressed perceiving themselves as a 'math person'. Hernandez-Martinez et al. (2008) suggest that for students of color, mathematics may be utilized as a tool in becoming a certain identity in the future (i.e., a successful mathematics career person) rather than a component of their current identity.

Looking within the three categories of Voigt's conceptualization of mathematical identity provides additional components that may influence women of color's mathematical identity construction. In terms of participation and perceived ability, fear of confirming a racial or gender mathematics stereotype can negatively influence women of color's perceptions of their mathematical ability and whether they feel safe fully participating in class (Blosser, 2018; Ernest et al., 2019; Mendick, 2006). Related to positionality, both peers and instructors can play an influential role in women of color's feelings of positionality and sense of belonging in mathematics (Carlone & Johnson, 2007). Narratives from students of color often express a lack of recognition by STEM authorities and instead describe striving toward other sources of recognition (e.g., community members, family) and convey isolation from their academic STEM community (Carlone & Johnson, 2007; Fong et al., 2019; Leyva, 2021). Joseph et al. (2020) identify a strong relationship between interpersonal relationships with peers and women of color's mathematical identity starting in the ninth grade. Unfortunately, many studies suggest weak institutional and instructional support for developing students of color's peer networks (Dortch & Patel, 2017; Leyva, 2021; Tate & Linn, 2005; Walker, 2006). However, these studies also showed how students of color with positive and inclusive academic peer networks felt better supported in their mathematical endeavors. One important identity resource for women of color in undergraduate mathematics includes study groups outside of the classroom. Research suggests that engaging in study groups can foster student solidarity as well as provide a safe social place, or counterspace, for marginalized students to feel support and belonging in exclusionary spaces such as mathematics (Ellington & Frederick, 2010; Leyva, 2021; Ong et al., 2018).

The studies above identify components that may impact the construction of and changes in women of color's mathematical identity in undergraduate education, while highlighting the need for further research to understand how these components influence women of color's mathematical identity. Additionally, further research is needed to consider how these components influence women of color differently through other intersecting identities and institutional cultures. Scholars continue to call for more intersectional research to highlight within-group differences in students' experiences in mathematics (Esmonde, 2011; Leyva, 2017; McGraw et al., 2006). They argue that this type of research promotes a more complex understanding of students' mathematics experiences and showcases the interplay between students' identities and these experiences. Furthermore, exploring within-group differences without comparison to dominant groups helps "avoid reverting back to the oversimplified discourse of male superiority" (Leyva, 2017, p. 425) in mathematics, as well as other dominant group superiority discourses (e.g., white, high socioeconomic status). This type of work also helps avoid perpetuating the "'gap-gazing' fetish" (Gutiérrez, 2008) in mathematics education, whereby marginalized groups are described only in relation to the dominant groups. Avoiding this comparison also emphasizes marginalized students' unique individual experiences, strengths, and spaces of support. These scholars call for further work that employs an intersectional lens when considering students' mathematics experiences and acknowledging variation within demographic groups. In response to this call, this work builds on the mathematical identity literature while adding an intersectional lens and critical theory to highlight the various and unique expressions of mathematical identity for undergraduate women of color. In particular, I utilize cluster analysis to address the following research questions:

1) What groups emerge based on attributes of mathematical identity for undergraduate women of color in introductory mathematics?
    a) With respect to which attributes do the groups differ?
    b) With respect to which attributes are the groups similar?

Theoretical Perspective

I employ a Data Feminist lens to inform this research. Coined by D'Ignazio and Klein (2020), Data Feminism combines ideas from Feminist thought and intersectional theory to analyze the sociohistorical use and implications of data. This theory posits that data have historically maintained inequitable power hierarchies through an unequal valuing in who collects data and their choices about who and what gets counted. Data Feminism examines the connection between data and power and asserts that "because the power of data is wielded unjustly, it must be challenged and changed" (D'Ignazio & Klein, 2020, p. 14). Projects rooted in Data Feminism challenge unjust power differentials through subject matter, data communication techniques, and processes of data collection and analysis. This perspective encourages research in which the data context includes people historically uncounted, data communication includes and leverages emotion, and data processes are inclusive. Data Feminism aims to restructure how we conceptualize data and data science as a whole such that they are "informed by direct experience, by a commitment to action, and by intersectional feminist thought" (D'Ignazio & Klein, 2020, p. 8).

Data Feminism prioritizes research methods that integrate multiple perspectives. This includes dismantling the gender binary of cisgender men/cisgender women, the racial binary of Black/white, the sexuality binary of heterosexual/homosexual, and others, all of which neglect other identity expressions and excludes them from important data implications. Defying these binaries within our data processes helps challenge classification systems that minimize who is counted and perpetuates oppression of those uncounted groups. However, rejecting binaries in research often necessitates an unfortunate narrowing of demographic information to categories and reveals the paradox of exposure, defined as "the double bind that places those who stand to significantly gain from being counted in the most danger from that same counting (or classifying) act" (D'Ignazio & Klein, 2020, p. 105). There is no one solution to these challenges, with the most ethical decision varying based on the context and environment of data collection.

This involves deeply considering the context surrounding the data themselves and the power structures within the collection environment to help determine both the potential benefits and harms to the participants.

As part of the argument for contextualizing data, Data Feminism firmly asserts that data are neither neutral nor objective and cannot speak for themselves. To conduct research that is both ethical and accurate, researchers must situate data based on social, cultural, historical, institutional, and material contexts. Ignoring context can lead to data misinterpretations or inaccurate results based on the erasure of inequitable underlying structures. For example, analyzing and interpreting data within mathematics education cannot ignore the underlying affective labor required by women of color to navigate the white, patriarchal space of undergraduate mathematics (Battey et al., 2022). D'Ignazio and Klein (2020) argue that "placing numbers in context and naming racism or sexism when it is present in those numbers should be a requirement" (pp. 166-167). Thus, Data Feminism is a critical lens by which to underpin this work exploring how undergraduate women of color build their mathematical identity within the gendered and racialized mathematical space.

Data Feminism also rejects the notion that quantitative data are less biased and more objective than qualitative data. D'Ignazio and Klein (2020) argue that "before there are data, there are people" (p. 10) such that every component of a research study relies on people counting, analyzing, visualizing, utilizing, and overall making choices regarding the data. As a white woman with an undergraduate degree in mathematics, my identity allows relatability though gender and my experiences with undergraduate mathematics while simultaneously providing a limited perspective on the gendered-racialized experiences for women of color in mathematics. I acknowledge my positionality and engage in numerous reflexive practices throughout the research process. Given the complexities of the human experience, this "process of converting life experience into data always necessarily entails a reduction of that experience – along with the historical and conceptual burdens of the term" (p. 10). Thus, Data Feminism suggests purposefully leveraging emotion by using both quantitative and qualitative data when communicating results to capture the complex and nuanced facets of the data in a holistic and inclusive way.

Methods

To better understand women of color's mathematical identity, I performed a cluster analysis using women of color's responses on the *S-PIPS-M* survey (Street et al., 2021). Cluster analysis helps answer the research questions by grouping women of color within the dataset, all of whom are undergraduate students in either precalculus, calculus I, or calculus II, based on similarities and differences across measures of mathematical identity. Given the under-examined area of women of color's within-group differences in their expression of mathematical identity, non-hierarchical, k-means cluster analysis appropriately requires no ordering of the clusters or prior knowledge of group responses. Furthermore, this method aligns with a Data Feminist lens by centering the perspectives of marginalized groups without holding a white, masculine default by comparing to these populations, as would be done in other statistical methods such as regression. Further, supplementing this analysis with qualitative data helps contextualize the clusters and humanize the data.

Participants

Participants in this analysis include women of color respondents to the *S-PIPS-M* survey administered during phase 2 of the Progress through Calculus (PtC) project (Street et al., 2021). This project cataloged pedagogical practices and student experiences in Precalculus, Calculus I, and Calculus II (P2C2) across the USA using multiple surveys over sequential terms (semesters or quarters). The *S-PIPS-M* survey asked P2C2 students from 12 different institutions in the USA questions regarding course experiences, mathematical affect, and demographic information. Utilizing a pre-collected dataset not originally collected for the stated research questions limits this work. However, multiple survey questions align with the conceptualization of mathematical identity used in this study, as described below. When classifying women of color in this study, a Data Feminism lens asserts that "whether to count gender, when to count gender, and how to count gender" should depend on the researcher's "awareness of context… and an analysis of power in the collection environment… to determine whose interests are being served by being counted, and who runs the risk of being harmed" (D'Ignazio & Klein, 2020, p. 111). I chose to focus on women (including cisgender women, transgender women, and a subset of nonbinary students) of color as a marginalized group in mathematics, but without comparison to white people and men. By centering women of color's variety of experiences and providing often submerged counter-narratives to the white, patriarchal mathematical context, this decision attempts to challenge oppressive power structures that maintain identity binaries and often classify the attributes of white people and men as default.

Within this dataset, I categorize women to include any participant who selected at least "woman" for the survey statement "Do you consider yourself to be (Select all that apply)" given the options Man, Transgender, Woman, Not listed (please specify). Thus, women in this study include cisgender women, transgender women, and subsets of gender non-binary and transgender students who selected woman as part of their gender identity. I categorize a student of color as any participant who selected at least one of the following: Alaskan Native or Native American, Black or African American, Central Asian, Hispanic or Latinx, Middle Eastern or North African, Native Hawaiian or Pacific Islander, Southeast Asian, South Asian, for the statement "Do you consider yourself to be (Select all that apply)." Participants who selected one or more of Central Asian, East Asian, Southeast Asian, South Asian and did not select any other option are coded as Asian and participants who selected more than one option (aside from the previous) are coded as Multiple Race/Ethnicity. Therefore, women of color represent the intersection of the above categorizations. Tables 4 and 5 below provide the number of women of color in this study by gender and race/ethnicity.

Table 4 Women of color by gender (n = 3293)

Gender	Frequency (Proportion)
Cisgender woman	3288 (0.998)
Gender non-binary	4 (0.001)
Transgender woman	1 (0.001)
Transgender	0 (0.000)

Table 5 Women of color by race/ethnicity (n = 3293)

Race/Ethnicity	Frequency (Proportion)
Alaska Native or Native American	27 (0.008)
Asian	575 (0.175)
Black or African American	689 (0.209)
Hispanic or Latinx	990 (0.300)
Middle Eastern or North African	134 (0.041)
Multiple Race/Ethnicity	858 (0.261)
Native Hawaiian or Pacific Islander	20 (0.006)

I also considered other components of women of color students' identities, including first-generation status and sexuality. Details about these distributions can be found in Appendix A. Given the distribution of the survey over numerous terms, some participants responded more than once in this dataset if they repeated courses or continued in the P2C2 sequence. However, responses may change over time or course and thus I maintain all responses from each participant within this analysis. This results in 3293 responses from women of color enrolled in P2C2 courses from this survey who responded to the questions used in this analysis (described below).

Factor Analysis

To reduce dimensionality and increase ease of comparison across clusters, I utilize factor analysis to group the selected survey questions into what I call mathematical identity subdomains. Informed by Voigt's (2020) conceptualization of mathematical identity, I selected a subset of survey questions based on (1) perceptions of ability and participation, (2) positionality and sense of belonging, and (3) identity resources such as programs, peers, and instructors. I summarize the survey questions I selected for each component in Appendix B. Each survey question was asked on an ordinal scale which I quantify and treat as continuous, also referred to as an ordinal approximation of a continuous variable, for the purposes of both the factor analysis and cluster analysis (Norman, 2010; Sullivan & Artino, 2013).

By utilizing factor analysis, I assume latent constructs underpinning correlation between the selected survey question responses and that responses to these questions are linearly correlated. I specifically used the maximum likelihood method for this factor analysis, which requires normality of the survey question responses. Before normalizing the responses, I removed participants who did not respond to any one of the selected survey questions, resulting in 3293 participants analyzed in the remainder of the study with normalized responses. To check the suitability of using factor analysis with these data, I ran a KMO (Kaiser-Meyer-Olken) test for factor adequacy which suggested adequate suitability (MSA = 0.88). To determine the appropriate number of factors, I visually evaluated the scree plot which suggested an optimal four factors. Running the factor analysis under a promax rotation with four factors, eliminating any items with a negative loading or a loading less than 0.2, and allowing items to load into more than one factor resulted in four subdomains I named *Classroom Experience*, *Inclusion/Positionality by Instructor*, *Self-Efficacy*, and *Mathematical Peer Interaction*. I constructed the factor names based on similar themes between the factor items and their relationship to the attributes of mathematical identity. Classroom Experience includes survey items related to students' perceptions of their actions and feelings within the classroom, such as how they participated in class and their feelings of classroom belonging. Inclusion/Positionality by Instructor includes items asking the participant to compare the amount of inclusion and attention from the instructor, such as through praise or encouragement, between themselves and their class peers. Self-Efficacy includes survey items measuring the change in students' perceptions of their mathematical ability, confidence, and interest in mathematics over the course duration. Given that the Self-Efficacy factor uniquely measures change during the course, I frequently consider this factor as a consequence of other factors within the results and discussion. Mathematical Peer Interaction includes items focused on students' amount of peer interaction both in class, such as working in groups, and outside the classroom, such as engaging in peer study groups. See Appendix C for details about factor items and coefficient weights. Using the coefficient weights, I created each of the four new composite factor scores for each participant and appended them to the dataset.

Cluster Analysis

To perform the cluster analysis, I similarly normalized the four new composite factor scores using min-max normalization on a scale of -0.5 to 0.5 for Self-Efficacy and 0 to 1 for the other three factors. A Classroom Experience score closer to 1 suggests a more active classroom, while a score closer to 0 suggests a more lecture-based classroom. For the Inclusion/Positionality by Instructor subdomain, a score above 0.5 indicates the student feels more included by the instructor than their peers, with the level of inclusion increasing the closer the score is to 1. A score at or near 0.5 indicates the student feels equally included by their instructor as their peers. A score below 0.5 indicates the student feels less included by their instructor as their peers, with the level of exclusion increasing the closer the score is to 0. A Mathematical Peer Interaction score close to 1 suggests more frequent interactions with peers both inside and outside of the classroom related to mathematics, while a score closer to 0 suggests infrequent to no interactions with peers related to mathematics. I chose -0.5 to 0.5 for the Self-Efficacy subdomain to maintain both negative and positive scores, given the items in this category measure a change between two questions – one question related to their feelings reflecting back on the beginning of the course and one question related to their feelings at the time of the survey. A positive score for Self-Efficacy indicates an increase in a student's perception of their mathematical ability, confidence, and interest over the course of the semester, with a larger amount of increase the closer the score is to 0.5. A negative score for Self-Efficacy indicates a decrease in a student's perception of their mathematical ability, confidence, and interest over the course of the semester, with a larger amount of decrease the closer the score is to 0.5. Scholars recommend normalizing before clustering to eliminate redundant data and improve the efficiency of clustering algorithms. Given that k-means is a Euclidean based clustering algorithm, I chose min-max normalization to help reduce sensitivity to outliers (Virmani et al., 2015).

Utilizing k-means cluster analysis requires a priori selecting the number of clusters, q, and q centroid points. The centroid of a cluster is a data point whose position represents the cluster's center and whose values represent the means of each variable dimension for that cluster. We can conceptualize an appropriate centroid as one whose characteristics coincide with the general properties of the participants within that cluster. Using the kmeans function in R, I dictated 25 (nstart = 25) iterations to select the centroids. To select the appropriate number of clusters, I used the elbow method while examining the plot of total within-cluster sum of squares between 2 and 14 clusters. This method suggested four clusters as optimal explaining 61.6% of the total variance. Thus, I discuss below the results of performing a k-means, non-hierarchical cluster analysis with four clusters using the previously described dataset.

Results

Results of the cluster analysis suggest four discernable expressions of mathematical identity for women of color in introductory undergraduate mathematics. Figure 1 outlines the mean value for each mathematical identity subdomain. Inclusion, Mathematics Peer Interaction, and Classroom Experience range from 0 to 1, while Self-Efficacy ranges from -0.5 to 0.5. The mean of each subdomain for all women of color in this analysis appears in the Overall Means box.

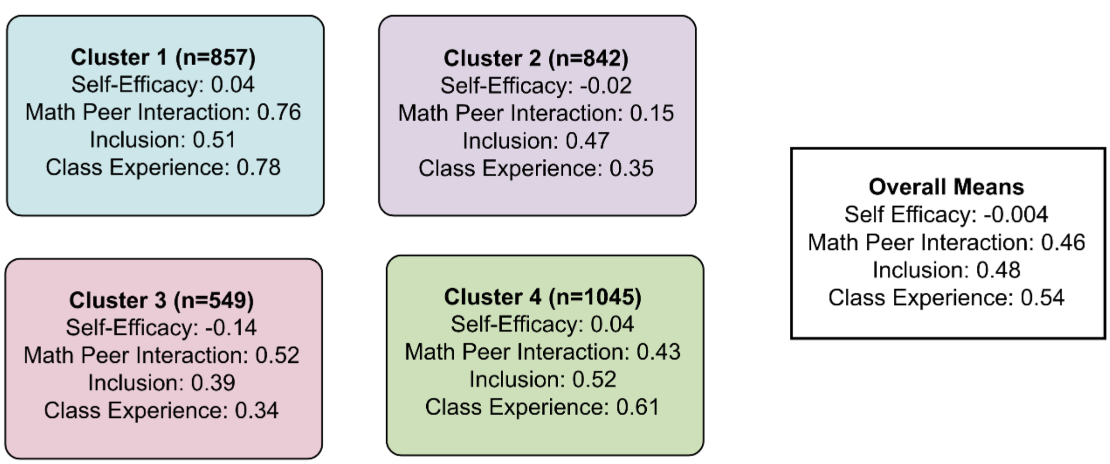

Figure 1 Results of the cluster analysis including mean value scores for each mathematical identity subdomain

The mean of each mathematical identity factor is the average value of the normed version of the composite factor scores for each participant in a single cluster (cluster mean) or in this analysis (overall mean). This is difficult to interpret explicitly in relation to students' responses on the actual survey instrument. To provide some clarity, Table 6 below provides the overall mean normed value and the equivalent value on the original survey scale for each factor.

Table 6 Overall mean normed values and equivalent survey values

Factor	**Overall mean – normed**	**Equivalent value on original scale**	**Original survey scale**
Self-efficacy	-0.004	-0.04	Change from -5 to 5 units on scale from (1) Strongly disagree to (6) Strongly agree
Mathematical Peer Interaction	0.46	2.84	(1) Does not occur to (5) Very descriptive
Inclusion	0.48	2.92	(1) A lot less than other students to (5) A lot more than other students
Class Experience	0.54	3.16	(1) Does not occur to (5) Very descriptive

I expand on each cluster in more detail below using a student vignette and a quantitative summary. The vignette draws on real, illustrative quotations from various students within the cluster to represent a hypothetical, representative woman of color from each cluster. The quotations emerged from free-response questions from the survey which asked students to describe helpful and unhelpful components of the course, ways in which aspects of their identity impacted their experience in undergraduate mathematics, and anything else they wished to share about their experience in mathematics not already addressed in previous survey questions. Informed by Data Feminism, bringing in free-response qualitative data from the same survey helps contextualize the components of mathematics identity and humanize the results.

Cluster 1: Non-impactful Active Teaching

Cluster 1 Vignette: Carmen

Carmen is a woman of color in Cluster 1. She describes her pre-calculus course as a mix of lecture and group work, with a professor who is "excellent… about asking questions and stopping to ask if we understand the material." She describes how the professor takes their time explaining the material and then provides time for class activities with peers. Given these activities, she has "been able to form very good friendships in class as well as help and get help from classmates." If Carmen needs help outside of class, she either stops by her professor's office hours or studies with her friends. In general, she had a fine experience this semester in mathematics that overall had minimal impact on her beliefs about her mathematics ability, confidence, and interest.

I label Cluster 1 as *non-impactful active teaching* for its combination of high peer interaction and classroom experience scores and average inclusion and self-efficacy scores. Cluster 1's classroom experience score of 0.78 is high compared to the average 0.54 across clusters. This suggests that the women of color within this cluster perceive their mathematics classroom to more frequently include practices the literature associates with active learning, such as whole class discussion and group work. Cluster 1's peer interaction score of 0.76 is also high compared to the average 0.46 across clusters. This suggests the women of color within this cluster perceive more mathematical interaction with their peers, potentially both within and outside of the classroom. The comparably average inclusion score within Cluster 1 of 0.51, compared to the average of 0.48 across clusters, suggests the women of color within this cluster perceive themselves as equally included in classroom interactions with the instructor as their class peers. Similarly, the comparably average self-efficacy score within Cluster 1 of 0.04, compared to the average of 0.004 across clusters, suggests little to no change in these students' perceptions of their confidence, interest, and ability to learn mathematics during the semester. Considering these scores together paints an image of an active, interactive, and inclusive classroom with no noticeable change to women of color's self-efficacy.

Cluster 2: Non-impactful Passive Teaching

Cluster 2 Vignette: Aiyana

Aiyana is a woman of color in Cluster 2. Her calculus I class is mainly lecture, with the occasional group work activity. These activities happen infrequently, and thus Aiyana sometimes feels like she's "rushing to solve 2-3 problems with a group of random people, [which] usually ends up in students working individually." Outside of class, Aiyana finds the homework and practice problems she does on her own helpful to her learning. She'll do a practice problem, and then "if [she] does not understand it, [she] will go to the lectures to see another way to do it." Every so often she goes to the tutoring center, but finds the help there inconsistent. Overall, Aiyana feels indifferent toward the class and finds it similar to previous lecture courses. She thinks that "more class activities or projects [would] make it worth coming to class," but acknowledges that she made it through the class just fine.

In contrast to Cluster 1, I label Cluster 2 as *non-impactful passive teaching*. While Cluster 1 and Cluster 2 share average inclusion and self-efficacy scores, Cluster 2 has below average peer interaction and class experience scores. Cluster 2's below average class experience score of 0.47 compared to the average score of 0.54 across clusters suggests the women of color within this cluster perceive less frequent usage of active learning teaching practices. Cluster 2's peer interaction score of 0.15 is far below the average score of 0.46 across clusters. This suggests the women of color within this cluster perceive a lack of mathematical interactions with their peers both inside and outside of the classroom. Cluster 2's average inclusion score of 0.47, compared to the average score of 0.48 across clusters, suggests the women of color in this cluster perceive equal inclusion by the instructor as their peers. Cluster 2's self-efficacy score of -0.02 is also comparable to the average score of 0.004 across clusters, suggesting minimal to no change in perceptions of confidence, interest, and ability to learn mathematics during the semester. When considered together, these scores suggest women of color in Cluster 2 perceive a more lecture-oriented classroom with little to no classroom practices supporting peer interaction. However, they perceive themselves as equally included as their class peers and experience no measurable change in their self-efficacy.

Cluster 3: Harmful Unsupportive Teaching

Cluster 3 Vignette: Brittany

Brittany is a woman of color in Cluster 3. She wishes her Calculus I course had group work components, but for the most part it's "just sitting and looking at the board for 50 minutes." She finds the professor's teaching generally confusing and unstructured and feels the professor's office hours are unapproachable. Instead, she found a study group where she and her friends from class frequently "gather to study, figure out and understand those materials covered in class, [and] do homework together. They help [her] a lot to understand the lessons." She also finds the tutoring center helpful for when she or her study group have questions. In general, Brittany is frustrated by the "inconsistency and lack of explanation during lecture [where they] almost never had time to ask any questions." She generally feels excluded by the professor in class, and although she entered the class feeling relatively confident in her mathematical ability, "this class is making [her] feel like an idiot."

Cluster 3 represents the smallest cluster (16.7% of the total sample), but presents an important combination of factor scores which I label as *harmful unsupportive teaching*. Cluster 3 has a lower than average score for classroom experience and an average score for peer interaction. However, Cluster 3 showcases the only below average scores for both self-efficacy and inclusion. Similar to Cluster 2, Cluster 3's below average class experiences score of 0.34 compared to the average score of 0.54 across clusters suggests women of color in this cluster perceive less frequent active learning teaching practices in class. However, Cluster 3's average peer interaction score of 0.52 compared with the average score of 0.46 suggests women of color perceive slightly more peer interactions within and/or outside of the classroom. Cluster 3's below average inclusion score of 0.39 compared to the average score of 0.48 suggests the women of color in this cluster perceive receiving unequal and less inclusive experiences with their instructor compared to other students in class. Additionally, Cluster 3's below average self-efficacy score of -0.14 compared to the average score of 0.004 suggests the women of color within this cluster perceived noticeable decreases in their confidence, interest, and ability to learn mathematics during the semester. The combination of these scores suggest a more negative mathematics experience for this cluster compared to other clusters.

Cluster 4: Non-impactful Basic Teaching

Cluster 4 Vignette: Marisa

Marisa is a woman of color in Cluster 4. She felt the class had a nice balance between instructor lecture and "group activities where [she] and [her peers] worked together to solve problems." She likes her professor, describing them as "helpful and fun… [and] helps [the class] very much with all [their] questions and needs." She sometimes will go to the tutoring center or study with a friend as a supplemental resource to learning in class. Overall, she found the teaching method of her math class generally helpful to her learning, appreciating both the direct instruction and the time devoted to group work and the occasional class discussion. She interacted with her peers about equally in-class as she did out of class. Throughout the course, her feelings about mathematics and her own abilities stayed relatively stable and overall she is content with her mathematics experience.

As the largest of the clusters (32% of the sample), I label Cluster 4 as *non-impactful basic teaching* for its relatively average factor scores across the board. Cluster 4's inclusion, peer interaction, and self-efficacy scores hover around the cluster averages while the class experience score is above average, although not as high as Cluster 1. The above average class experience score of 0.61 compared to the average score of 0.54 across clusters suggests the women of color within this cluster perceive somewhat more frequently to experience active learning teaching practices in their math class. Cluster 4's average inclusion score of 0.52 compared to the overall average score of 0.48 suggests the women of color in this cluster perceive equally inclusive interactions with their instructor as their peers. Cluster 4's average peer interaction score of 0.43 compared to the average score of 0.46 suggests at least some mathematical interaction with peers inside and/or outside of the classroom. Lastly, Cluster 4's self-efficacy score of 0.04 compared to the average score of 0.004 suggests little to no perceived change in these women of color's mathematical confidence, interest, or ability during the semester. Considering these scores together suggests a slightly more active classroom experience with average amounts of peer interaction and perceived equal treatment by the instructor with minimal change in self-efficacy.

Discussion

The resulting clusters showcase unique combinations of women of color's classroom experiences, peer interactions, feelings of inclusion, and self-efficacy within introductory mathematics. These differing combinations can have similarly unique influence on women of color's relationship with mathematics and their perception of themselves as a doer of mathematics. In this discussion, I expand on the relationship between peer interaction and mathematical identity and how gendered and racialized mathematical discourses may underpin this relationship. Although other identities (e.g., sexuality) may also play a role, the participants' free responses often did not center other identities and thus I leave that focus to future work..

Peers and Friendship

The peer interaction score exhibited the largest range of the four factor scores, with the lowest average score at 0.15 and the highest average score at 0.74 (Fig. 2). Across the clusters,

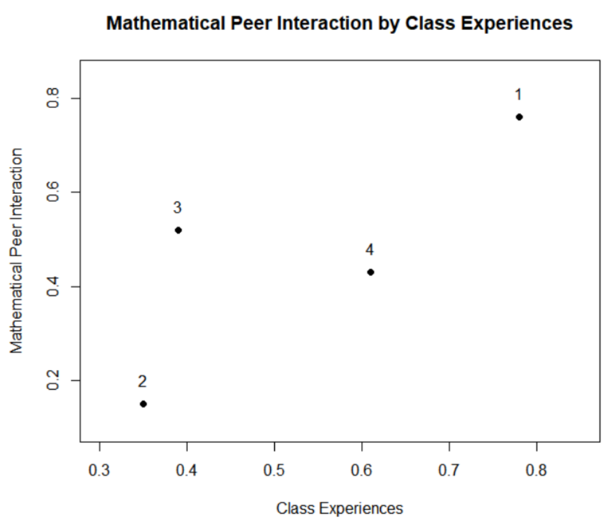

Figure 2 Scatterplot showing mathematical peer interaction by class experience score for each cluster

many participants in the free response section acknowledged the role of peers and friends in their mathematical experiences. Research highlights the importance of peer networks for women of color in mathematics (Dortch & Patel, 2017; Leyva, 2016, 2021; Tate & Linn, 2005; Gallagher, 2020) and how friendship and peer support can help reduce feelings of isolation and provide counterspaces to marginalizing environments (Johnson et al., 2017; Ong et al., 2018; Ellington & Frederick, 2010) . For instance, Joseph et al. (2020) found a significant positive relationship between interpersonal relationships and women of color's mathematical identity starting in high school.

Within the qualitative survey responses, participants described their mathematical interactions with peers in different ways. Students in Clusters 1 (Non-impactful Active Teaching), 3 (Harmful Unsupportive Teaching), and 4 (Non-impactful Basic Teaching) frequently labeled peers and friends as notably helpful aspects of their course, while students in Cluster 2 (Non-impactful Passive Teaching) rarely mentioned peers. For Clusters 1, 2, and 4, the peer interaction score aligned with the class experience score. In conjunction with their relatively higher class experience scores, Clusters 1 and 4 perceived more opportunities to engage in mathematics with their peers both inside and outside of class. The peer interaction score for Cluster 1 was above average, which aligned with student responses mentioning group work components in class as well as engaging in study groups and tutoring (although not as prevalently as in Cluster 3). One woman of color in Cluster 1 described how "class activities are helpful for this course. We work in groups which I think is a good and different way of learning." Cluster 4's peer interaction score was average, with student responses including in-class interactions such as group work, but not to the extent of Cluster 1, and out of class interactions such as tutoring, but not to the extent of Cluster 3.

Cluster 2's peer interaction score was far below average and the students in this cluster discussed minimal interaction with peers, both inside and outside of the classroom. Inside the classroom, some students mentioned discomfort working with peers given the infrequent and unstructured implementation of this activity, which has also been documented in the literature (e.g. Yoon et al., 2011). A student in Cluster 2 described this as feeling "rushed to solve problems with a group of random people." Outside of class, many students mentioned completing homework or practice problems on their own as helpful to their learning, such as "reading books myself is a good way to learn calculus. I always study the book after classes," with less frequent mentions of study groups or tutoring.

In contrast, Cluster 3 maintained an average peer interaction score even with a below average class experience score. Within the qualitative survey responses, students in Cluster 3 appeared frustrated with in-class lectures and would have preferred more opportunities to work with others in class. This suggests that the average mathematical peer interaction score mainly covers interactions outside of class. Accordingly, many students in the free response section discussed working with tutoring centers, private tutors, and/or classmates and friends to learn and practice the material. Notably more so than other clusters, these students used the term "friends" in their free responses. Coupled with the low class experience and inclusion scores in Cluster 3, these friendships may have acted as what Leath et al. (2022) describe as "communicative resistance" (p. 9) toward exclusion and frustration in class. For example, a woman of color in Cluster 3 noted "My classmates have been helpful to me, not my professor. We have a 2 hour study group after every math class and I find that to be very helpful."

Follow-up interviews will help bridge the connection between peer interactions and women of color's mathematical identity and the potential distinction in this connection between classroom-specific peers and those they consider friends. It appears that both in-class and outside-of-class interactions are notable aspects of women of color's mathematical experience, with outside-of-class interactions potentially mitigating against negative in-class experiences. These experiences included both positive instructor-supported collaborations and counterspaces necessitated by negative and exclusionary classroom environments. Future research will explore the ways peer interactions can bolster women of color's mathematical identity and how instructors, departments, and institutions can support positive mathematical peer interactions and peer networks for women of color in mathematics.

Conclusion

The cluster results support various and unique experiences for undergraduate women of color in P2C2 courses in the USA related to class experiences, peer interactions, feelings of inclusion, and self-efficacy. Given previous literature in this area, these varying experiences suggest within-group differences regarding women of color's mathematical identity. However, based solely on these results, it is unclear in which particular ways these components may support women of color's mathematical identity. In future research, these clusters will act as springboards to explore these varying expressions and more specifically address the connection between these components and mathematical identity for women of color. Further research will also address the ways gendered and racialized discourses intertwine with these experiences and potentially influence different expressions of mathematical identity.

Implications of this work add to the growing call to encourage more investigation into within-group differences within undergraduate mathematics, especially related to marginalized groups (Leyva, 2017). Studies continue to conclude how women of color compare to other demographic groups, without considering how women of color differ in their mathematical experiences and perceptions. However, this study implies different experiences across several areas of women of color's undergraduate mathematics education. Future work aims to continue to explore within-group differences for women of color related to mathematical identity, including further investigation into the variety of questions raised in the discussion.

CHAPTER 3 – CONNECTIONS BETWEEN INSTITUTIONAL RESOURCES AND WOMEN OF COLOR'S MATHEMATICAL IDENTITY: THE INFLUENCE OF GENDERED AND RACIALIZED MATHEMATICAL DISCOURSES

A plethora of recent research speaks to the ways inequity still perforates the academy, especially in the sciences and mathematics (Corneille et al., 2019; Denaro et al., 2022; Laursen & Austin, 2020; Maries et al., 2022). Systemic approaches to transform institutions, increase diversity, and create more equitable academic spaces vary in their success (Denaro et al., 2022; Koskinen, 2022; McQuillan & Hernandez, 2021). Particularly in mathematics, long-standing discourses that value masculine and white characteristics may hinder opportunities for systemic change (Battey & Leyva, 2016; Laursen & Austin, 2020; Leyva, 2017). Research shows how women of color often experience more barriers navigating both gendered and racialized discourses in mathematics simultaneously (Laursen & Austin, 2020; Leyva, 2021). Thus, more work is needed to understand what institutional resources women of color describe as valuable or hindering in undergraduate mathematics.

One approach in the call for more equitable mathematics spaces is to better support students' mathematical identity. A strong mathematical identity can bolster students' mathematical enjoyment, persistence in a mathematical field, and well-being (Seyranian et al., 2018; van Laar et al., 2010). Women of color often experience tension developing their mathematical identities while navigating exclusionary mathematical discourses that communicate gendered and racialized ideologies about who belongs and can succeed in mathematics (Leyva et al., 2020; McGee & Bentley, 2017; Rodriguez et al., 2019). While various studies showcase the benefits of particular institutional programs or relationships to women of color’s mathematical identity, minimal scholarship considers what institutional resources women of color have access to and utilize that support or hinder their mathematical identity. In response, this paper explores what institutional and departmental resources support women of color’s mathematical identity.

Literature Related to Institutional Resources

An important area of research that I draw on examines the influence of particular institutional resources on women of color’s experiences and success in undergraduate mathematics. Given the limited studies that center women of color’s identity as the primary outcome, I further draw on studies examining the role of such resources on women of color’s persistence and success within STEM.

Mentors and Role Models

Multiple studies demonstrate how mentors and role models act as an important institutional resource, especially those who share identity components with their students. A diverse group of role models can help support a more diverse student population with increased retention, feelings of inclusion, and performance (Main et al., 2020; Ong et al., 2011; Rask & Bailey, 2002). Laursen & Austin (2020) highlight how “women of all races as well as men of color want to see and interact with faculty who look like them and share some of their life experiences” (pp. 20). However, women of color continue to make up the smallest percentage of mathematics faculty when considering race and gender (NCSES, 2023). Furthermore, women of color faculty often leave STEM departments for numerous systemic reasons, including a lack of mentoring, feeling like a ‘token’ or ‘pioneer’ based on their gender or race, and high levels of harassment, isolation, or discrimination (Clancy et al., 2017; Laursen & Austin, 2020; Main et al., 2020). One way to better support women of color in mathematics may be through the additional hiring and continued support of diverse faculty. This requires restructuring mathematical spaces to value women of color faculty and their mentorship to marginalized students, such as through additional compensation for this work (Casad et al., 2020; Hess et al., 2013).

Department and Institutional Programs

Research also suggests various benefits for women of color participating in department or institutional programs, such as the McNair Scholars Program or the Emerging Scholars Program mathematics workshops. Participation in the McNair Scholars Program can help elevate women of color's academic self-efficacy, likelihood to pursue a STEM graduate degree, and STEM identity (Foltz et al., 2014; MacPhee et al., 2013; Renbarger & Beaujean, 2020). This work aligns with results from Gentile et al.'s (2017) report that found marginalized students who participate in undergraduate research experiences have higher retention rates in STEM disciplines, are more likely to finish their degree within 6 years, and have higher GPAs. Within the classroom, Oppland-Cordell (2014) found that Latino/a students' participated more and presented stronger mathematical identities within a diverse, collaborative Emerging Scholars Program Calculus I workshop than a traditional classroom setting. Together, this work provides strong evidence that formalized institutional and departmental programs designed to service marginalized students can provide opportunities for stronger mathematical identities for women of color in STEM.

Peer Networks

Studies also point toward the significance of peer networks for women of color in mathematics (Dortch & Patel, 2017; Leyva, 2016, 2021; Tate & Linn, 2005; Gallagher, 2020). Beginning in secondary school, Joseph et al. (2020) recognized a strong connection between women of color’s mathematical identity and their interpersonal relationships. Unfortunately, many studies suggest weak institutional and instructional support for developing women of color’s peer networks. Dortch and Patel (2017) and Leyva (2021) reveal how gendered and racialized discourses of mathematics along with a lack of institutional support for Black women in mathematics contributed to their participants’ feelings of isolation from both white men and women peers but also within the Black community on campus. In their study identifying supports and challenges for women of color engineering students, Tate and Linn (2005) found that while the students’ felt included within their larger university social groups, they expressed a lack of belonging within their engineering peer groups. However, these studies also showed how women of color with positive and inclusive academic peer networks felt better supported in their mathematical endeavors.

Institutions and departments can support women of color’s peer networks, such as through STEM-related extracurriculars, formalized study groups or tutoring programs, and STEM-related affinity groups. Espinosa (2011) found increased persistence in women of color who joined STEM-related student organizations and perceived their institution as having a robust STEM community. Studies also provide narratives of women of color describing positive experiences with department-structured study groups, tutoring programs, and affinity groups, which can provide women of color in mathematics group community and solidarity to “disrupt normative experiences of underrepresentation and isolation” (Leyva, 2021, pp. 143, Tate and Linn, 2005). Through providing community-based spaces while centering the identities of students from marginalized groups (such as women of color), institutions and departments can better support women of color in mathematics.

These studies speak to particular initiatives and resources that benefit women of color in mathematics by strengthening retention, belonging, and mathematical identity. It remains unclear what resources are generally available to women of color STEM majors in different universities across the United States. Furthermore, a systemic approach when exploring these resources requires examining how different institutional contexts shape women of color's experiences and how inequity manifests differently depending on these contexts. While the studies above suggest promising results, implementing initiatives and support structures for women of color in mathematics necessitates addressing underlying structural biases and exclusionary discourses that may limit the efficacy of such supports. This study considers resources that support or hinder women of color's mathematical identity and the ways in which these resources reflect or challenge gendered and racialized discourses in mathematics.

Mathematical Identity

Definitions of mathematical identity broadly consider how students connect with, relate to, and position themselves within mathematics. Mathematical identity often includes students' perceptions about their abilities in mathematics, their motivation to learn and excel in the subject, and their sense of belonging to the mathematical community (Black et al., 2015; Boaler & Greeno, 2000; Cobb & Hodge, 2011; Voigt, 2020). I draw from Voigt's (2020) work in particular, where mathematical identity is:

> the dispositions and deeply-held beliefs that individuals develop, within their overall self-concept, about their ability to participate and perform effectively in mathematical contexts. Accounting for how individuals position themselves within or outside the community as potential creators of mathematics… [and] is constantly negotiated through

social discourses that are shaped by institutions, individuals, society, and intersecting systems of oppression (p.32)

Voigt breaks down this definition into three categories that inform students' mathematical identity, including their perceptions of their mathematical participation and ability, their connection to mathematical communities, and the influence of identity resources. These aspects transform based on context, experiences with mathematics, and interactions with peers and instructors (Carlone & Johnson, 2007; Gardee & Brodie, 2021; Hall et al., 2018). Participation relates to "taking part in activities, interacting, negotiating, agreeing, disagreeing, formulating, and sense-making" within the mathematical environment (Voigt, 2020, p. 29) This often depends on the norms of the environment and the resources available to support students' relationship with mathematics (Lave & Wenger, 1991; Nasir, 2011; Voigt, 2020). Perceived mathematical ability encompasses students' belief in their capability to learn, understand, and communicate mathematics, but tangentially includes other affective components such as confidence, interest, and enjoyment. These perceptions often reflect both broader societal mathematical discourses as well as local factors that communicate who can excel in the subject (Leyva, 2016, 2021; Mendick, 2006). Voigt (2020) describes positionality as students' ability or willingness to "position themselves within or outside the community as potential creators of mathematics" (p. 32). I extend this component to include students' sense of belonging within mathematics spaces. Sense of belonging often connects with both race and gender, and thus I argue that it is an important factor when considering women of colors' perception of their positionality within mathematical communities (Good et al., 2012; Master & Meltzoff, 2020; Rainey et al., 2018; Rodriguez & Blaney, 2021). Identity resources capture interpersonal and institutional resources that interact with students' mathematical identity constructions, including material, relational, and ideational resources (Nasir, 2011).

Within this definition, both social influences and personal components affect students' mathematical identity construction (Gardee & Brodie, 2021; Graven & Heyd-Metzuyanim, 2019; Voigt, 2020). Scholars argue that social influences emerge and are constrained by gendered and racialized mathematical discourses, such that women of color experience potentially greater tensions perceiving themselves as "doers of math" (Leyva, 2016, 2021; Mendick, 2006). Studies suggest that instructors and peers may not recognize women of color as mathematically capable and position them as "math people" as readily as they would men or white people (Jaremus et al., 2020; Rodriguez et al., 2019). Institutions, individuals, and society each inform students' constructions of their mathematical identity, providing multiple and sometimes contradicting gendered and racialized discourses around mathematical ability, participation, and belonging (Leyva, 2016; Mendick, 2006). Amplifying marginalized students' narratives around resources that support or hinder their mathematical identity can challenge gendered and racialized "binaries of success in mathematics" (Leyva, 2017, p. 417) that inequitably communicate who belongs in the space. With this in mind, this work explores the research questions:

- What material and relational identity resources do undergraduate women of color STEM majors utilize within their institutions?
- In what ways do they describe these resources as supportive or hindering to their mathematical identity?

Theoretical Framework: Identity Resources

I draw from Nasir's (2011) framework of identity resources to structure this work. She identifies three types of identity resources: material, relational, and ideational. These are resources that students utilize in the environment to construct practice-linked identities. The availability of these resources in the learning environment influences students' access to some identities while constraining others. Within mathematics, engaging with certain resources may afford or limit a students' access to social labels that position them as good at math or a "math person". For this study, I focus only on material and relational resources within mathematics. Material resources include physical aspects of the environment, institutional structures, and formal organizations that may support a connection between students and mathematics. Relational resources include interpersonal relationships that either afford or limit students' access and participation in mathematics. For example, Ntow & Adler (2019) drew from Nasir's framework to explore what resources were offered within a professional development (PD) and how those resources supported the participants' mathematics teaching identities. They discussed material resources such as mathematical software, textbooks, and laminated grid paper and relational resources such as fellow PD participants, graduate and postdoctoral PD facilitators, and the PD project members. I also utilize Voigt's (2020) additional division of each identity resource into classroom-related resources and external resources. Classroom-related resources are those within or tangential to the classroom experience while external resources exist within the broader educational context, such as the department or institution.

Nasir (2011) employed these identity resources to look beyond students' individual characteristics and instead "focus on the organization of learning environments and the ways in which settings create more or less access to identities as learners" (p. 9). In particular, she focuses on the experiences of African American students to consider the interplay between racialization, racial identity formation, and practice-linked identity formation. She argues that culture and context are fundamentally linked to processes of learning and identity formation.

Scholars recognize how mathematics culture and environments align with and promote white, masculine values that create challenges for those unwilling or unable to conform to those values (Carlone & Johnson, 2007; Leyva, 2017). These gendered and racialized mathematical discourses determine the availability of identity resources, who has access to these resources, and the appropriate way to utilize these resources. For example, multiple studies outline the benefits of mathematics centers and tutoring programs for mathematics students (Byerley et al., 2023; Tate & Linn, 2005). However, scholars suggest that stereotypes about mathematical ability and cultural norms may affect marginalized students' help-seeking behavior and thus make them less likely to use these services (Chang et al., 2020; Gupta et al., 2011). Nasir's (2011) framework provides an important lens for this work to consider the identity resources available to women of color in undergraduate mathematics while considering how the accessibility of those resources connect with gendered and racialized mathematical discourses.

Methods

Data Context and Participants

I recruited the participants for this study from women of color who originally completed the *S-PIPS-M* survey instrument administered during phase two of the Progress through Calculus (PtC) project (Mathematical Association of America, n.d.). Participants included undergraduate students in precalculus, calculus I, and calculus II courses from 12 institutions across the USA. The survey contained questions about classroom activities, instructor and peer interactions, affective components, and demographic information (Street et al., 2021). To recruit participants for this follow-up study, I sent an interest survey (Appendix E) by email to the women of color from the *S-PIPS-M* survey who consented to future contact. This email described the follow-up study as an exploration of women of color STEM majors' experiences in undergraduate mathematics. Thus, those that completed the interest survey self-selected as women of color. I interviewed 12 participants in total and this analysis focuses on three participants: Callie, Sky, and Sara. I selected these three participants for this analysis because they vary in their racial backgrounds, however Callie and Sky completed the same degree and Sky and Sara attended the same university. This potentially highlights both similar and different experiences across and within majors and universities based on context and culture. Brief descriptions of the participants appear in Table 7, including their self-described gender and racial identities collected as part of the interest survey.

Table 7 Description of participants

Callie	**Sky**	**Sara**
Callie (she/her) is a Hispanic/Latino cisgender woman. She recently graduated with a degree in Biology from a public Minority Serving Institution (MSI) on the East coast of the United States. Within the mathematics department at her university, she completed College Algebra, Precalculus, Trigonometry, Statistics, and Calculus I.	Sky (she/her) is an Asian-America, Filipino-American cisgender woman. She recently graduated with a degree in Biology from a public university in the Northeast of the United States. Within the mathematics department at her university, she completed Calculus II, Calculus III, Ordinary Differential Equations, and Intro Statistics for Biologists.	Sara (she/her) is a Middle Eastern cisgender woman. She is completing her degree in Mathematical Sciences at the same public university as Sky in the Northeast of the United States. Within the mathematics department at her university, she has completed numerous courses, including Calculus I Calculus II, Multivariable Calculus, Linear Algebra, Number Systems, Statistics/Probability, and Ordinary Differential Equations.

Data Collection

During the Spring 2022 semester, I conducted virtual, 60-90 minute, semi-structured interviews with each participant. The interview protocol included a variety of questions to capture both specific and broad responses about the participants' undergraduate mathematics experience (Appendix D). This included questions about participants' experiences and feelings regarding their perceptions of themselves as doers of mathematics and institutional and departmental resources that supported or hindered them as a mathematics learner. For example, I asked "What extracurriculars or clubs, if any, were you involved in related to mathematics/STEM and how did this involvement support you, if at all, in mathematics?" I arranged the interview questions into four categories, three of which reflected the three components of Voigt's (2020) conceptualization of mathematical identity and one focused specifically on potential gender and racial influences. Using this protocol, I aimed to capture participants' narratives around material and relational resources and how these resources connected to their mathematical identity.

Data Analysis

I first transcribed each interview and replaced identifying information with pseudonyms, including names and institutions. During transcribing, I noted particularly meaningful or interesting statements related to resources or mathematical identity through the process of pre-coding (Saldaña, 2013). After transcribing, I utilized Saldaña's (2013) cyclical method of coding to build themes. During the first cycle of coding, I used a list of start codes informed by Nasir's (2011) definition of material and relational resources and Voigt's (2020) analysis of these resources with Queer-spectrum undergraduate students. I allowed additional codes to emerge from the data to reflect the participants' unique experiences connected to the research questions, including statements related to material resources, relational resources, mathematical identity, social identities, and affective components. I allowed statements to include multiple codes to capture overlapping ideas. For example, I coded the statement "There was like, the [engineering club for women] and I just, like I went, I felt like I didn't mesh with the kind of person that was in that club," as *material - clubs/extracurriculars* and *relational - STEM peers*. During the second cycle of the coding process, I divided the first-cycle codes into material and relational resources, determined whether each code fit within the classroom or broader context, and then grouped together similar first-cycle codes into theoretical codes to represent identity resource categories. Within these theoretical code categories, I also noted any other statements where participants discussed how their mathematical identity or social identities connected to these resources. The combination of the theoretical codes and identity statements formed the final themes that respond to the research questions. This resulted in six themes that capture material resources and six themes that capture relational resources. I describe and expand on each theme in the Results section.

Results

Classroom-related Material Resources

Classroom Structure

Scholars frequently promote collaborative learning as a more equitable mathematics classroom structure, with multiple studies suggesting women's and student of color's preference for collaborative mathematics environments (Esmonde, 2009; Kogan & Laursen, 2014; Vaughan, 2002). Sky experienced minimal collaborative mathematics classes while Sara and Callie experienced no collaborative mathematics classes. Each expressed some variation of how they felt like they were just "on your own." However, all participants expressed positive attitudes toward in-class collaboration. When asked about what teaching style she felt most supported her in mathematics, Sky commented that "I think when we were like, encouraged to do problems with your neighbor, that was the most helpful for me, but it wasn't always done." Sara recognized how “there was never any group work” but “I think the main way we got through [the math classes] was forming like, our own study groups.” Callie talks about her experience in other non-mathematics courses and that “there was a lot of like peer learning environments,…, where you kind of have a group, like for the whole semester, and… I did like those,…[but] I don’t think I ever did math classes like that.” Although the participants experienced minimal to no collaborative class structures in their mathematics courses, each expressed how working with peers in class was or could have been beneficial.

Sky, Sara, and Callie also expressed support in terms of classroom-related technology tools. Sara outlined how her introductory courses were all “WebAssign based, which I enjoyed, because I was like, I need practice questions. In order for me to learn math, I need to do it a lot.” Having this technology tool integrated into her class structure increased Sara’s perceptions of her knowledge and ability. Sky also expressed how much she enjoyed multivariable calculus, in part because “to see like, the whole [multivariable derivative], like graphed out, is really cool… [the instructor] showed us like a software where like, you could change the numbers to see how it changes the… graph. Yeah, that was fun.” Callie and Sara also expressed how sometimes they depended on technology because the class structure did not provide them adequate resources. In response to a fast-paced, lecture-based course, Callie says that “at least for me, I would have to… look up videos and stuff on the internet to kind of learn it better” while Sara similarly expresses “watching YouTube videos like all the time, trying to teach myself.” For each of the participants, technology supported or supplemented their in-class learning.

Each participant also conveyed unique perspectives on how certain class structures impacted their mathematical identity. Callie described the fast-paced structure of her courses, where “the math teacher [was] just kind of spit vomiting a bunch of math… and I would just take notes as fast as I can". She implied that this structure influenced her perceptions of her mathematical ability because she frequently needed to look up information online after class or "I always ended up having to ask people in class, like, oh, how do you do this?" Sara's mathematics identity was impacted when she withdrew from a course she described as "chaotic" and had "no structure," where the instructor never assigned homework and "out of nowhere one day, [the instructor] was like, you have an exam." Sky communicated an increased sense of belonging within a small-sized class structure, saying that "I felt more, more comfortable talking out in like a discussion section than, like… where it was… the whole class… And so I think I just spoke more and, like, got to know my TA better."

Curriculum

Societal views generally paint undergraduate mathematics as extremely difficult to the point of being understood only by those considered most intelligent or "genius" (Leyva et al., 2021; Reinholz et al., 2019). The participants each discussed their feelings of pride and reward after successfully navigating the challenge of the mathematics curriculum. Callie commented that "I should have been more confident about it. Yeah, because they were hard classes and I should have just been more proud about myself." Sky similarly felt like "I think I built up my confidence somewhat, because the classes were definitely a lot harder…and it was like, being able to juggle all of my other stuff… with like, these ramping up math classes, I was impressed that like, how much I was able to do." These statements showcase how the participants' mathematical confidence improved after completing difficult mathematics courses. However, this perceived level of difficulty also harmed their mathematics identity when coupled with negative perceptions around asking for help. Sara felt this effect when she started "taking classes that I've never seen the material in before," and she "started to doubt myself. Am I really cut out for this? Do I belong here? Have I been faking it this whole time?" During this class was the "first time I had to go to like office hours… and I felt almost like, oh, am I not as good as I thought I was in math?" Callie similarly started to doubt her mathematical ability when asking for help, saying "because I had some type of like, insecurity that I'm like, not where the average student would be…so if I asked a stupid question, like, that's embarrassing and annoying." Sky expressed how this hesitancy to ask for help emerged in part because of her racial identity and disability status. Reflecting on the "model minority myth" (McGee et al., 2016) related to Asian students in mathematics, she commented how "I'm supposed to be like this great, like, math prodigy just because of my race or something. And it like, it gets to you. Because when you do fail [in math or science], you feel like you shouldn't." She also discussed how having a developmental disability "just like, contributed to me not seeking help when I needed it… And then along with the pressure [of being Asian], it just like, amplified it…, you know, if you can't do this on your own, then you're like, you're flawed or something." While the participants each conveyed positive feelings related to succeeding through difficult mathematics, they also expressed the deleterious effects on their mathematics identity based on negative perceptions around asking for help.

In terms of supportive curriculum materials, Callie, Sky, and Sara all describe their enjoyment or interest in "real-life" mathematics. Sky talked about how "I think my interest… kind of waned when I got to the point where… it really like disheartened me to see like how, how foreign the math was to like my actual life" and Sara concurred with how she liked when math "connect[ed] to something… [but] that's like, what killed math for me… when I could not see why I was learning what I was learning." Callie specifically stated "that's why I enjoyed statistics so much, because they were almost like problems that, like, you would see normally, in real life." Seeing how the curriculum connected to the real-world increased the participants' interest and enjoyment of mathematics, while contextually-weak curriculum "disheartened" and "killed" the joy of mathematics.

Broader Context Material Resources

Department Structure

Callie, Sky, and Sara each described various departmental structures that supported or hindered their mathematical experiences. In particular, they all touched on how mathematics departments often designate more time to research than teaching and assign graduate students as instructors of records for introductory courses. Callie described how she felt many of her instructors "[are] in academia for some reason or another, maybe they like, are doing math research, but then they have to teach at the same time. And then that's not necessarily what they want to do maybe… they're just a little bit more difficult in delivering information." Sara as well recognized that when departments focus on hiring faculty for research without considering their ability to teach that "[instructors] don't really form the right teaching methods. [They] don't know how to teach properly, [they] don't know how to communicate with, like, your students." Sky started to bridge this mindset with her experiences taking courses instructed by graduate teaching assistants (GTAs). Reinholz et al. (2019) found that compared to biology, chemistry, and physics, mathematics is the only department to commonly assign graduate students as instructors of record for introductory courses. Unfortunately, studies show that mathematics GTAs often have little to no prior teaching experience and receive minimal or "unofficial" teaching preparation through the department (Deshler et al., 2015; Ellis et al., 2016). Sara describes both the influence of the "research over teaching" mindset and assigning GTAs to teach courses, saying "I think for some reason, we think that like when you get to college, you don’t have to be a good teacher…our math department was literally just like, [to GTAs], Oh, don’t spend that much time on this section because you’re here for research, not teaching.” Sky also describes how she felt underserved by having a GTA teach her course who was “really busy being a master’s student” and how “I wish I felt more comfortable, like going to like, an actual professor because for all these, like, lower level classes… it seemed like the only person you could talk to was your TA.” The participants recognized that their feelings of frustration were not solely directed toward the GTAs themselves, but more toward the department structures that stretched graduate students across multiple responsibilities and encouraged instructors to focus more on research than teaching.

The participants’ experiences also reflect how office hours within mathematics departments often depend on the instructor and their willingness to engage with students during this time. Callie, Sky, and Sara each describe both positive and negative experiences going to office hours and how this may have influenced their perceptions of their mathematical ability. Sara often sought out office hours because “I enjoy more of the one-on-one [help]” and “I feel like the professors were finally able to like, break down the material more… So office hours definitely was the way that I was able to pass a lot of a class.” Sky also described how sometimes office hours provided an opportunity to “at least [get] like a better feel for who my teacher was. And I felt a little bit more comfortable asking more questions.” However, the inconsistent structure of office hours between faculty emerged when Sky described how “and then like, I would go to office hours for differential equations and… he would just like, explain everything in the same way. And I would still be confused and then he’d be like, Why are you confused?” Callie discussed minimal positive experiences with office hours and instead described them as “daunting. I did not like doing that…I remember I, like, went in once and this professor,… he was just not very welcoming… and then I was just like, Okay, I'm gonna leave now and like, try to look for it on a computer instead… as opposed to asking a question." Mathematical identity frameworks often suggest how instructors play a key role in how students position themselves within mathematics and office hours can present a critical opportunity for students to feel recognized as mathematical doers by their instructors (Cribbs et al., 2015). Thus, these varied experiences may suggest ways in which Callie, Sky, and Sara's did or did not feel recognized as competent by their instructors.

Tutoring Centers

Callie, Sky, and Sara each commented on multiple positive aspects of tutoring centers in their interviews. Callie expressed how "I think [the tutoring center] definitely did support me because it would kind of force me to do my homework and then… you can get help [from learning assistants]." She also generally liked how the learning assistants were "trained to kind of like ask you a question instead of just giving you the answer." Sara credits tutoring services as "one of the main reasons that I was able to pass [linear algebra]." In particular, she emphasized how much she liked "students teaching other students, it was amazing… like that pressure is not there anymore so I'm able to, like, freely ask [questions]." Sara also stressed how important it was as a student from a low-income background for the tutoring to be "publicly available" as a free resource.

Sky and Callie also noted unique components of the tutoring centers that may have negatively influenced their mathematical identity. The mathematics department at Callie's university required students to attend the tutoring center for a set number of hours per week as part of their introductory courses. Because of this, the system tracked the amount of time Callie utilized the center "because like, you would swipe in and out, and I remember like, I would be in there alone sometimes way more than what was required… I was like, oh my god, I'm in here for so long and… I'm still just like barely passing or like, I don't get it perfectly." Having a time stamp on her studying influenced Callie's sense of competence relative to the time she put into the course. Sky explained how she did not go to tutoring because she did not know it existed during the beginning of her degree. She expressed how "I don't think I've heard a single time that mentioned that there were math tutors at our school. Like you just had to find it yourself." The 'find it yourself' mentality wove throughout Sky's narrative and this lack of communication regarding tutoring services may have added to Sky's isolation.

Institutional Support Programs

Callie's experiences strongly mirror the results of studies that show the effectiveness of institutional support programs for women of color in STEM, especially those specifically designed for marginalized populations (e.g., Breen & Newsome, 2022; Oppland-Cordell, 2014). She relayed numerous positive attributes and outcomes through her participation in the McNair Scholars Program. The program provided tangible supports such as understanding the operations of a research lab and finding a research mentor, to more emotional support such as "help[ing] me a lot with just like the reassurance of like, listen, this isn't a common thing, like, you're a woman, you're a minority, there is so much support, or there is a lot of like, potential in you going this far." The effect on her mathematics identity is clear when she credits the program as "a very big reason why I continue to do so well in all these [math] classes,… like I probably would have changed my major completely if I wasn't in this fellowship."

Sky and Sara discussed how they were not aware of institutional support programs until it was too late to participate. Sky expressed how "I think it would also have been helpful if like, they promoted the support services at our school better." Even as a first-generation student, Sara conveyed how “I did learn now, as a senior, that [the university] actually provided like, additional help for first-generation students.” She describes the miscommunication in part because the university used an acronym she did not realize represented first-generation students. Sara continued to describe how now as a master’s student in the business school of the same university, “what is so sad is I realized that… there’s so many resources that are available to the students [in the business school],… but like, when I was in the math department, we never had any of these resources.” Thus, Sky and Sara lacked access to student programs, either through limited communication or because they did not exist.

Representation

Numerous scholars continue to call for systemic changes to challenge structural biases and better support gender and racially diverse faculty and student populations in higher education (e.g., Casad et al., 2020; Hess et al., 2013; Laursen & Austin, 2020). Laursen and Austin (2020) summarize work that highlights the importance of marginalized students in STEM seeing and interacting with faculty who share identity markers and lived experiences. When I asked during the interview “In what ways do you think institutions in general could better support women of color in mathematics?”, each participant immediately provided an answer that emphasized increased diversity and more women of color represented in the mathematics faculty. To this question, Callie responded “I think…just having like, more women of color teaching or like, being in positions of power within a university… like usual people in these positions have been white males or just males in general especially. So I think, yeah,… just having these positions filled with more diverse people.”

Each participant described the current lack of representation within their undergraduate mathematics courses. Both Sky and Sara explicitly recall never having a woman or person of color as a mathematics instructor, instead “all my professors were males. They were all white.” Sara recognized that there were “maybe two or three [women mathematics professors] out there” in her department, but she never had the chance to interact with them. Sky, Callie, and Sara also recognized the lack of diversity in their peers as well. Sky described how her classmates were “mostly white people, or like Asian people,… I rarely saw any Latinx, any African American [students], they were just like, nowhere to be found.” Sara as well noticed this when “almost all the times I would enter my math classes, and I would do a little headcount of how many women are in this class, and I would just see the numbers dwindle down as I’m progressing [in the math major].” Even though Callie attended a Minority Serving Institution (MSI) and noticed the prevalence of students who shared her racial background, she also talked specifically about how the lack of woman of color in mathematics influenced her perceptions of herself as a doer of mathematics, saying how it wasn’t common to “have a woman of color be in these types of [math] classes… it’s just not normalized that a person like me is in these types of spaces… These institutions are built with like, having a white man in these spaces.”

Callie, Sky, and Sara also communicated their personal reasons as to why representation in mathematics is such an important topic. Sara conveyed how having more women of color in mathematics teaching positions “is probably the best way to uplift anyone who’s doubting themselves because it’s going through high school and like, all my teachers were white. It just seemed like, that was not something that I could ever do because none of these people looked like me.” Sara shared a similar viewpoint, saying “when you’re able to see educators of color, women of color, like in the field themselves teaching, you feel like I have a space where I can belong… I’m going to try to do better and to take up the space myself.” In these responses, the participants outline how seeing women of color as mathematics instructors can benefit women of color's mathematics identity through a sense of belonging and confidence.

Classroom-related Relational Resources

Instructors and GTAs

Instructors can play an instrumental role in students' mathematical identity through various means, including supporting a sense of belonging, interest, and mathematical self-confidence (Carlone & Johnson, 2007; Solomon et al., 2011). However, women of color often perceive less recognition as a mathematical doer and less care from their instructors than other race and gender populations (Carlone & Johnson, 2007; Rainey et al., 2019). For Sky, Callie, and Sara, they each describe one or two positive relationships with a mathematics instructor while describing the rest as neutral or negative. They related the most to instructors they described as understanding, open to questions, encouraging, excited about teaching, clear, and kind. Sara had a particularly impactful instructor who "made such an impact on me… He allowed me to believe in myself again when it came to mathematics because this was a course that I had withdrawn from the first time around." She described this instructor as "a really kind soul. He was there to listen to everyone… you know that you've formed a great connection when you're visiting that professor even after you've taken the class." Sky also talked about both an instructor and a GTA who she connected with because "they were both very into the idea of being a teacher. Like they just both seemed very open to answering questions, and they actually seemed like, they liked being there and seeing you, helping you."

While Sara felt very connected to the instructor mentioned above, she expressed that "quite honestly,… most of the math professors didn't try to form any connection with me… I'd never really received help or praise from any professor, except for the one I talked about." Sky and Callie conveyed similar sentiments. When asked about instructors, Sky said that she "just felt like they kind of just didn't interact with us at all" and the majority of interactions with them were in the exchange of assignments and tests. Callie expressed that sometimes interactions with instructors would heighten her insecurities around her mathematical performance because their comments were less praise and more "you finally got it, yeah, like, good." For the most part, the participants described a lack of inclusion or connection with their mathematics instructors and minimal recognition as a mathematical doer from these important figures.

Classroom Peers

Similar to their instructor relationships, Sara, Callie, and Sky each convey a few positive peer connections situated against the perception that for the most part "I was always like, alone, just trying to figure it out by myself." Callie described a peer she frequently studied with, who offered both encouragement and help with the content. She acknowledged that "I honestly don't know if I would have been able to score high without her." Sky described a similar peer connection formed in her Calculus II course and Sara in her Linear Algebra course. Interestingly, in each of these cases, it was the participant who went out of her way to form the connection. Sara described this succinctly, saying "I don't think I've had anyone specifically approach me, unless I was the one to first approach them and formulate like, that connection." Sky recounted how she formed the connection with the peer from Calculus II because "I just happened to like, see him somewhere and asked him about a calc thing." This was sometimes easier said than done. Sara expressed how as a woman "I was so afraid to just go up to someone to ask them [for help], and maybe because they were a lot of males at the time and I was just like, a little bit intimidated." Overall, the participants describe important peer connections that supported them in undergraduate mathematics, however, this was often difficult and only occurred through self-determination.

One specific way peers can influence a student's mathematical identity is through recognizing them as mathematically capable (Cribbs et al., 2015; Rodriguez et al., 2019). Both Sky and Sara discussed instances where they felt recognized as mathematically capable by peers in their classes. Sara related this back to Calculus I, where she felt very confident in her own ability having taken the class in high school. Peers would reach out to ask her questions about the content and she was happy to help. This started to change in later courses, where she started to notice that "just being a woman… a lot of the groups that were formed…were all men, just talking amongst themselves, because I felt like, and I don't know if this is true,… well you're a guy and you're a guy and you are probably smart." Sky also connected peer recognition with her identity as an Asian student. She described a moment in class where a peer she had not talked with before "randomly comes up to me and asks me for help on a problem. Like, why me?" She goes on to express that maybe this peer assumed her mathematics capability because of her race and jokes about the "model minority stereotype," but "like, every joke that you make is just like a little like hit to your heart." While peer recognition can be very supportive to students' mathematical identity, Sky and Sara struggled with peers' perceptions of their mathematical ability and how it related to their gender and race.

Broader Context Relational Supports

Mathematics Community

Neither Callie, Sky, nor Sara felt part of the mathematical communities at their institutions. Callie and Sky credit this somewhat to their majors of Biology and Engineering, respectively, which meant they spent less time in mathematics courses than a mathematics major.

They still perceived things about the community from the outside, such as Sky when she described how “I don’t think there was much of a community. I wasn’t deep into the math department. It just seemed everyone always was on their own.” She justified this by discussing her roommate who is a master’s student in the mathematics department and “she’s like, also a woman of color and like, she feels very like, isolated in our math department.” However, Sky and Callie do talk more broadly about the university community and how it relates to their identities. Callie described how “I was surrounded by people that were kind of in my similar background… [and] I think overall, it was really great that I was with people that were kind of like, similar to me.” Sky also mentioned that she “never felt out of place” at her institution because of the large number of Asian American and international students and it helped “talking to other people who are in similar situations [with immigrant parents]. It kind of just felt like we had, like a deeper understanding of what it means just like, growing up in America.”

Even as a mathematical sciences major, Sara also felt like an outsider to the mathematics community. She ascribed this in part to perceptions of ability, saying how “I probably noticed [the community] a little bit more… amongst the students that shined a little bit brighter in the math courses” while she positioned herself as “just observ[ing] kind of from the sidelines and just see like, okay, so they’re all together, but then you have like the students that are just staggering behind.” This may relate to the sense of competition Sara described within the mathematics department. She talked about how in the mathematics department “we always relied on the curve” which meant that “there was always the competitive factor, obviously, because like… the students that did the best were the ones that were going to pass.” Thus, a competitive culture within the mathematics department determined access into and belonging within the mathematics community.

Student Groups

Sara, Sky, and Callie each expressed different experiences with extracurriculars and the ways these clubs supported or did not support a stronger sense of belonging in mathematics or STEM more generally. Sara began college as an actuarial major and quickly joined the actuarial club, where she described the woman president, who had already passed a few of the actuarial exams, as a "superstar." As part of this club, Sara described how she felt like "I learned more from this organization than the actual department that is supposed to tell us, like" what classes to take, information about the professors, and how many hours to expect studying for courses. Once she entered the business school, Sara also joined the National Association of Black Accountants because "I saw that like, that was the most diverse organization that the campus had as a business organization. And the previous president was a Middle Eastern woman, Muslim, I was like, Okay, I feel like I have a space that I would belong to."

Sky and Callie both expressed not feeling like they "fit in" with many of the STEM organizations on campus. Sky specified that she did not "mesh" with the people in the clubs related to biomedical engineering and women engineers, because "it seemed like all those people were just like, the heavy overachievers… and I felt like I was just so like, almost under-qualified to be in this club." Callie talked about how she did not feel like STEM clubs "were advertised to me at all" and the ones she was aware of "were pre-med and like, I just didn't really like that type of stuff or crowd even." Instead, Callie really enjoyed participating in an ecology club, which focused on "just like sometimes shar[ing] frustrations about certain [math] classes, but… it was definitely more about like, bio and environmental sciences." Sky joined an affinity club around Filipino culture and the origami club, which were both more social and were "kind of like a break from all the science engineering people." While both Sky and Callie expressed some disconnect with STEM clubs on campus, they instead found clubs that supported their science and ethnic identities.

Upperclassmen

Upperclassmen also supported each of the participants in mathematics. Sara talked about a peer tutor she had for multiple courses who was "a year ahead of me, so she was able to provide me with like, a lot of great resources and just like her opinions on certain classes, so I was glad for that connection." She described how she felt an additional connection because "that was the only time that I had like, a female actually teaching me math and I was able to understand it so much quicker." Sky also described upperclassmen who provided similar resources, such as information about courses and past notes, saying "they basically just got you ready for like, how difficult [the course] was gonna be." Callie met a graduate student because "he recruited me and a few other undergraduates to do research in his lab," which she was grateful for because "I just had no idea, like, I don't know how to connect myself with [research]." She goes on to say how helpful the graduate student was in supporting her with the mathematics used in the research. In each case, an upperclassman supported the participants in both academic material and navigating the mathematics and undergraduate environment.

Family Support

The role of family has been shown to play an especially important role in relation to women of color's mathematics experiences (Ellington & Frederick, 2010; Fernández et al., 2023; Leyva 2016). Sky, Sara, and Callie each describe aspects of strength and tension related to familial relationships. Sara conveyed that in terms of content support, as "a first-generation college student… my parents are immigrants, so they couldn't really help," however they provided emotional support when things got hard, reminding Sara that "you're human, the person teaching you is human. They had to learn the same way you did. Like, you're gonna be fine." Sky described her experience as a child of immigrants as well, however she felt "very lucky that my parents were so educated… like, [my dad] could still help me with math in school growing up." When Sky arrived at college, she initially enrolled in engineering courses with support from her engineer dad.

Callie described instances of tension she experienced with family perspectives and university expectations as a Hispanic, first-generation student. She expressed conflicting views with her dad when it came to pursuing college before getting a job and how "his perspective didn't help at all… I love him, but if he had another type of view of like, Wow, that's amazing…like, keep going! Obviously that would have helped, but… it was hard for him to understand, like… what can [college] help you achieve?" This perspective, however, was coupled with high expectations as the oldest child of "you're like, the child that's gonna make it… that's a very intense pressure to have." Callie also addressed feeling challenged as a commuter student with the university's strong expectation to live on campus. She talked about how "as a Hispanic, like, it's just the culture is, you kind of stay with your parents until you get married" which meant that at the beginning of college "it was pretty difficult for me, I mean, I had to drive to school… 30 minutes there and back." However, when she decided to move closer to campus, "moving out was kind of like, a very intense thing. [My parents] were just like, why, you're so young!" She described numerous benefits in having her own space close to campus, but "just the way that was set up, it probably definitely affected me in my learning experience."

Discussion

In the results, I detail material and relational resources women of color identify as supportive or hindering in their undergraduate mathematics experiences. I also specify instances of dissent between participants' experiences with similar resources or if participants discussed a unique resource. The resources listed do not cover the entirety of resources available to women of color in mathematics nor all the resources available for these participants. It is likely that there are resources they used that they did not discuss in the interviews and resources that exist of which they were unaware. To this point, there are multiple instances the participants address this explicitly, such as when Sky expressed how "I don't think I've heard a single time that mentioned that there were math tutors at our school." The participants also discussed resources unique to their experience that did not neatly fit into a category. For example, Callie briefly talked about her partner and his role in her mathematical experiences. Overall, the results point toward important connections between these resources and women of color's mathematical identity. The material and relational resources outlined here mediated the participants' mathematical identities through different means, including positionality aspects, such as a sense of belonging and recognition and care from instructors and peers, as well as self-efficacy aspects, such as their perceived mathematical ability, enjoyment, interest, and confidence.

Material Resources

The material resources connected with the participants' mathematical identity through their positionality, including feelings of recognition and belonging. In the classroom, the lack of group work components limited opportunities for the participants to connect with others in class. Department structures also influenced how the participants felt recognized by instructors. The perception of a "research over teaching" mindset led the participants to feel unimportant when compared to the instructors' other responsibilities. Attending office hours differentially impacted the participants depending on the instructor. Positive experiences in office hours provided time to better connect with instructors while negative experiences left participants feeling unwelcome in the space and insecure about their ability. When advertised, institutional student programs provided important identity support. In this study, Callie was the only participant to engage in a student program and she talked about how this experience strongly influenced her decision to stay in STEM. The lack of representation in mathematics detrimentally influenced the participants' ideas of who belonged in mathematics and they strongly encouraged more representation in the field to better support their feelings of belonging and confidence.

Material resources also connected to participants' mathematical identity through self-efficacy components. The inclusion of technology and applications in class supported the participants' perceptions of their ability, interest, and enjoyment. They also felt confident and competent when reflecting on their success through challenging mathematics. However, their perceptions of ability were hindered by the negative implications of asking for help. This led to feelings of doubt around their ability to succeed in mathematics and increased pressure related to racial and disability identities. However, participants' talked positively about tutoring centers and how attending tutoring helped bolster feelings of competence and removed some of the above pressures.

Relational Resources

The participants additionally describe connections between relational resources and aspects of positionality. Relationships with instructors and GTAs provided opportunities for connection and recognition. Each participant described at least one positive connection with an instructor and how that connection supported their belonging and confidence. For the most part, however, they describe a lack of connection with their mathematics instructors. Similarly, each participant described forming an inclusive and supportive connection with a class peer. However, they all felt distanced from the mathematical community itself, with reasons ranging from not frequently engaging within the mathematics department to feeling less competent than those in the community. STEM extracurriculars offered increased belonging for Sara, especially related to shared gender and racial identity peers. However, Sky and Callie expressed a lack of belonging related to STEM extracurriculars, including a lack of "fit" or of not "mesh[ing]" with others in the club.

Relational resources also influenced the participants' mathematical identity through aspects of self-efficacy. Participants described how both instructors and the mathematical community negatively influenced their perceptions of ability through a particular focus on students who "shined a little bit brighter" and were recognized as more confident or competent. For Sky and Sara, family members increased their confidence and interest in mathematical fields, but Callie described more tension with family members who wanted to offer support but also increased pressures to perform. Lastly, participants described how upperclassmen supported their mathematical confidence, especially related to providing information about courses beforehand and connecting them with research.

Conclusions and Implications

The discussion above centers several identity resources for women of color that afforded or limited access to a strong mathematical identity. The participants also describe ways that their gender, race, and other social identities intertwine with these resources, further reinforcing Nasir's (2011) call to consider context and culture when exploring students' mathematical identity. These results provide implications for academic institutions and mathematics departments to better support women of color in mathematics.

In terms of material resources, our results imply a need for institutions and mathematics departments to create multiple spaces for mathematics tutoring. These spaces not only provided the participants content support, but also a place to connect with class peers and upperclassmen tutors. Importantly, these spaces need to be well advertised in a way that communicates asking for help as a normal part of the mathematical learning process and not reflective of individual deficits. Related to the classroom, institutions and departments could offer support for instructors in implementing collaborative, contextually-rich curriculum with supplemental technology. This could look like creating workshops or modules, providing resources on group tasks and applications, and purchasing software. Departments would also need to provide instructors adequate time and compensation for implementing these instructional changes. Additionally, the results point toward the importance of GTA training and how to better support GTAs as they balance teaching, research, and other responsibilities. In terms of relational resources, the results strongly emphasize the need for more gender and racial representation in mathematics faculty. However, initiatives to hire more women and people of color as mathematics faculty "must be coupled with other institutional changes that address structural biases and enable [them] to succeed on equal terms" (Laursen & Austin, 2020, pp. 42). These results also support the implementation of institutional student support programs, especially those that center marginalized students such as the McNair Scholars Program. This may also translate into mathematics specific support programs, such as Emerging Scholars workshops. Similar to extracurriculars and tutoring, these programs need to be well-advertised and maintained as an inclusive and safe space for marginalized students. Interwoven within these material resources lies opportunities for instructors and departments to promote relational resources for women of color. Based on the results, this could include structuring time in class to work with peers, assisting students in creating out-of-class study groups, promoting clubs and support resources, and outlining the benefits of instructor-student connections.

These results specifically suggest multiple material and relational resources to support women of color's mathematical identities. Nasir (2011) also outlines a third category, called ideational resources, that encapsulates "ideas about oneself and one's relationship to and place in the practice and the world, as well as ideas about what is valued and what is good" (pp. 44). In this case, ideational resources refer to mathematical norms and what is valued about mathematics and within mathematical spaces. While not explicitly included in this work, these ideational resources certainly interweave throughout the participants' experiences. For example, Sara expressed how those students within the mathematics community were ones that "just understood the material without having to put in like, all the extra work." This speaks towards the valuing of innate ability in mathematics (Hottinger, 2016; Leyva et al., 2021; Reinholz et al., 2019). In future work, I will explore how mathematical values may act as ideational resources in undergraduate mathematical environments. Further, I will consider in what ways the mathematical values as expressed in undergraduate mathematical spaces and through a sociohistorical lens of the discipline align or misalign with mathematical and cultural values of women of color.

CHAPTER 4 – EXPLORING UNDERGRADUATE WOMEN OF COLOR'S MATHEMATICAL VALUES IN THE UNITED STATES THROUGH CULTURAL VALUES AND MATHEMATICAL DISCOURSES[4]

The call for more equitable mathematics education in the USA is apparent; several professional mathematics organizations in the USA have released position statements addressing issues of equity and diversity and the importance of supporting students with marginalized identities related to race, ethnicity, gender, class, language, culture, sexual orientation, religion, and physical ability (e.g., American Mathematical Society, n.d.; Association for Women in Mathematics, n.d.; Association of Mathematics Teacher Educators, 2015; Mathematical Association of America, 2018; National Council of Teachers of Mathematics, 2014). Scholars argue that incorporating and reflecting various students' values in the mathematics classroom may be one way to create a more equitable and inclusive environment (Battey & Leyva, 2017; Seah et al., 2016). To this point, research suggests that this incorporation of values into the classroom positively influences students' mathematical learning and affect (Hill et al., 2021; Hunter et al., 2016; Seah et al., 2016).

However, undergraduate mathematics in the United States often does not reflect the cultural values of women or students of color (Fong et al., 2019; Leyva, 2021; McGee, 2016). Various scholars recognize how mathematical discourses in the US often align with, and thus give power to, dominant masculine and white values such as competition, risk, and individualism

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(Bullock, 2019; Jaremus et al., 2020; Leyva, 2016, 2021; Martin, 2006). Leyva (2021) argues that academic mathematical contexts function as white, patriarchal spaces that maintain "inequities at intersections of gender, race, and class" (p. 121). Thus, unique and possibly additional tensions within mathematical spaces emerge at the intersection of race and gender for women of color (Carlone & Johnson, 2007; Leyva, 2017). Supporting and incorporating women of color's cultural values within undergraduate mathematics may help reduce these tensions and counter inequities (Battey & Leyva, 2017; Seah et al., 2016).

While research globally has considered cultural values alongside mathematics education values, minimal work is this area is based in the USA or at the undergraduate level more generally. Given the white, patriarchal values rooted in undergraduate mathematics in the USA, more work needs to consider what women of color value about mathematics and mathematics education and in what ways mathematics instructors and departments can better align with those values. This research engages critical frameworks at the intersections of gender and race to challenge exclusionary adherence to dominant Western values in mathematics. The overall goal of this work is to encourage counternarratives to white, masculine mathematical discourses and highlight ways institutions and instructors can incorporate women of color's values into mathematics. I utilize qualitative data from two women of color STEM majors in the USA to explore what they value about mathematics and mathematics education and to what extent they saw these values reflected in their undergraduate mathematics courses. In particular, I ask:

1. What do two women of color STEM majors in the USA describe as valuable/important about mathematics and their undergraduate mathematics education?
2. To what extent do these values align with the values traditionally held in the discipline and in their undergraduate mathematics spaces?

Values and Valuing

The conceptualization of values and valuing continues to transform and grow with the development of new research and theoretical viewpoints. Bishop (1999) defined mathematics education values as affective qualities fostered through students' experiences in school mathematics. Other researchers describe this fostering of values as more cognitively driven, including a stage of individual choosing of values based on experiences and the options available (Raths et al., 1987). More current research positions values as a combination of affective and cognitive variables, with additional motivational or volitional components (Hannula, 2012; Seah & Andersson, 2015). Parks and Guay (2009) posit that values are the motivating factor in setting, striving, and accomplishing goals. The addition of a volitional perspective supports values as not only motivating factors, but also a driving factor in an individual's determination to maintain an action even when faced with challenges or obstacles (Seah & Andersson, 2015). For this work, I align with this latter perspective and borrow directly from Seah & Andersson (2015) to define values in mathematics education as follows:

> Values are the convictions which an individual has internalised as being the things of importance and worth. What an individual values defines for her/him a window through which s/he views the world around her/him. Valuing provides the individual with the will and determination to maintain any course of action chosen in the learning and teaching of mathematics. They regulate the ways in which a learner's/teacher's cognitive skills and emotional dispositions are aligned to learning/teaching in any given educational context. (p. 169)

Implicit in this definition is the belief that values are inherently influenced by contextual, social, and cultural factors (Schwartz et al., 2001; Seah, 2018). Arenas of influence include educational settings, social interactions, societal norms, and everyday experiences (Reinholz et al., 2019; Hyun, 2001). While values are often considered effectively internalized and stable, this perspective reflects how values can shift or transform based on context and experiences (Seah, 2018). Furthermore, Perez et al. (2014) summarize theory that suggests that personal and collective identities help frame individuals' self-perceptions of their values. On a personal level, values help support notions of uniqueness, while on a collective level, values build connections between oneself and salient social groups.

These various viewpoints support the idea that social identities, such as gender and race, relate to individual values. Schwartz and Rubel (2005) in their research assessing gender differences across 10 basic values show that women tend to value benevolence and universalism more than men, while men value power and achievement more than women. Research also suggests that people of color value collectivism more so than white people (French et al., 2020; Sue et al., 2022). Various work also highlights specific values at the intersections of gender and race. For Latina women, *marianismo* represents "a Latino cultural value that describes both positive and negative aspects of traditional Latina femininity… emphasiz[ing] culturally valued qualities such as interpersonal harmony, inner strength, self-sacrifice, and morality" (Da Silva et al., 2021, p. 3755). In Del-Mundo and Quek's (2017) study considering second-generation Filipino American women's meanings of gender identity, various participants discussed values focused on familial connections and respecting elders. Given these studies, it appears that community and interpersonal relationships are common values for women of color. However, STEM careers are more frequently perceived to align with agentic values (e.g., power, recognition, individualism) more so than communal values (e.g. helping others, serving community, working with people) (Diekman et al., 2010). This perception aligns with undergraduate mathematical spaces in the USA and other Western nations that continue to uphold dominant masculine and white values (Leyva, 2017; Martin, 2006; Mendick, 2006).

Categories of Values and Valuing in Mathematics Education

Stemming from Bishop et al.'s (1999) work, values and valuing in mathematics education span three subcategories. The first category is general education values, which encapsulate broad moral and ethical values embedded in society's perception of the goals of education (e.g., valuing honesty). The second category is mathematical values, which convey values associated with the discipline itself (e.g. valuing rationalism). The third is mathematics education values, which relate to the teaching and learning of mathematics and the norms of the specific mathematics environment (e.g. valuing collaborative learning). These categories are not distinct and their boundaries necessarily blend and inform one another (Seah et al., 2016). This work focuses on the latter two categories, mathematical values and mathematics education values. Similar to the more general values outlined above, mathematical and mathematics education values are also strongly intertwined with the culture of the learner and societal influences (Hunter, 2021; Lee & Seah, 2015; Zhang, 2019). Research from around the globe suggests that the mathematical values of Swedish students differ from those of Turkish students which further differ from those of Chinese students (Andersson & Österling, 2019; Dede et al., 2022; Tang et al., 2021). Given this context-dependent notion, I draw from literature on "Western" mathematics that describe mathematical and mathematics education values present in the USA.

Bishop (1988) developed a well-known framework to describe Western mathematical values in which he categorizes three complementary mathematical value pairs by sentimental, ideological, and sociological components. The sentimental value pair – *control* and *progress* – capture society's valuing of, on the one hand, the security and control mathematics offers in which there are “right” answers to big problems and, on the other hand, the promise of progress offered through mathematical problem solving given the inevitability of change. The ideological value pair – *rationalism* and *objectism* – relates to mathematical values associated with logic and an adherence to sensible connections between things. The value of *objectism* covers Western culture’s need to make tangible the abstractions from reality. The sociological value pair – *openness* and *mystery* – encapsulates mathematics as accessible knowledge open to examination by all, while also remaining abstract and surprising. Iterations of these values emerge in other research as well. Mendick (2006) posits that Western mathematical values align with those traditionally associated with dominant masculinity, such as logical, ordered, competitive, and innate ability. She argues that these values emerge along numerous dichotomous value pairs that position dominant Western masculinity against femininity, such as logical versus emotional and ordered versus creative. Various scholars also note how these mathematical values, such as innate ability and individualism, are submerged in notions of whiteness (Leyva et al., 2021; McGee, 2016). This is reflected in Reinholz et al.’s (2019) work looking at the similarities and differences in cultural components across STEM, where participants perceived mathematical knowledge as largely innate, objective, logical, and individually-driven.

Similar results appear when considering Western mathematics education values. Reinholz et al. (2019) describe how the overarching perception of undergraduate mathematics teaching emulates a “sage on the stage,” where instructors individually transfer knowledge to the students. Participants explained how this method of teaching related to valuing pedagogical autonomy, teaching as an individual endeavor, and a focus on knowledge acquisition. Ferrare & Hora (2014) as well in their study exploring science and math instructors’ views on learning, found that the most prevalent view was that students learn best when they engage in individual, sustained struggle. However, they implicitly suggested that this struggle was not a part of the classroom experience. These pedagogical values seemingly conflict with literature around marginalized students' mathematics education values. Voigt et al. (2022) suggest that women may feel more interest and confidence in mathematics courses that include deep engagement with mathematical tasks during class. Espinosa (2011) found that women of color who frequently engaged with peers to discuss course content remained in a STEM major more often than those who did not. These results propose that Western mathematics education values that promote isolated knowledge acquisition imparted solely by the instructor may not align with women of color's mathematics education values around collaborative and exploratory learning.

The Gendered-Racialized Mathematics Space

The above description of Western mathematical and mathematics education values helps frame recent theory in mathematics education research that positions the mathematics space in the USA as both gendered and racialized (Leyva, 2017; Martin, 2006; Mendick, 2006). Although focused on British college students, Mendick (2006) provided instrumental work for scholars to detail the gendered nature of undergraduate mathematical spaces in the USA and other Western nations. Mendick (2006) positions mathematics as a gendered space by exploring dichotomies within mathematical discourses that structure femininity against masculinity. Mathematical discourses often value and empower dominant masculine characteristics, such as framing mathematical reasoning as ultimate rational thought, mathematical ability as innate, and mathematicians as culturally deviant (e.g. the aloof nerd) (Jaremus et al., 2020; Mendick, 2006). In particular, Mendick (2005) argues discourses that define mathematics as ultimate rational thought stemmed from long-standing gendered discourses of rationality which associated logic with masculinity and emotions with femininity. These discourses communicate masculine norms around mathematics participation, e.g. competitive, risk-based, and speed-focused, that often exclude women and compromise their ability to develop robust mathematical identities (Barnes, 2000; Leyva et al., 2021) With mathematics culturally defined in this way, those whose values more naturally align with these masculinities have easier access to social labels that position them as good at math or a "math person." Thus, women and girls often experience more tension and pressure within mathematical spaces while negotiating societal ideas of femininity with mathematical masculinities (Leyva, 2017; Mendick, 2006; Rodd & Bartholomew, 2006).

Scholars also recognize mathematics in the USA as a racialized space (Leyva, 2016, 2021; Martin, 2006). Bullock (2019) argues that reforms for "all" in K-12 mathematics education in the USA continue to define "all" as those who "can embrace the whiteness that standardization represents" (p. 77). In his work deconstructing the Mathematics for All rhetoric, Martin (2003) describes how the goals of mathematics education policy often do not reflect the goals and values held by Black parents for their children's mathematics education. This idea extends to various communities of color within undergraduate mathematics education. The values of students of color often conflict with those expected in STEM departments, such as the disconnect between Indigenous American students' cultural and familial values with a mathematics curriculum detached from community needs and contexts (Abrams et al., 2013; Fong et al., 2019). This conflict of values often goes unchallenged within the racialized discourse of *color-evasiveness* within mathematics education (Annamma et al., 2017; McNeill et al., 2022). The color-evasiveness discourse centers "the ideology that mathematics is a body of knowledge independent of culture and race, so there is no need to attend to racism or student race in teaching mathematics" (Leyva et al., 2021, p. 3). Furthermore, this racialized discourse also perpetuates the idea of mathematical ability as innate and communicates a deficit narrative around students of color who struggle with mathematics. Coupled with racial and cultural stereotypes, this discourse imposes a racial hierarchy of ability whereby Black, Latine, and Indigenous students innately lack mathematical ability compared to white students (Abrams et al., 2013; McGee, 2016). Multiple studies also illustrate covert and overt instances of racism in the mathematics classroom and marginalized students' use of coping strategies and stereotype management in response (Jett, 2019; Leyva, 2021; McGee et al., 2016). These stereotypes range in their inaccurate assumptions, from placing Asian students as "model minorities" to presuming a lack of ability for Black, Latine, and Indigenous students (Abrams et al., 2013; McGee et al., 2016; McGee & Martin, 2011; Oppland-Cordell, 2014). In both cases, these stereotypes in mathematics often impart undue cognitive effort on marginalized students to navigate these assumptions and define their own mathematical identity (Martin, 2006; Masten et al., 2011). In his research studying African American parents' beliefs regarding mathematics participation, Martin (2006) suggests many participants internalized mathematics as existing outside of the community and struggled to value mathematics as "ours." Thus, students of color often experience more tension and pressure within mathematical spaces while navigating color-evasive and stereotyped mathematical discourses (Leyva et al., 2021; McGee & Martin, 2011).

Values Alignment in Education

Scholars suggest that supporting and incorporating marginalized students' values within undergraduate mathematics can help counter inequities by challenging dominant masculine and white norms (Battey & Leyva, 2016; Hunter, 2021; Seah et al., 2016). Seah and Andersson (2015) borrow from Branson (2008) to highlight the notion of values alignment in education. They describe values alignment as a cooperative and collaborative process whereby the members of an organization work together to clarify common values and develop strategies and systems aimed to support those values and guide actions and norms of behavior in the space. That is to say that the instructor and students collectively negotiate the norms of the classroom to reflect each other's values. Importantly, this process does not propose values inculcation, rather "values alignment facilitates the coexistence of different values as these are held by different people interacting in any given context… [such that] students perceive that their knowledge, skills and dispositions are valued" (Seah & Andersson, 2015, p. 178).

Several studies demonstrate the negative outcomes for marginalized students related to a misalignment of values in the mathematics classroom, including decreased perceptions of ability, sense of belonging, and performance. In their study considering gendered and racialized components of undergraduate Calculus instruction, Leyva et al. (2021) suggest how the value of mathematical knowledge as innate and the valuing of the instructor as the sole mathematical authority displayed in certain instructional instances misaligns with values held by marginalized students. Several of the participants, all undergraduate students of color, perceived these instances to relay "messages of minoritized students lacking ability and not belonging in STEM" (p. 802). Other studies demonstrate how the particular misalignment between Indigenous students' valuing of family and community with the individualistic and self-promotion values embedded in mathematics can harm these students' mathematical performance, interest, and belonging (Fong et al., 2019; Hunter et al., 2016). Given the prevalence of value misalignment between undergraduate mathematics in the USA and the cultural values of women and students of color, these studies necessitate more work considering how to promote value alignment (Abrams et al., 2013; Fong et al., 2019; Leyva, 2021).

Other studies showcase how an alignment of values can promote positive outcomes for marginalized students in mathematics, such as increased comfort, participation, and sense of belonging. A commonly recognized equity-based pedagogy in the USA, culturally relevant pedagogy, strongly supports this ideology. Culturally relevant pedagogy identifies how current racialized mathematical discourses value certain ways of knowing, mathematical content, and pedagogy that preserve the norms of the dominant group (Allen, 2004; Ladson-Billings, 1995). Teaching practices using a culturally relevant pedagogical lens confront white, masculine discourses of mathematics through "empower[ing] students intellectually, socially, emotionally, and politically using cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billings, 1994, pp. 17–18, Howard & Rodriguez-Scheel, 2017). Acknowledging the cultural capital students of color already bring into the classroom and valuing its role in STEM success can help bolster mathematical identity and support a sense of belonging (Adiredja & Zandieh, 2020; Ortiz et al., 2019). In her study exploring how Latino/a students' participation shifted during a diverse, collaborative Calculus I workshop, Oppland-Cordell (2014) also found that the students participated more and were more comfortable in this space that specifically challenged dominant values around mathematics ability as innate and learning as individualistic and instead supported the students' cultural values. Other studies demonstrate increased student engagement and interest when instructors align their pedagogical practices with their students' values (Hill, 2018; Kalogeropoulos & Clarkson, 2019). These various results point toward the promise of value alignment within undergraduate mathematics to counter gendered and racialized inequities for women of color in the USA.

Theoretical Perspectives

In this work, I utilize two theoretical lenses to frame how values encompass and inform the gendered and racialized nature of undergraduate mathematical spaces. Given the sensitivity of mathematics educational values to the culture of the learner and societal influences (Hunter, 2021; Lee & Seah, 2015; Zhang, 2019), I draw on sociopolitical and intersectional perspectives. Adiredja and Andrews-Larson (2017) draw from social and political contexts in the USA to describe a sociopolitical perspective toward postsecondary mathematics. This perspective emphasizes how students' negotiations of knowledge, power, and identity emerge and are often constrained by the norms and values of the environment and broader social discourses. This viewpoint considers how "accepted" norms and values within mathematics privilege certain groups of students while excluding others. Thus, using this lens situates this work alongside other scholars suggesting that the adherence to white, patriarchal values in undergraduate mathematics excludes and devalues women of color's experiences (Leyva, 2016, 2021).

The sociopolitical perspective focuses on the interrelatedness of knowledge, power, and identity subsumed by mathematical culture. Within mathematical discourses, there are certain types of knowledge and practices that are more valued than others. This includes mathematical knowledge that is abstract, comes from innate ability, and is learned individually (Ernest, 2016; Hottinger, 2016; Lane et al., 2019). This positioning of knowledge connects to how identity and power emerge in mathematical spaces. Identity in this sense captures a dynamic conceptualization of one's beliefs, values, and position relative to others in a certain context (Esmonde et al., 2009). The social construction of gender, race, and other social identities certainly influence this conceptualization of oneself within undergraduate mathematics in the USA (Joseph et al., 2020; Leyva et al., 2021). The valuing of certain knowledge and identities determines who and what has power in mathematical spaces, including not only formal positions of power, but also the ability for individuals to resist and shape mathematical discourses (Adiredja & Andrews-Larson, 2017). Thus, the sociopolitical perspective provides a lens to consider how institutional systems, such as mathematics departments or classrooms, resist or uphold traditional values embedded in Western perceptions of masculinity and whiteness. Furthermore, this lens rejects student assimilation and instead promotes a system that considers, supports, and affords space to various backgrounds and identities.

I also utilize an intersectional lens to ground this work. Intersectionality describes the ways in which interactions between race, gender, class, and other social constructs account for overlapping discrimination imposed on people with multiple marginalized identities within societal systems (Crenshaw, 1991). Specifying race and gender as social constructs is not to say that these categories are insignificant, but rather they provide critical understandings about “the particular values attached to [gender and race] and the way those values foster and create social hierarchies” (Crenshaw, 1991, p. 1297). Often, systems fail women of color because the discourses and narratives around those systems privilege the values and experiences of dominant groups. Thus, in this work I recognize that the values women of color hold are both individually unique as well as shaped by both societal influences and mathematical discourses related to gender, race, and other social constructs. Considering women of color’s values requires recognizing that identities are interconnected and concurrently influencing how they navigate and perceive the values upheld and empowered within undergraduate mathematical spaces.

An intersectional lens is also especially important in mitigating monolithic narratives of marginalized groups within power-laden environments (Esmonde, 2011; Leyva, 2017). As previously discussed, masculine norms produce tensions for women in mathematics. These tensions emerge differently for each woman and can fluctuate with intersecting identities such as race, class, sexuality, and other social markers. Esmonde (2011) warns against essentializing identity by treating a group, such as women, “as if they were monolithic groups with little internal variation” (p. 28). Essentializing potentially erases group differences regarding individual negotiations of social identities within mathematics by either treating everyone as equally advantaged or masking the disadvantages of certain individuals within the group (Esmonde, 2011; Leyva, 2017). Utilizing an intersectional lens helps illuminate varying mathematical experiences across intersecting subgroups of students and highlights the power relations within the gendered and racialized mathematical space (Leyva, 2017; Young & Cunningham, 2021). Given that undergraduate mathematics in the United States often does not reflect the cultural values of women or students of color, showcasing a variety of both unique and overlapping intersectional narratives outside of dominant groups paints a broader picture of mathematics education and can inform and support more inclusive mathematics education values (Abrams et al., 2013; Fong et al., 2019; Leyva, 2021). Thus, the sociopolitical perspective speaks towards how values and norms help frame power, identity, and knowledge relationships in undergraduate mathematics, while an intersectional lens expands on the nuances of identity, especially when considering a population with multiple marginalized identities in the USA.

Methods

Data Context and Participants

The data for this study include transcripts of follow-up interviews from participants who completed the *S-PIPS-M* survey instrument administered by the Progress through Calculus (PtC) project in 2017-2018 (Mathematical Association of America, n.d.). This survey collected information about undergraduate students' experiences in precalculus and calculus in the USA, including mathematical activities, interactions, and affect (Street et al., 2021). To recruit participants for this study, I sent out an interest survey in Spring 2022 to all women of color from the survey who consented to future contact (*n* = 1121). Women of color within this dataset includes any participant who selected at least woman from the following select-all response options related to gender: Man, Transgender, Woman, Not listed (please specify) and who selected at least one of the following select-all response options related to race and/or ethnicity: Alaskan Native or Native American, Black or African American, Central Asian, Hispanic or Latinx, Middle Eastern or North African, Native Hawaiian or Pacific Islander, Southeast Asian, South Asian. The recruitment email described the study as an exploration of women of color STEM majors' experiences in undergraduate mathematics and thus participants self-selected as a woman of color to participate in this follow-up study. The interest survey included questions about demographics, various experiences and feelings related to undergraduate mathematics, and how those experiences and feelings related to race and/or gender, if at all.

From the interest survey, I selected participants based on results from a previous analysis as well as aiming to diversify the sample in terms of gender, race/ethnicity, university, and major. A previous analysis using this dataset grouped women of color into clusters based on components of mathematics identity. Thus, I selected 12 participants to interview that span across these clusters while attending to the above characteristics. For this analysis, I focus on two participants, Lyka and Callie. Brief descriptions of Lyka and Callie appear in Table 8, including their self-described gender and racial identities.

Table 8 Description of participants

Lyka	**Callie**
Lyka (she/her) is a Filipino and white cisgender woman. She recently graduated with degrees in Biomedical Engineering and Multidisciplinary Studies from a public university in the Eastern half of the United States. Within the mathematics department at her university, she completed College Algebra, Trigonometry, Calculus I, Calculus II, Multivariable Calculus, and Ordinary Differential Equations.	Callie (she/her) is a Hispanic/Latino cisgender woman. She recently graduated with a degree in Biology from a public university on the East coast of the United States. Within the mathematics department at her university, she completed College Algebra, Precalculus, Trigonometry, Statistics, and Calculus I.

Data Collection

In Spring 2022, I conducted 60 - 90 minute, semi-structured virtual interviews with each participant. The interview protocol included questions about participants' experiences and feelings related to undergraduate mathematics, including their perceptions of themselves as doers of math and what they found to be supportive and valuable in mathematics spaces. For example, I asked "what type of teaching style did you feel best supported you in undergraduate mathematics and in what ways?" I divided the interview questions into four categories, three of which were informed by Voigt's (2020) definition of mathematical identity and one focused specifically on potential connections to gender and race. This categorization intended to bring forth participants' narratives around important and valuable components of mathematics and their undergraduate mathematics education as well as their mathematical identity. In this work, I focus on participants' responses related to their mathematical and mathematics education values.

Data Analysis

Before analyzing the data, I transcribed each interview and replaced identifying names and institutions with pseudonyms. While transcribing, I engaged in pre-coding whereby I noted particularly interesting or powerful statements related to values (Saldaña, 2013). I then continued to use Saldaña's (2013) first cycle and second cycle coding methods. During the first cycle, I open-coded by attending to prior work characterizing students' mathematical and mathematics education values, but without specific codes in mind. In particular, I utilized prior work such as Hill et al. (2021), Reinholz et al. (2019), and Hunter (2021) that stretch across mathematical, mathematics education, and cultural values. In general, I labeled anything connected to the research questions, including statements related to cultural values, mathematical values, mathematics education values, social identities, and expressions of emotions. I did not restrict a statement to a singular code and often a statement stretched across multiple. For example, the statement "It was definitely, mostly like lecture where it was just like, on your own" was coded as *class structure – lecture* and *reputation – individual*. These codes became the basis of the second cycle coding process which involved grouping the initial codes into theoretical codes. These theoretical codes (all related to values) included career/future, mathematics reputation, real-world meaning, community, accomplishment, pedagogy, and various types of social support. I then split, combined, and rearranged these theoretical codes and subcodes to finalize themes speaking toward the research questions. This resulted in six themes: meaning of mathematics, mathematics as fast-paced, innateness of mathematical ability, mathematics is competitive, mathematics as a gatekeeper, and mathematics as a lone pursuit.

Results

Meaning of Mathematics

Hill et al. (2021) describe the dimension of meaning related to mathematics values as "having a sense of direction in mathematics, feeling mathematics is valuable, worthwhile, or has a purpose" (p. 353). This can include perceiving math as valuable for its applications to the real-world, to one's life, to a future career, or in and of itself. Values associated with the mathematics discipline tend to emphasize pure or context-free mathematics over applied. This is seen through pedagogical approaches in mathematics that focus on content knowledge rather than applications and the view that pure mathematical research holds more prestige than applied mathematical research (Reinholz et al., 2019). This value reflects back as early as Plato, who regarded numeration and calculation as less valued mathematical activities appropriate for lower class persons for practical purposes, while pure mathematical thought regarding abstract objects and connections were reserved for those in the upper echelon (Ernest, 2016). This value also appears through the disconnect between mathematics education and students' community. Students' often perceive mathematics as the memorization of procedures devoid of context, thus limiting their ability to see mathematics as a useful tool in non-classroom settings (Boaler, 2000).

Both Callie and Lyka challenge this view by expressing valuing the meaning of mathematics in terms of its applications to the real-world, future careers, and their community. Callie spoke about how she "was always more interested in those real applications… like this specific thing that you're learning right now, look how it's used, like in a real world application." Lyka as well discussed how excited she was to see how calculus could be applied in a real-world setting through her engineering courses, how "wow, like you can use calculus [in engineering] and you know, a lot of my transport class has been differential equations the entire time… so just like actually being able to apply that in the setting. Not only do I know how to do math now, like I know how to apply it." In contrast, Lyka expressed her frustrations with courses that she did not find applicable, such as "ugh, I'm stuck in algebra… I don't need to know this. I just didn't find it very applicable."

Both Callie and Lyka also emphasized value in seeing connections between mathematics and a future career. The importance of a career and the pressure to succeed connected back to their identities. Callie addressed how diverging from a pre-medicine track was challenging given "my family they're like, you need to be a doctor and all that and yeah, it's kind of the typical Hispanic like, the doctors are the best .. . and I did like it for a while but then I realized it wasn't for me." She also described how being a first-generation student and the oldest child in her family, so there was "another added pressure of you're like, the child that's gonna make it." Lyka talked similarly about her first-generation status when she said "I need to prove myself…So I'm getting two degrees. The first-generation [status], I'm just like, setting the bar high." These experiences align with their perceptions that mathematics is also meaningful when it relates to career success. Lyka mentioned this explicitly, noting how "I didn't just spend all these years in these math courses to not use any of it, like it's very much applicable and prevalent in my career."

Lyka in particular also valued mathematics when it could help others and her community. She expressed alignment between college mathematics and this value when she says how "I feel confident that I'm able to do [math], and it's just, it makes it better, because I know it's going towards something that's going to help someone and improve their quality of life." However, she emphasized a strong misalignment between college mathematics and how it can apply to societal issues. In reference to the increase in hate crimes towards Asian people in the USA, she admonished how "this was what I was seeing in my community, like, how am I supposed to want to do [math] or think [math] is valuable in the moment, when all these things are happening, when … I'm needed in my community in some way." She acknowledges that she is referencing a specific current event, but at the same time emphasizes how generally disconnected she perceives mathematics is from confronting issues in society at large.

Callie and Lyka's mathematical education values in this regard appear to emerge along similar lines as their mathematical values. While these values misalign with the traditionally held valuing of pure and "context-free" mathematics, they describe varying experiences in their mathematics courses. Both participants explicitly brought up how in their calculus courses, applications "[weren't] necessarily talked about in classes… it was just like the concepts, how you learn it, and that's it" and "in like calculus… you're learning the foundations and setting up that knowledge…you're not necessarily always applying that." However, both participants also positively spoke of courses in which they could see connections between mathematics and the real-world or future careers. Callie spoke about how "that's why I enjoyed statistics so much, because they were almost like problems that you would see normally, in real life." Lyka described a lesson in high school mathematics where the teacher connected the lesson to a project completed by engineers at a national beverage company. She reflected on that experience, saying "I think finding ways to translate math is still important in the undergraduate setting, and just looking for those experiences like, if you know how to do this [math], then you know, you can do this in the future." While they experienced a variety of mathematics pedagogy, both Callie and Lyka valued having mathematics courses and instructors connect mathematics to real-life contexts and careers.

Mathematics as Fast-paced

Another long-standing value ingrained in mathematics is the ability to do math quickly and "keep up" with mathematics course content. Various scholars report that students across grade levels strongly believe that success in mathematics requires knowing answers and completing problems quickly (Chinn, 2012; Darragh, 2013; Ernest, 2011). This reflects mathematics classrooms that embody a fast-paced curriculum toward the goal of a timed exam (Geist, 2010). In the college setting, this value of speed aligns with the standardization of common courses, with mathematics departments often including common syllabi, homeworks, and exams across coordinated courses. This standardization enforces a fast-paced approach to avoid falling behind other sections and cover the required content for the exam (Reinholz et al., 2019)

Callie and Lyka both acknowledged and expressed their frustrations with the value of speed embedded into their undergraduate math courses. Callie recognized that "there's just so much to learn about [math] and I had to do it in such little time that I kind of wish that I could go

… at a better, at my own pace in learning these concepts" and how she wished that there "wasn't so much pressure on the student to learn it immediately." Lyka as well felt like her grade suffered because she "just couldn't learn it as fast as the other [students]." Thus, while the participants successfully navigated the fast-paced mathematics curriculum as STEM majors, they did not value the focus on speed within mathematics learning.

Callie and Lyka both expressed challenges in courses that reflected the fast-paced value of mathematics. Callie described how the majority of her undergraduate math courses involved "the math teacher just kind of spit-vomiting a bunch of math information and then you have to take notes…I would just take notes as fast as I can and then I would have to look over it after class…so I think it was pretty difficult to kind of learn things that way." Lyka similarly expressed that in most of her math courses, if she did not understand a concept, she just accepted that "that's just something I don't know, I'm going to continue to learn new material, because you really don't have the time or opportunity in class to go over what you missed. It's like, alright, on to the next material, you failed that exam, oh, better study well for the next one." However, Lyka enthusiastically described her experience in her mastery-based upper-level calculus courses. A main component of these courses was the ability to work through previously missed exam problems and present your understanding to the professor. She emphasized how grateful she was that "I was able to actually go back and learn what I missed" in comparison to her other courses where they did not have time.

Innateness of Mathematical Ability

Another commonly held value in Western mathematics upholds the discipline as a place for those with innate mathematical brilliance (Hottinger, 2016; Leyva et al., 2021; Reinholz et al., 2019). This underlines the belief that there are those who are "math people" and those who are not, emphasizing that math ability is something with which someone is born (Ernest, 2011). Scholars suggest that this value also permeates into racialized perceptions of mathematical ability. In their study examining student of color's perceptions of racialized and gendered experiences in introductory undergraduate mathematics, Leyva et al. (2021) found that many of the participants who perceived certain classroom instances to imply mathematics ability as innate also perceived these instances to relay messages suggesting minoritized students inherently lack mathematical ability.

Lyka recognized this value explicitly, saying "in our society, they say there are two types of people – math people and not math people… I've always been into math from a very young age." However, rather than adhering to the value that math ability is solely innate, she continued to say that "the reason for that can be just, some people didn't have the… extra attention that they may have needed, so they just grew up with this hatred towards math because it seemed so unattainable." Even though she labels herself as a person interested in math from a young age, she also described how that interest faded at the beginning of college and did not return until her mastery-based upper level calculus course where "having the opportunity to fail and learn from my mistakes, I could actually take an interest into what I was learning and not just focusing on memorizing the steps for the next quiz." In this regard, Lyka valued the work it took to learn from her mistakes rather than feeling disconcerted over a lack of "innate" ability. However, Callie expressed in retrospect that she should have given herself more credit for her hard work in her mathematics courses. She describes how "looking back, I should have been more confident about [math], because they were hard classes and I should have just been more proud about myself and not like, so hard on myself." She wished that there was more reassurance that "you are studying a somewhat difficult topic. It's okay and you'll get it eventually."

While Callie did not discuss explicitly how this mathematical value played into what she valued about her mathematics education, Lyka expressed this connection thoroughly as part of her introductory mathematics courses versus her mastery-based upper level calculus courses. She addressed how messages about mathematical ability interacted with gender and race and her feelings about asking for help. For example, she describes how "when you're a woman, you have to work a little bit harder, or like stand out a little bit more,… because if you mess up, or if you're not as good as your classmates, it's like a reflection not on you, but like on your gender and your race" and how that feeling "just added pressure when it comes to just needing help in math and not like performing well.' The perception that mathematical ability is innate influenced how Lyka reflected on her own mathematical performance as a woman of color and affected her mindset around asking for help. However, enrolling in the mastery-based mathematics courses "naturally raised my interest and actually doing the math and understanding it, because I wasn't being penalized for not getting it on the first try." This type of course challenged notions about innate mathematical ability and instead valued students' hard work and perseverance to understand mathematics – something Lyka deeply valued from those courses.

Mathematics is Competitive

Another value of the mathematics discipline is competition, or the view that a competitive disposition is necessary to succeed in mathematics (Hottinger, 2016; Mendick, 2006; Reinholz et al., 2019). Mendick (2006) argues that this mathematical value emerges from the dichotomization in Western culture between concepts that are masculine versus feminine, with competition as masculine and collaboration as feminine. Various studies show women and student of color's preference for collaborative mathematics environments compared to competitive ones (Kogan & Laursen, 2014; Vaughan, 2002). A focus on competition may also undermine marginalized students' mathematical performance. Literature supports the position that men have less aversion to competitive situations and thus women may underperform on mathematics situations posed as more competitive (Eble & Hu, 2022; Niederle & Vesterlund, 2011; Cai et al., 2019). Scholars also suggest that the presence of stereotypes may negatively impact marginalized students' performance during competitive or high-risk mathematics situations (Steele, 2018).

Neither Callie nor Lyka spoke explicitly about their mathematical values related to competition versus collaboration in mathematics, but they both aligned with a more collaborative atmosphere in regards to their mathematics education values. Callie talked about how "in other classes there was a lot of like, peer learning environments, like they set up the classes…where you have a group…and I did like those in certain classes but…I don't think I ever did math classes like that. It was definitely mostly the lecture, where it was just on your own." Thus, although she did not experience a collaborative mathematics course, she did value that type of learning in other courses. Lyka experienced a variety of pedagogy in her mathematics courses, some that were collaborative and others that were not. In terms of the mathematics courses that did not include collaborative components, Lyka mentions that she "really wasn't a fan" and those courses "didn't really align with my teaching style." However, she describes a more collaborative course saying "I liked the design of that class... the teacher wouldn't just lecture on the board" and instead "days would just be dedicated to solving problems…and you could work in groups." A collaborative learning environment was also a large part of her deeply valued mastery-based calculus courses.

Regardless of the course style, both Callie and Lyka created a more collaborative mathematics environment for themselves through valuing collaboration with peers rather than competing with them. Callie admited that learning in courses that focused on fast-paced lectures was difficult for her, so she "always ended up having to ask people in class, like, oh, how do you do this?" and they would share their understandings back and forth. Callie further talked about a specific friend that she had numerous classes with and when it came to mathematics, "it was really great to have her as a friend to study with… I think she was a really great help in that because she'd [give] all this type of encouragement…like, I honestly don't know if I would have been able to score high without her." Rather than compete for a higher grade, Callie and her friend supported each other both through mathematical understanding and encouragement. Lyka as well collaborated with her peers frequently, especially in her upper-level calculus courses, describing how "most of our homework was done together…it really worked out, we all got together and did math and then too, before exams [we'd study]…it was a really good experience, like I was able to get through the [COVID-19] pandemic because of them." Similarly to Callie, Lyka valued collaboration with her peers not only for mathematical support but also emotional support. While both Callie and Lyka did not explicitly address competition in their mathematics courses, they each talk about valuing collaborative atmosphere in the classroom and with peers.

Mathematics as a Gatekeeper

Introductory undergraduate mathematics courses are often labeled as gatekeeper courses – courses structured to "weed out" certain students and prevent them from continuing in a STEM degree (Bryk & Treisman, 2010; Leyva et al., 2020). Mathematics often portrays a reputation of being difficult to the point of being unattainable to learn, and thus maintaining success for only those considered most intelligent or potentially "genius" (Leyva et al., 2021; Reinholz et al., 2019). Aligning with the notion that math should be difficult is the perception that mathematical reasoning is purely logical and emotionless (Mendick, 2006). Mendick (2006) argues that the dichotomy of logical versus emotional also emerged from masculine mathematical discourses. This value can present itself in the ways students perceive and value care from their mathematics instructor. Women often value having a positive relationship with their mathematics instructors more so than men, however, research suggests that women of color perceive the least amount of instructor care (Rainey et al., 2019; Solomon et al., 2011).

Both Callie and Lyka acknowledged society's perception of mathematics as extremely difficult and exclusive. Lyka talked about how some people "just grew up with this hatred towards math because it seemed so unattainable and so hard…I think more than half of society will be like, yeah, that's not worth it…like, eww, either people say eww math or they're terrified of it." Callie expressed similar sentiments when she says "A lot of, most of the world… they're just like, oh yeah, [math is] hard, it's like unattainable, it's impossible to do." Lyka reflected on how she felt the "gatekeeping" value in her introductory mathematics courses, expressing how "it was really math holding me back" and in particular, described Calculus II as "the weed out class" and one of her "worst experiences." Callie related this value to the culture of mathematics and how she wishes "just to kind of get that like, culture of harshness out of math…or just not as daunting." Alongside these acknowledgements, though, they did express valuing the challenge mathematics presents for the reward they feel when accomplishing a difficult task. Callie emphasized that "math inherently is, it can be hard, but then I remember like, when I would answer stuff, like I'd get really happy." Lyka as well described a similar feeling, saying "[math] is definitely not easy…I'm not gonna downplay the content of math…[but] just completing a problem is, it just feels like you've accomplished something." Overall, it appears that Lyka and Callie both valued mathematics as a challenging discipline, but disagreed that mathematics should continue to be promoted as impossible and exclusionary.

Both Callie and Lyka described situations where this value was reflected in their mathematics and the tension they felt in those scenarios. Callie described how one of her class "was really hard. I remember I was very stressed out with that class," however she was insecure about asking for help because "if I asked a stupid question, like, that's embarrassing and annoying." Thus, the harshness of mathematics translated to the existence of "stupid questions" even when the class was hard. Lyka illustrated this disconnect of values with a specific exam experience, where "I was the last one to leave and I was just so stressed out and I actually ended up crying after the exam…I didn't understand the material…and I wasn't seen as a math doer, I was just seen as a failing student." She continued to say how after the exam, she was further disappointed that there was no check-in or follow-up about the exam and everything "proceeded in class like normal."

Lyka and Callie experienced this value differently when it came to relationships with mathematics instructors. Callie explained how "[going to office hours] was daunting. I did not like doing that…I went in once and this professor, he was just not very welcoming." Interestingly, she specified that "I think the math [office hours] were definitely a bit more intimidating for me, as opposed to the science classes." Thus, there is a specific placement of this value of intimidation in mathematics that Callie does not perceive in science. Lyka described a very positive experience where she felt an instructor went out of his way to support her and challenge this idea of "weeding out" weaker students by offering mathematics help to former students in their future mathematics courses. Overall, Lyka and Callie both experienced situations in their mathematics education that align with or challenge the value that mathematics is a "gatekeeper" and impossible, however, their own values align with the mindset that while math is difficult, students should feel supported and that they can succeed.

Mathematics as a Lone Pursuit

In the early 19th century rose the image of Western mathematicians as "lonely geniuses, toiling in obscurity, whose brilliance and insight go unacknowledged by an arrogant establishment and an uncaring world" (Alexander, 2006, p. 717 – 718). This image permeates in the mathematical value around understanding mathematics on one's one and leading a more solitary, mathematics-centric life (Lane et al., 2019; Mendick et al., 2008). In undergraduate mathematics, faculty primarily discuss working alone, reflected in mathematics papers having the least amount of authors on average compared with other STEM disciplines, such as biology and physics (Newman, 2004; Reinholz, 2019). This value may also influence students' help-seeking behavior in mathematics, creating a stigma around collaborating with others and asking for help (Butler, 2006; Ryan et al., 2001).

Lyka acknowledged this value explicitly, especially as a woman of color, saying that there is "just an added pressure when it comes to just needing help in math and not like performing well." However, her own mathematical values conflicted with this view, in particular when it came to understanding the influence of current events on students' learning and focus. She wishes that instructors would more frequently "recognize that something outside of school, a current event is affecting students in [the] classroom…and maybe it'd be time to like not just strictly focus on math." This view challenges the value that to succeed in mathematics requires constant individual focus on the subject. Callie as well throughout her interview recognized how for the majority of her mathematics experiences, she was "just kind of on my own" and "just kind of rolling through the punches, because I knew I did want to graduate…and that was just mostly me." However, in response to those feelings, she expressed that when she could "I think I was really good at like forming friends in those classes so that we can study together." Thus, Callie's mathematical values challenged the traditional view of a lone mathematician.

Both Callie and Lyka contested mathematics as a solo endeavor by seeking out social support. As previously discussed, Callie had a friend she frequently worked with on mathematics and expressed truly valuing both her friend's content and emotional support. Callie also described a graduate student research mentor that supported her application of statistics in research that she really enjoyed. However, Callie described some challenges when seeking support outside of school. She recognized that "no one in my family is a STEM major…so I never really got to share that frustration or experience with anyone in my family" and her partner at the time "wasn't in college. So he never knew exactly like…it was just not a thing." While Callie certainly expressed feeling proud of herself and her mathematics accomplishments, she did not want to "go it alone" and sought out other areas of support instead. Within the mastery-based calculus courses, Lyka talked about how collaboration provided both content and emotional support. If she struggled with the content, "I got the help from my peers or we were in the same boat, like we didn't know either." Emotionally, "we just had all engineers in our [calculus] class, so we understood the same struggles." Lyka also mentioned other relational support, including her family and partner, which although they "[don't] understand what I'm doing, they still have really supported and have offered help." Although the level of support Callie and Lyka received related to their mathematics education varied, they both valued partnership and emotional encouragement from others rather than going through it on their own.

Discussion

The results of this work corroborate other studies showing the misalignment between marginalized students' mathematical values and the values of the mathematics discipline in the

USA (Diekman et al., 2010; Fong et al., 2019; Leyva et al., 2021). The women of color in this study particularly acknowledge and confront the mathematical values regarding the meaning of mathematics, speed as a marker of mathematical knowledge, learning mathematics individually, mathematical ability as innate, mathematics as a gatekeeper, and the image of mathematicians as loners. In each of these areas, Callie and Lyka describe ways in which they notice these values embedded in their mathematical experiences and the negative feelings associated with trying to navigate those values. At times, they also expressed their views on how to challenge those values and create mathematics spaces with values alignment. For example, they both discuss how they value mathematics that applies to the real-world or their lives and suggest integrating more applications into the classroom to support this value. In this way, the distinction between mathematical values and mathematics education values start to blur. This reflects how these categorization of values necessarily overlap and inform one another (Seah et al., 2016). It follows that one way to prompt mathematical values in the USA to better reflect the values of women of color and other marginalized groups may be to start integrating more undergraduate mathematics pedagogies that reflect the mathematics values of these groups.

The results suggest that Callie frequently navigated undergraduate mathematical spaces misaligned with her mathematical and mathematics education values, which caused her stress and reduced her interest in mathematics. She mainly discusses frustration with mathematics courses that included fast-paced, context-free lectures where instead she valued going at her own pace and learning mathematics applicable to the real world. Unfortunately, students frequently experience instructor-centered lecture enacted in the undergraduate mathematic classroom (Apkarian et al., 2021; Seymour & Hunter, 2019). However, Lyka consistently reflected throughout her interview on the positive experiences she encounters within specific courses that more closely align with her values – her mastery-based upper-level calculus courses. The mathematics education values interwoven into the very nature of the classroom structure – consistent collaborative learning, a student-driven pace, the ability to improve from previous mistakes, interactions with the instructor – challenged long-standing mathematical values such as individual learning, speed, emotionless, and innate ability. It was clear that experiencing a class more aligned with her own mathematical values provided Lyka a very positive perception of that type of course. One main reason Lyka states for volunteering for this study was "I'm definitely a huge advocate for mastery based grading, so like, any opportunity that I can talk about it, because it's just shaped my math career so much… so yes, mastery based grading everywhere…that's how math needs to be taught." The benefits Lyka described from experiencing a course with aligned values speaks to other literature on the benefits of reflecting marginalized students' mathematical and mathematics education values in the classroom (Hill, 2018; Kalogeropoulos & Clarkson, 2019) and furthermore, how to envision this type of classroom in the undergraduate environment.

Values and Identity

The role of identity also stretches throughout Callie and Lyka's discussion about their values, suggesting the importance of gender, race, and other identities when considering women of color's values in mathematics. In some ways, they talked about this influence directly. For example, Callie spoke about how sometimes she felt like her actions represented those of her entire race and gender and this added pressure around asking for help. Both Callie and Lyka also identify as first-generation, which research suggests that cultural mismatch in higher education may also negatively influence first-generation students' help-seeking behavior (Chang et al., 2020).

A lack of representation in undergraduate mathematics may also influence the values embedded in that space. Both Lyka and Callie noticed how few women, people of color, and women of color faculty they saw in the mathematics department. Lyka expressed that “I never had a professor that looked like me or shared similar experiences to me... the same financial background, [or] was a first-generation student.” When asked how institutions could better support women of color in mathematics, Callie answered quickly “just having like, more women of color teaching or like, being in positions of power within the university.” The values of a space are majorly influenced by the people that hold power in that space. White men continue to represent the largest proportion of undergraduate mathematics majors, mathematics graduate students, and mathematics faculty members (NCSES, 2023). Thus, it is not surprising that mathematics continues to uphold and give power to white, patriarchal values, whether purposefully or not. Diversifying mathematics faculty and structuring the environment to include, value, and support them and their ideas may help shift the culture of mathematics to better reflect marginalized students’ mathematical and mathematics education values. This may also happen with a more diversified student population in mathematics. Another aspect of Lyka’s experience with the mastery-based calculus courses was the diversity in the class. She noticed that “it was the first time I was, I didn’t feel like an only or an other in my class…it was like, white people were the minority.” Thus, the diversity of the students in the class may have also supported the ways in which the course confronted and diverged from the socio-historical values of the mathematics discipline and corresponding pedagogy. Given the positive outcomes of value alignment for marginalized students, this adds to the work of various other scholars continuing to encourage institutions to hire more faculty and recruit more students from diverse backgrounds and identities and restructuring higher education mathematics spaces to better support these faculty and students (Casad et al., 2020; Hess et al., 2013).

Conclusion

This work supports other results that suggest women of color's values are not reflected in undergraduate mathematics spaces in the USA (Abrams et al., 2013; Leyva, 2021). Lyka and Callie expressed misalignment with each of the six traditional mathematical values presented in the results. From a sociopolitical viewpoint, this suggests that women of color may feel excluded or hindered by a misalignment of values while navigating white, masculine discourses in undergraduate mathematics. However, Callie and Lyka experienced different pedagogical settings that influenced how corresponding mathematics education values emerged in the classroom. Lyka enthusiastically talked about her mathematics courses that challenged traditional mathematical values, while Callie felt like she was just getting through her mathematics courses that strongly reiterated traditional mathematical values. These results speak to the potential for institutions in the USA to better support women of color through value alignment in the mathematics classroom. Implementing pedagogy that portrays mathematical and mathematics education values such as collaborative learning, perseverance, asking for help, and application to the real-world may better reflect those of women of color in the USA and spur more positive cognitive and affective outcomes. Future work aims to explore this connection between value alignment and positive outcomes for women of color in the USA in undergraduate mathematics more explicitly. Additional interviews and survey data may add to these results by asking participants more directly their mathematical and mathematics education values and whether they perceive these values imbued in their undergraduate mathematics courses. Supporting and aligning with marginalized students' values in undergraduate mathematics classrooms may be one approach to answer the powerful call for more equitable and inclusive mathematics education in the USA.

CHAPTER 5 – CONCLUSION OF THE STUDY

Discussion and Overall Conclusions

This dissertation study explores women of color's various and unique expressions of mathematical identity and the institutional mechanisms surrounding these expressions. Using a transformative, mixed methods approach, each paper zooms in on an important component related to women of color's mathematical identity while connecting together to tell a broader story. First, Paper 1 quantitatively demonstrates that there exist various expressions of mathematical identity among women of color in introductory undergraduate mathematics. Paper 2 qualitatively explores one of these groups in more depth to provide contextual details and showcase how material and relational resources connect to women of color's mathematical identity. Lastly, Paper 3 draws on qualitative data to explore ideational resources and examines the continued prevalence of gendered and racialized values in undergraduate mathematics. In this discussion, I connect and expand on each of these contributions and integrate additional results not presented in the papers.

Paper 1 showcases within-group differences related to women of color's mathematical identity using cluster analysis, which resulted in four groups representing different expressions of mathematical identity among undergraduate women of color in P2C2 courses. Informed by Data Feminism and an intersectional lens, instead of comparing to other gender or racial groups, this analysis offers insight into what ways different components relate to women of color's expressions of mathematical identity. To this point, Paper 1 discusses the role of peers and friends, both inside and outside of the classroom, to support women of color's mathematical identity. Cluster 3, labeled *harmful unsupportive teaching,* stood out in this regard because their peer interaction score remained relatively high even with a below average class experience score. Another result from the cluster analysis not discussed in Paper 1 is the connection between the self-efficacy score and the inclusion by instructor score. Research points to the connections between inclusion, self-efficacy, and mathematical identity (e.g. Joseph et al., 2020; Tellhed et al., 2017). Clusters 1 (*non-impactful active teaching*), 2 (*non-impactful passive teaching*), and 4 (*non-impactful basic teaching*) display on average no change in self-efficacy and an inclusion score close to 0.5. However, Cluster 3 exhibited both a negative change in self-efficacy and a below average inclusion score. When considering the qualitative student responses, students in Clusters 1, 2, and 4 generally described their instructor positively while students in Cluster 3 mainly pointed out negative qualities about their instructors' teaching style or described them as unapproachable. Many students in Cluster 3 expressed how negative or exclusionary experiences in their course contributed to confusion and frustration, which negatively affected how they viewed mathematics and their ability and confidence in the subject. This result was further explored within Paper 2.

Paper 2 examines material and relational resources available and accessible for undergraduate women of color STEM majors to support their mathematical identity. The results of Paper 2 showcase various positive and negative material and relational resources these women of color experienced in undergraduate mathematics. During interviews, the participants discussed supportive material resources such as technology, application-based curriculum, tutoring centers, and institutional student programs. They also talked about material resources that hindered their mathematical identity such as the department's focus on research over teaching, unwelcoming office hours, and a lack of representation. Relational resources such as good relationships with instructors, peers, and upperclassmen supported their mathematical identity while feeling excluded by extracurriculars and the mathematical community hindered their mathematical identity.

While not explicit in the article, I specifically chose the three interview participants from Cluster 3 for analysis in Paper 2 to additionally contextualize the results from Paper 1. I selected Cluster 3 as the unit of analysis because of the interesting differences in factor scores when compared to the other clusters. Cluster 3 was the only cluster to exhibit both below average self-efficacy and inclusion scores and also a relatively high peer interaction score given its low class experience score. These scores suggest two relationships regarding women of color's mathematical identity: (1) a connection between decreases in mathematical self-efficacy and feeling less included by the instructor when compared to peers, and (2) the role of peers in supporting mathematical identity outside of class in contrast to frustrating or exclusionary in-class experiences. The results of Paper 2 support these conclusions from Paper 1. It is necessary to note that the research interviews occurred 4 - 5 years after the participants completed the *S-PIPS-M* survey. Among the participants in Paper 2, Callie completed the survey in her Precalculus course, Sara in her Calculus I course, and Sky in her Calculus II course. This is important when examining their instructor relationships and self-efficacy as they relate to the cluster scores. Each of the instructors the participants' described a positive relationship with taught courses *after* the participants completed the survey. For example, the instructor Sky described taught Calculus III (outside the scope of the P2C2 focus). Therefore, during the time of the survey, the participants' instructors would most likely fall under the neutral or negative instructor relationships category. Specifically, participants expressed ways in which these instructors often negatively influenced their perceptions of ability and confidence through a lack of recognition either in class or in office hours. The results of Paper 2 also reflect the second result of Paper 1 related to peer interaction. Sara, Sky, and Callie each discussed an especially supportive peer or positive experiences with peers aligned with the time of the survey. Sky described her study partner throughout Calculus II. Sara expressed how she happily answered questions from various peers in her Calculus I course. Callie talked about an impactful peer she took multiple courses with who supported her both emotionally and with the content. However, each participant conveyed neutral or negative feelings about how their mathematics classes throughout college contained mostly lecture-based teaching. In conjunction with the discussion from Paper 1, this connection suggests that peers may have acted as a bolster to the participants' mathematical identity that they did not experience in the classroom.

Paper 3 deeply explored undergraduate women of color' values related to mathematics and mathematics education, which connects to Nasir's (2011) third category of identity resources called ideational resources. The results of this paper show a clear misalignment between sociohistorical mathematical values and women of color's mathematical and mathematics education values. In particular, we see how the white, patriarchal roots of mathematical values still perforate undergraduate mathematical spaces and contrast with women of color's mathematical and cultural values. This implies that the systems within undergraduate mathematics heavily limit the ideational resources women of color can use to support their mathematical identity. These exclusionary values also interweave within the participants' descriptions of their material and relational resources. For example, the participants' hesitancy to ask for help through office hours or tutoring centers relates to the valuing of innate mathematical ability. As discussed in both papers, this reflects gendered and racialized discourses in mathematics that position women and people of color as less innately mathematical able. The valuing of mathematics as a lone pursuit emerged throughout the participants' narratives about being “on your own” and “alone, just trying to figure it out by myself.” The combination of Papers 2 and 3 suggest that the lack of ideational resources, or the continued presence of white, patriarchal values in undergraduate mathematics, not only hinders women of color’s mathematical identity directly, but also limits their access to material and relational identity resources as well.

Considering the three papers combined speaks to the various ways undergraduate women of color STEM majors express and develop their mathematical identity. While there are numerous ways institutions purposefully or implicitly aim to support women of color’s mathematical identity, these resources are often inaccessible or diminished because of the white, patriarchal values still ingrained in undergraduate mathematical spaces. The few experiences the participants discuss as especially supportive challenge these values and create spaces that align with women of color’s values. For example, Lyka strongly emphasized the ways her experience in mastery-based calculus courses (an Emerging Scholars Program initiative) influenced her decision to enroll in a mathematics minor and Callie described how the McNair Scholars Program was significant to her continuation in a STEM field. These programs are explicitly designed to challenge white, patriarchal values in mathematics and support marginalized students through collaboration, representation, and relationships. This suggests that successful resources and initiatives to support marginalized students in STEM need to first address the underlying exclusionary values within mathematics.

Limitations and Delimitations

This dissertation study has four main limitations. The first limitation is the choice to use a dataset not originally designed or collected by me as the researcher to capture students’ mathematical identity. While many of the survey questions related to components of mathematical identity, that was not the original intent of the survey and thus limits the breadth of information captured by the survey about mathematical identity. In terms of qualitative data collection, the nature of participant recruitment limited the interview sample to those who self-selected into the study and thus cannot represent women of color overall. For example, the sample happened to mostly include participants who attended universities on the Eastern half of the USA. It is likely that different patterns may have emerged given a sample concentrated in a different part of the USA, more diversely spread across the USA, or pooled internationally. Given the fluidity of mathematical identity, the interview structure also limited participants' ability to express everything that influenced their mathematical identity. Participants mostly likely experienced additional influences that they did not talk about in the interviews, either purposefully or because my interview protocol did not bring up certain topics. Thus, this study suggests some, but certainly not all, of undergraduate women of color's mathematical identity resources. Lastly, the time between the initial survey collection and the time of the interview could be viewed as a limitation because participants may not have remembered experiences that occurred throughout a multi-year span. However, I also view this as a strength in terms of the ways participants recounted their experiences over their entire undergraduate career. Instead of focusing on just one class, participants discussed how their experiences over time influenced their mathematical identity and offered rich comparisons related to the ways resources supported or hindered their mathematical identity in different times and spaces.

This study also has multiple delimitations. The scope of this research focuses solely on undergraduate women of color STEM majors in the USA. I decided to limit this sample to STEM majors given that non-STEM majors have fewer experiences with undergraduate mathematics, often concentrated to one or two classes over a shorter period of time. I specifically focused on women of color for multiple reasons discussed throughout this dissertation. The decision to include only undergraduate students from 4-year institutions arose from the delimitations of the original survey collection process. I also delimitated this study to concentrate on mathematical identity and values. While my interview protocol aimed to capture both specific and broad features of women of color's mathematical experiences, my analysis narrowed in on participants' discussions around mathematical identity resources and descriptions of their mathematical values. This process allowed me to better capture both individual and collective identity resources and values and focused the analyses back to the research questions.

Implications

Implications for Practice

I present various implications for practice throughout this dissertation study focused on how instructors can better support women of color's mathematical identity in the classroom. The inclusion of applications and connections in mathematics curriculum stretched across Papers 2 and 3. The participants expressed appreciating mathematics that connected to real-life scenarios, their future careers, and the community. They also described positive attitudes toward collaborative, in-class activities even though most of their courses included little to no collaboration. The results suggest that promoting peer relationships and instructor interactions during collaboration were integral parts of these activities. Paper 2 outlined the benefits of technology to support women of color's mathematical experience. The participants described how technology added interesting visualizations in-class and supplemented learning mathematical content outside of class. Paper 3 stressed the importance of including opportunities for students to learn from their mistakes. While a mastery-based course encompasses this aspect within the course design, other ways to include this aspect in a course are through assessment corrections or discussing homework problems in class.

An important consideration underlying these implications is ensuring that in-class resources challenge gendered and racialized values in mathematics. Paper 3 highlights the misalignment between various sociohistorical mathematical and mathematics education values and women of color's mathematical and mathematics education values. This misalignment of values emerged in Paper 2 when participant's described certain resources as exclusionary or unwelcoming, such as STEM extracurriculars, office hours, or the mathematics community. Sara perceived the mathematical community to include only those with a natural ability in mathematics, reflecting the valuing of innate mathematical ability. In relation to practice, various scholars point out how collaborative activities in mathematics can perpetuate inequities when not designed to challenge white, patriarchal values Ernest et al., 2019; Esmonde et al., 2009; Rosser, 1998). Thus, integrating any of the above implications within the classroom requires consideration of these exclusionary values and systems present in mathematics. For example, utilizing group activities based on positive interdependence (e.g., turn-taking, group roles) and prioritizing understanding over speed can both help challenge gendered and racialized mathematics discourses and support marginalized students' comfort and learning during collaborative activities (Leyva, 2021; Theobald et al., 2017).

Implications for Policy

I also address various implications for policy throughout this dissertation study, both at the departmental and institutional levels. Similar to the implications for practice, policy implications must also consider ways in which to challenge gendered and racialized discourses in their design and implementation. One promising area to support women of color's mathematical identity is through organized student support programs. Participants specifically described both the McNair Scholars Program and the Emerging Scholars Program as particularly supportive and instrumental in their decision to remain in STEM. These results suggest that those benefits could span to other Federal TRIO Programs or locally-designed student support programs specifically designed to challenge exclusionary norms and values and support marginalized students in their undergraduate career. Another policy initiative to support marginalized students in mathematics centers on additional and purposefully-designed mathematics tutoring spaces. The participants found these spaces particularly beneficial when they were well-advertised, included peer tutors, and normalized asking for help. Another way tutoring spaces could challenge gendered and racialized mathematical discourses is by housing them within cultural centers. This positioning supports affinity spaces where students with shared racial or gender backgrounds can cultivate group community and solidarity within mathematics (Espinosa, 2011; Leyva, 2021).

This dissertation study also further implies the need for policy changes directed toward increased representation of women and people of color faculty in mathematics. Both Papers 2 and 3 showcase the participants' emphasis on the importance and current lack of gender and racial diversity in the mathematics faculty. Various scholars demonstrate the benefits of increased representation through shared identity mentorship and providing inclusive spaces for marginalized students to feel welcomed and valued (Akin et al., 2022; MacPhee et al., 2013; Ong et al., 2018). To re-emphasize from Papers 2 and 3, policy initiatives aimed at hiring more women and people of color as mathematics faculty "must be coupled with other institutional changes that address structural biases and enable [them] to succeed on equal terms" (Laursen & Austin, 2020, pp. 42). Especially for women of color faculty, studies demonstrate how a lack of mentoring, feeling like a "token" or "pioneer" based on their gender or race, and high levels of harassment, isolation, or discrimination push them to leave STEM departments (Clancy et al., 2017; Laursen & Austin, 2020; Main et al., 2020). Thus, policy initiatives to increase the diversity of mathematics faculty must similarly consider ways to challenge gendered and racialized norms and values within the larger department context.

Implications for Research and Future Work

This dissertation study highlights the importance and richness of within-group, intersectional analyses. Focusing specifically on the variation across women of color's mathematical experiences provides both depth and breadth. Without comparing to other racial or gender groups, the results detailed complex and diverse mathematical experiences, feelings, and values for each participant while highlighting a variety of within-group differences and similarities. This focus provided more detailed and nuanced data to determine in what ways different institutional aspects support or hinder women of color's mathematical identity. Thus, this work advances and further promotes the call for research that considers within-group variation.

Utilizing critical theoretical perspectives throughout this research was essential. In Paper 1, a Data Feminist lens helped humanize the data as people, not datapoints, and provided broader context in which to situate the data. This lens inspired research choices such as the inclusion of qualitative data from free-response questions, the use of vignettes, and the overall grounding of the work within gendered and racialized mathematical discourses. Data Feminism has become an integral perspective with which I view quantitative data and I fully encourage the use of this lens within mathematics education research. An intersectional lens was integral to participants' narratives in Papers 2 and 3. This perspective illuminated ways in which mathematical instances within and outside the classroom are gendered and racialized. For example, participants connected their hesitancy around asking for help to both gender and racial expectations. An intersectional lens helps explicate this experience not as an individual component, but rather a consequence of the white, patriarchal values embedded within mathematics. This dissertation study exemplifies the benefits and strengths of using an intersectional lens in identity research.

Future research will continue to utilize an intersectional lens to further explore women of color's mathematical identity and identity resources. Related to Paper 1, I will contextualize and humanize the other clusters through analyzing the interview data from the other participants within those clusters. I will then utilize a cross-case analysis to compare the similarities and differences across clusters, including further consideration of the role of peers as presented in the discussion. I similarly plan to look at the identity resources of these other clusters to assess in what ways the availability and access to different resources may account for differences in mathematical identity.

Future work will also engage more deeply with mathematical and mathematics education values both broadly and related to mathematical identity. From this work, I believe that values are a critical area of focus when considering systemic change in undergraduate mathematics. The results across the three papers suggest that promising resources to support marginalized students were impeded by white, patriarchal values in mathematics. Thus, future work will explore ways in which to deconstruct these values through practice and policy initiatives. I envision further work designed to explicitly ask women of color what they value about mathematics and mathematics courses and in what ways and to what extent these values are reflected in their mathematics experiences. Following from Paper 3, this work will also look at in what ways, if any, undergraduate mathematical spaces that reflect women of color's mathematical and mathematics education values better support their mathematical identity. This dissertation study shows how gendered and racialized discourses still underpin undergraduate mathematical values. However, the participants do discuss unique spaces challenging these values and creating environments that support women of color in mathematics. That is to say that while these results still present various challenges women of color face in undergraduate mathematics, there exist mathematical spaces and initiatives that are pushing against exclusionary values and supporting women of color that need to be recognized and disseminated.

Final Thoughts

This work affected me in both my professional and personal life. I developed as a researcher, I learned as an instructor, and I also grew as a person. I couldn't have asked for more engaged, open, and honest participants and I'm glad that this research provided space for their stories to be heard and shared. I feel immensely grateful for their time and sincerity; many of the participants thanked me for doing this type of research and for listening to and commiserating with their experiences. At the end of one of the interviews, a participant took a deep breath, laughed, thanked me, and said that it felt like a therapy session she didn't know she needed. Getting a glimpse into their lives and sharing that time together is something I'll never forget. They helped me feel less alone in my mathematics journey and I hope they felt similarly.

Throughout this work, I sometimes felt conflicted about my identity as a white woman exploring women of color's mathematical identity. I questioned parts of the interview protocol, I sought out more literature from different perspectives, I revised and rewrote sections of the manuscripts, and more - but this all amounted to stronger and more authentic research. While I still approach this work as a guest in the space, I believe this dissertation reflects the connections and trust I was able to build with the participants through the shared belief that mathematical systems need restructuring to better support women of color. While numerous challenges remain, reflecting on my conversations with the participants only makes me more inspired to keep promoting equity in all areas of my life. I am very proud of this work, but I know it is just one more step in the direction of a more inclusive and joyful mathematics education.

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APPENDIX A – ADDITIONAL DEMOGRAPHIC INFORMATION

I also considered first-generation status and sexuality in this study. Students identified their first-generation status within the *S-PIPS-M* survey by checking either yes, no, or prefer not to disclose in response to "Do you consider yourself to be: First-generation college student." Students identified their sexuality based on the statement "Do you consider yourself to be (Select all that apply)" with the option choices Asexual, Bisexual, Gay, Lesbian, Queer, Straight (Heterosexual), Not listed (please specify), and Prefer not to disclose. I applied Voigt's (2020) recategorization of these responses related to sexuality, where the additional category Straight+ refers to a selection of Straight (Heterosexual) and at least one other option and the category Queer+ refers to a selection of more than one option excluding Straight (Heterosexual). The tables below show the number of women of color in the dataset by first-generation status and sexuality.

Table A1 Women of color by first-generation status (n = 3293)

First-generation status	Frequency (Proportion)
Yes	1285 (0.390)
No/NA	2008 (0.610

Table A2 Women of color by sexuality (n = 3293)

Sexuality	Frequency (Proportion)
Asexual	81 (0.025)
Bisexual	208 (0.063)
Gay	8 (0.002)
Lesbian	41 (0.012)
Queer	16 (0.005)
Queer+	42 (0.013)
Straight	2718 (0.825)
Straight+	22 (0.007)
NA	157 (0.048)

APPENDIX B – SELECTED SURVEY QUESTIONS FOR PAPER 1

I selected the following 22 survey questions from the *S-PIPS-M* survey to use in Paper 1 based on Voigt's (2020) conceptualization of mathematical identity, which includes the three components within the table.

The question scales are as follows:

- Questions with a (D) represent statements within the survey section asking participants to "Indicate the degree to which the following statements describe your experience in [P2C2 course]" with the scale of (1) Does not occur, (2) Minimally descriptive, (3) Somewhat descriptive, (4) Mostly descriptive, and (5) Very descriptive.
- Questions with a (C) represent questions within the survey section asking participants to "Consider your regular course meetings of [P2C2 course] and primary instructor. As compared to other students in class…" with the scale of (1) A lot less than other students, (2) Somewhat less than other students, (3) The same as other students, (4) Somewhat more than other students, and (5) A lot more than other students.
- Questions with a (Q) represent statements within the survey section asking participants to "Please indicate your level of agreement for the following statements from the beginning of the course and now" with the scale (1) Strongly agree to (6) Strongly disagree for both Beginning of course and Now. For analysis, the responses to these questions are quantified as the numerical difference between the response for Beginning of course and Now for each participant.
- The question with an (E) represents a statement within the survey section asking participants "How would you describe the overall climate within [P2C2 course]?" with a scale from (1) Excluding and Hostile to (5) Including and Friendly.

Mathematical Identity Component from Voigt (2020)	Survey Questions
Component 1: Perceptions of ability and participation I refer back to Voigt (2020), where participation relates to "taking part in activities, interacting, negotiating, agreeing, disagreeing, formulating, and sense-making" (p. 29) within the mathematical environment. This aligns with survey questions 1, 2, 3, 5, 6, and 8. Perceived ability refers to students' perceptions of their own mathematics ability which aligns with survey questions 4, 7, 9, and 10.	1. I make connections between related ideas or concepts when completing assignments (D) 2. I talk with other students about course topics during class (D) 3. I constructively criticize other student's ideas during class (D) 4. I discuss the difficulties I have with math with other students during class (D) 5. I share my ideas (or my group's ideas) during whole class discussions (D) 6. How much opportunity do you get to answer questions in class? (C) 7. How much help do you get from your instructor? (C) 8. How much opportunity do you get to contribute to class discussions? (C) 9. I am confident in my mathematical abilities (Q) 10. I am able to learn mathematics (Q) 11. I am interested in mathematics (Q)
Component 2: Positionality and sense of belonging in mathematics Positionality and sense of belonging relate to students' perceptions of feeling accepted, valued, included, and encouraged in the mathematical space and self-identifying as a doer of mathematics. Thus, these survey questions capture students' perceptions of classroom community and inclusivity (questions 2 and 6) and their position as recognized from the instructor (questions 1, 3, 4, and 5).	1. The instructor knows my name (D) 2. There is a sense of community among the students in my class (D) 3. How much attention does the instructor give to your questions? (C) 4. How much encouragement do you receive from the instructor? (C) 5. How much praise does your work receive? (C) 6. Excluding and Hostile vs Including and Friendly (E)

Component 3: Identity resources such as institution or instructors These survey questions capture potential identity resources, including the institution (questions 3), the instructor (questions 1 and 5), and peers (questions 2 and 4).	1. I see my instructor(s) outside of class for help (D) 2. I work with peers outside of class on math problems (D) 3. I attend tutoring sessions outside of class time (D) 4. Class is structured to encourage peer-to-peer support among students (D) 5. My instructor uses strategies to encourage participation from a wide range of students (D)

APPENDIX C – FACTOR ITEMS AND COEFFICIENT WEIGHTS

The results from the factor analysis which produced four factors which I label mathematical identity subdomains: *Classroom experience, Inclusion/Positionality by instructor, Self-efficacy,* and *Mathematical peer interaction*.

Factor 1: Classroom Experience

Factor items from survey questions	Coefficient weight
I make connections between related ideas or concepts when completing assignments	0.509
I constructively criticize other student's ideas during class	0.326
I share by ideas (or my group's ideas) during whole class discussion	0.552
My instructor knows my name	0.560
Class is structured to encourage peer-to-peer support among students	0.556
There is a sense of community among the students in my class	0.678
Excluding and Hostile vs Including and Friendly	0.542
I see my instructor(s) outside of class for help	0.300
My instructor uses strategies to encourage participation from a wide range of students	0.860

Factor 2: Inclusion/Positionality by Instructor

Factor items from survey questions	Coefficient weight
How much opportunity do you get to answer questions in class?	0.643
How much attention does the instructor give to your questions?	0.790
How much help do you get from the instructor?	0.780
How much encouragement do you receive from the instructor?	0.818
How much opportunity do you get to contribute to class discussions?	0.773
How much praise does your work receive?	0.731

Factor 3: Self-Efficacy

Factor items from survey questions	Coefficient weight
I am confident in my mathematical abilities	0.924
I am able to learn mathematics	0.846
I am interested in mathematics	0.750

Factor 4: Mathematical Peer Interaction

Factor items from survey questions	Coefficient weight
I talk with other students about course topics during class	0.735
I discuss the difficulties I have with math with other students during class	0.867
I work with Peers outside of class on math problems	0.535
I constructively criticize other student's ideas during class	0.324
I share by ideas (or my group's ideas) during whole class discussion	0.236
Class is structured to encourage peer-to-peer support among students	0.219
I attend tutoring sessions outside of class time	0.275

APPENDIX D – INTERVIEW PROTOCOL

The interviews were semi-structured and thus I adapted this interview protocol for each participant. This included removing questions, adding follow-up questions, and asking questions in a different order than listed.

Background info:

- So I see here you're a ________________________ major, very cool! Did you have a concentration or any minor with that?
  - Why did you choose to major in that?
- What were the (first and the last) math courses you took during your undergrad?
- Now, could you describe a typical math lesson you experienced from your undergrad (your most common style), what kinds of things did you do in class? What did the instructor do in class? Was there lecture, group work, discussion?
  - How did you feel during those lessons?
- What type of teaching style did you feel best supported you in undergraduate mathematics? In what ways did you feel supported? How frequently did you experience this type of teaching?
  - If not the most frequently, in what ways do you think the most frequent style of teaching supported or hindered you in mathematics?

Position within the field:

- What are some words you would use to describe mathematics?
- How would you describe society's image of mathematics and mathematicians? In what ways is this similar or different to your perception?
- Thinking back to undergrad, can you think of a time where you felt an instructor during your undergrad really recognized or acknowledged you as a mathematician or doer of mathematics?
  - Can you think of a time where you felt an instructor undermined or failed to recognize you as a mathematician or doer of mathematics?
- Could you provide an example, if any, where you felt your mathematics instructor cared about you as a person or you felt they cared about your learning personally?
- Similar question, but now think about your peers in undergrad. Can you think of a time where you felt a peer really recognized or acknowledged you as a mathematician or doer of mathematics?
  - Can you think of a time where you felt a peer undermined or failed to recognize you as a mathematician or doer of mathematics?
- How would you describe the mathematical community at your institution?

  - Were you part of this community?
    - If yes, what did this community feel like for you, what was your part in that community?
    - If not, why do you think you weren't part of that community?
      - What changes would you suggest that would have made that community more inclusive and supportive?
- In what ways did others, whether within this community or not, so this could include instructors, peers, family, coworkers etc. support you in your mathematics education?
  - Did you have a group of peers that you worked with on mathematics?
    - Were these peers friends outside of that setting? Were they part of your main social group?

Okay, now I'm going to ask you some questions related to ways your institution supported (or did not support) you in mathematics.

Identity resources:
Well start with extracurricular things:

- What extracurriculars or clubs, if any, were you involved in related to mathematics/STEM or helped support you in mathematics?
  - If **yes**, could you talk a little about how this involvement did or did not support you in mathematics?
  - If **no**, for what reason, if any, did you not participate in a STEM club?
- Did your institution/department provide any programs or clubs that you were aware of designed to support diversity, equity, or inclusion in Science Technology Engineering and Mathematics (STEM)?
  - If **yes**, were you part of this club/program? Why or why not?
  - If **no**, did you ever feel you wanted a club/program of this type? Why or why not?
- Were there other clubs/programs, maybe outside of STEM, that supported you in undergraduate mathematics?
- What type of mathematics tutoring, if any, did you experience during your undergrad? And this can include tutoring centers, private tutors, instructors, etc.
  - If **yes**, in what way did this tutoring support or not support you in mathematics, this could be academically, socially, emotionally, etc.?
  - If **no**, Was there any specific reason you didn't seek out tutoring?

Next we'll talk a little about your experience(s) in the classroom

- What type of teaching style did you feel best supported you in undergraduate mathematics? In what ways did you feel supported? How frequently did you experience this type of teaching?
  - If not the most frequently, in what ways do you think the most frequent style of teaching supported or hindered you in mathematics?

- In what ways do/did you notice your gender and/or race represented in the mathematics classroom? In your department?

Now we'll talk a little more generally about the institution or department

- In what ways did you feel your Institutional culture support and/or hinder you and your mathematics learning?
- In what ways did your institution or department support or hinder your mathematics experience in undergrad?
- In what ways do/did you notice your gender and/or race represented in the mathematics classroom? In your department?
- What would you have liked to see, if anything, within your institution or department in general to have supported or better supported you in mathematics?
- In what ways do you think institutions in general could better support women of color in mathematics?

Next we'll get into how you feel about mathematics and your mathematical abilities

Self-ability perception:

- To start, think about you now, after graduation. Finish the sentence "when I think about mathematics, I feel…"
    - Were these feelings always the same throughout undergrad?
- How would you describe your mathematical ability during and throughout undergrad?
- When you experienced a particularly difficult mathematical task, how did you go about overcoming that challenge?
- In what ways did you most commonly participate in your mathematics classes?
- How did your confidence as a mathematics learner develop over the course of your undergrad?
- How do you feel about learning or doing mathematics now? What makes you feel this way? Is this feeling different at all from your experience in undergrad?
- In what ways do you use mathematics now?
    - How do you feel completing those tasks?

Now just a couple questions about mathematical enjoyment

Enjoyment

- Could you describe a math topic, lesson, or anything in this area that you remember really enjoying during your undergrad?
    - Why do you think you enjoyed it so much?
- What part or parts of mathematics were most enjoyable for you in undergrad? Did this change at all throughout your undergrad? Is that still how you feel?
- In what ways do you think mathematics instructors could foster enjoyment in the mathematics classroom?

Okay, now these next few questions ask specifically about race and gender related to your math experience more generally
Social Identity questions:

- In what ways, if any, did your identity as a woman of color interact with your mathematical experiences in your undergrad?
- How do you feel women of color are encouraged or discouraged from pursuing mathematics?
- In what ways, if any, did other parts of your identity interact with your mathematical experiences in your undergrad?
- What advice would you give your younger self just as you were starting a STEM major?

Lastly, I'd like to ask you a wrap up question and then a fun question.

- Is there any question that you thought I might ask, but didn't, that you'd like to answer?
- Is there a preferred pseudonym you would like us to use for you within this work?

APPENDIX E – INTEREST SURVEY

The interest survey sent to women of color respondents to the *S-PIPS-M* survey that consented to future contact.

Q1 Thank you for your interest in this study!

My name is Ciera and I am a researcher from Colorado State University in the Mathematics department. We are conducting a research study examining the unique and various ways women of color identify with mathematics and relate to their mathematics education. The title of our project is Investigating Women of Color's Expressions of Mathematical Identity: The Role of the Institution and Connections to Mathematical Enjoyment. The Principal Investigator is Dr. Jessica Ellis Hagman and I am the Co-Principal Investigator.

We would like you to take an online interest survey. Participation will take approximately 15 minutes. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty. We will be collecting your name, email address, institution, and demographic information. This information will only be retained if you qualify and are selected for the study, otherwise it will be deleted. If selected, when we report and share the data to others, we will use pseudonyms for any identifiable information (e.g. name, institution). We will keep your data confidential; your name and data will be kept separately in a password protected folder within a secure cloud server accessible only to the research team.

There are no known direct benefits to you, but your participation in this study may positively impact future women of color in undergraduate mathematics by helping inform institutions ways in which they can more fully support women of color in mathematics. If selected, you will receive $100 for participating in this study.

It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential (but unknown) risks.

If you have any questions about the research, please contact me at ciera.street@colostate.edu or Dr. Jessica Ellis Hagman at jess.ellis@colostate.edu If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970-491-1553.

Please indicate your consent to participate in this survey below and click the next arrow. If you choose to participate, you will be taken to the rest of the survey.

○ I understand and consent to participate. (1)

○ I do not wish to participate. (2)

Skip To: End of Survey If Q1 = I do not wish to participate.

Q2 To participate in this study, you must be at least 18 years old. Are you at least 18 years old?

○ Yes (1)

○ No (2)

Skip To: End of Survey If Q2 = No

End of Block: Default Question Block

Start of Block: Block 2

Name Welcome to the beginning of the survey! First, please fill out the following.

○ Name (1) ____

○ Pronouns (5) ____

○ Email (2) ____

○ Undergraduate Institution (3) ____

○ Major (4) ____

Page Break

Q6 The next few questions focus on demographic information. This is intended to help our research team to better understand the variety of experiences at your institution and identify more ways in which institutions can support their students. This information will be kept confidential and used anonymously. If for any question you do not feel comfortable sharing this information, please leave the response box blank.

What is your gender identity?

____

Page Break

Q7 What is/are your racial and/or ethnic identity(ies)?

____

End of Block: Block 2

Start of Block: Block 2

Current The next section includes questions related to your undergraduate experiences in mathematics. Many of the following questions include space to expand upon your response. Please write as much as you would like, although you are also welcome to write brief responses of 1-2 sentences.

Are you currently completing an undergraduate degree?

- ○ Yes (1)
- ○ No (2)

End of Block: Block 2

Start of Block: Block 3

Display This Question:

If Current = Yes

Q10 Do you recognize yourself as a "math person"?

○ Yes (1)

○ Sometimes (2)

○ No (3)

Display This Question:

If Current = Yes

Q13 Why or why not?

____

____

____

____

____

Page Break

Display This Question:

If Current = Yes

Q14 Do you believe others (peers, faculty, etc.) recognize you as a "math person"?

○ Yes (1)

○ Sometimes (2)

○ No (3)

Display This Question:

If Current = Yes

Q15 Why or why not?

____

____

____

____

____

Page Break

Q16 Do you feel included in a mathematics community at college?

- ◯ Yes (1)
- ◯ Sometimes (3)
- ◯ No (2)

Q17 Why or why not?

____

____

____

____

____

Display This Question:

If Q16 = Yes

Or Q16 = Sometimes

Q18 Did you feel supported within this community?

○ Yes (1)

○ Sometimes (2)

○ No (3)

Display This Question:

If Q16 = Yes

Or Q16 = Sometimes

Q19 Please describe this community you are a part of and how it supports or does not support you as a mathematics student.

____

____

____

____

____

Page Break

Q20 Do you feel supported as a mathematics student by your institution/department?

○ Yes (1)

○ Sometimes (2)

○ No (3)

Q21 In what ways do you feel supported and/or not supported as a mathematics student by your particular institution/department?

____

____

____

____

____

Page Break

Q22 Do you believe your gender and/or race interacts with your experience as a mathematics student?

- Yes (1)
- Sometimes (2)
- No (3)

Display This Question:

If Q22 = Yes

Or Q22 = Sometimes

Q23 In what ways do you believe your gender and/or race interacts with your experience as a mathematics student?

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End of Block: Block 3

Start of Block: Block 5

Q25 During college, did you consider yourself a "math person"?

◯ Yes (1)

◯ Sometimes (2)

◯ No (3)

Q26 Why or why not?

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Page Break

Q27 During college, do you believe others (peers, faculty, etc.) recognized you as a "math person"?

◯ Yes (1)

◯ Sometimes (2)

◯ No (3)

Q28 Why or why not?

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Page Break

Q29 Did you feel included in a mathematics community during college?

○ Yes (1)

○ Sometimes (2)

○ No (3)

Q30 Why or why not?

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Display This Question:

If Q29 = Yes

Or Q29 = Sometimes

Q31 Did you feel supported within this community?

- Yes (1)
- Sometimes (2)
- No (3)

Display This Question:

If Q29 = Yes

Or Q29 = Sometimes

Q32 Please describe this community you were a part of and how it supported or did not support you as a mathematics student.

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Page Break

Q33 Did you feel supported as a mathematics student by your institution/department?

- Yes (1)
- Sometimes (2)
- No (3)

Q34 In what ways did you feel supported and/or not supported as a mathematics student by your particular institution/department?

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Page Break

Q35 Do you believe your gender and/or race interacted with your experience as a mathematics student?

○ Yes (1)

○ Sometimes (2)

○ No (3)

Display This Question:

If Q35 = Yes

Or Q35 = Sometimes

Q36 In what ways do you believe your gender and/or race interacted with your experience as a mathematics student?

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End of Block: Block 5

Start of Block: Block 4

Q24 Are you able to engage in the following research activities this semester?
- Participate in an individual, virtual interview lasting between 60 and 90 minutes
- Write a brief (1-2 page) reflection on your mathematical experience
- Provide optional follow-up feedback on our interpretation of your data

○ Yes (1)

○ No (2)

End of Block: Block 4