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Pathways in Engineering: Identifying Hidden Barriers to Graduate School for Undergraduate Engineering Students

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Introduction

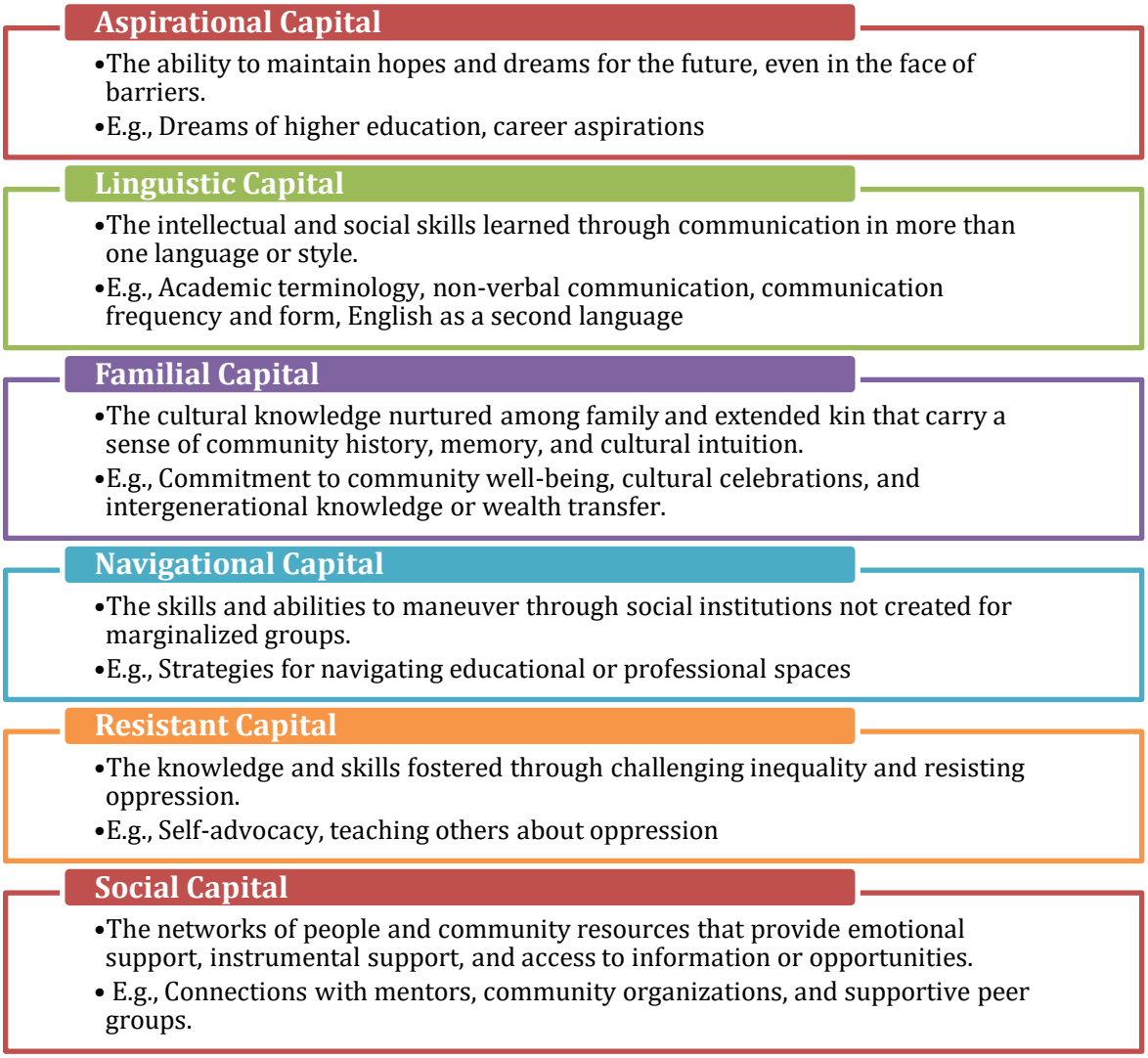
Students underrepresented in STEM research and graduate education face persistent barriers to participation, yet they also bring valuable assets that often go unrecognized in traditional academic structures. Using Yosso's Community Cultural Wealth (CCW) framework [1], this study explores how underrepresented students at a Hispanic-serving, majority-minority R1 public institution navigate these barriers and leverage forms of familial, aspirational, navigational, and resistant capital to shape their academic and career pathways. By focusing on existing mentorship, career clarity, and the intersection of identity and belonging, we offer novel insights into the systemic challenges these students encounter and the strategies they employ to succeed. This work contributes to the growing body of research in STEM education by highlighting actionable practices that institutions can adopt to better support underrepresented students, ultimately fostering a more empowered pipeline to STEM research careers.

Background and Related Work

The persistence of underrepresented undergraduate students in research and graduate pathways remains a pressing issue in higher education. The Community Cultural Wealth (CCW) framework, proposed by Yosso [1], provides an assets-based lens to explore how students from marginalized communities leverage familial, aspirational, social, navigational, linguistic, and resistant capital to overcome systemic barriers. Familial capital reflects the cultural knowledge and support drawn from family and community networks. Aspirational capital represents the ability to maintain hope and envision a brighter future despite challenges. Social capital includes the networks and relationships that provide access to resources and opportunities, while navigational capital refers to the skills needed to maneuver through institutions not designed for marginalized communities. Linguistic capital highlights the unique communication skills and multilingual abilities that enrich a student's experience. Lastly, resistant capital represents the knowledge and resilience developed through confronting and challenging inequities. Figure 1 displays an overview of the different forms of capital.

These interconnected forms of capital provide students with emotional support, resilience, and strategies to navigate institutional structures, ultimately shaping their persistence, research involvement, and graduate school aspirations. These assets notably include forms of capital—such as familial, social, and aspirational—that often go unrecognized within traditional academic structures. By examining these forms of capital, scholars have illuminated the ways in which students leverage their cultural strengths to navigate systemic barriers. While all of these factors—familial, aspirational, social, navigational, linguistic, and resistant—have demonstrated impacts on the success of undergraduate STEM students [2], [3], [4], [5], our work is particularly focused on familial, aspiration, navigational, and resistant factors based on our discussions with undergraduate STEM students.

Figure 1: Overview of Forms of Community Cultural Wealth, Including Definitions and Examples of Each Form of Capital



This section explores literature relevant to themes identified through focus groups conducted with underrepresented undergraduate students. These themes—familial support, mentorship, identity, and skill-building—are examined within the broader context of existing scholarship. While the findings of the focus groups serve as a point of connection, this review aims to situate these themes within the larger body of knowledge on student experiences in higher education, providing a foundation for understanding their implications for research engagement and graduate aspirations.

Familial Encouragement and Aspirations

Within the CCW framework, familial capital refers to the cultural knowledge and resilience that students gain through their family connections and support. Families often play a pivotal role in

fostering academic persistence and ambition, particularly for underrepresented students [6], [7], [8], [9], [10], [11], [12]. Research has consistently demonstrated that familial encouragement—whether through emotional, logistical, or financial support—positively influences students' educational trajectories. For example, Latinx engineering students have been shown to persist more often in the face of expressive support from family and close friends [12].

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However, not all forms of familial support are uniformly experienced or valued. Some families may emphasize non-academic contributions to the household, creating tensions for students balancing familial obligations with academic aspirations [14], [15]. This variability underscores the importance of understanding familial support as a dynamic and context-dependent factor. Despite these complexities, the literature highlights familial encouragement as a cornerstone of student success, offering both emotional resilience and practical guidance for navigating higher education.

Early Mentorship and Career Clarity

Early mentorship is instrumental in shaping students' academic and career trajectories, particularly for those from underrepresented backgrounds. Mentorship during primary and secondary education can provide critical exposure to career pathways, fostering clarity and confidence in long-term goals [16]. Effective mentors help students identify opportunities, navigate barriers, and build the skills necessary for success in higher education. As one example of the barriers to career clarity, research engagement is a critical component of academic and professional development, yet underrepresented students often face significant barriers to participation. These barriers include a lack of awareness about research opportunities, insufficient institutional support, and limited access to faculty mentors [2]. Early exposure to research is particularly important, as it fosters clarity on research as a career pathway.

The transition to college often marks a decline in the continuity of mentorship for underrepresented students. Studies have shown that these students frequently encounter limited access to faculty mentors, compounded by unclear pathways to research involvement [2]. This gap highlights a systemic issue: while mentorship is widely recognized as essential, institutional structures often fail to ensure equitable access, leaving many students without the guidance needed to fully realize their potential.

Identity and Belonging

Identity plays a complex and multifaceted role in shaping students' academic experiences. For some students, navigating identity-related challenges can significantly impact their sense of belonging and willingness to engage in research [17]. These challenges often stem from systemic inequities, including microaggressions, implicit biases, and institutional climates that fail to affirm diverse identities. However, not all students experience identity-related challenges in the same way [18]. This variability highlights the need for institutions to create inclusive environments that affirm diverse identities and actively address barriers to belonging.

Building Communication and Networking Skills

Communication and networking skills are vital for navigating academic and professional environments, particularly for students aspiring to graduate education. Within the CCW framework, these skills are often linked to social capital, which encompasses the networks and relationships that facilitate access to resources and opportunities [1]. Studies have found that students who actively engage in activities that enhance their communication and networking skills are better equipped to navigate research environments and build professional relationships [19].

Co-curricular activities, such as internships, student organizations, and professional development workshops, play a crucial role in fostering these skills. However, access to such opportunities is often inequitable, with systemic barriers disproportionately affecting underrepresented students [2]. Addressing these inequities requires intentional efforts to ensure that all students have access to the resources and support needed to succeed.

The literature highlights the critical role of various forms of capital, mentorship, identity, and skill-building in shaping the academic and career trajectories of underrepresented students in STEM. Drawing on the Community Cultural Wealth (CCW) framework, researchers have underscored how familial, aspirational, navigational, and resistant capital enable students to navigate systemic barriers and pursue their goals. Familial encouragement emerges as a cornerstone of student success, providing emotional and practical support, though its impact can vary based on context. Similarly, early mentorship fosters career clarity and research engagement but remains inequitably distributed, often limiting access for underrepresented students. Identity-related challenges further complicate students' experiences, influencing their sense of belonging and engagement in academic spaces. Finally, the development of communication and networking skills plays a vital role in facilitating access to research opportunities and professional pathways, though systemic barriers continue to restrict equitable participation.

Building on these findings, this study uses focus groups with STEM students that have underrepresented racial identities at a Hispanic-serving institution to explore how these themes manifest in their academic experiences and aspirations. The subsequent sections detail the methodology, initial findings, and implications for fostering equity in STEM education and graduate pathways.

Methodology

This study explores the academic and career decision-making processes of underrepresented undergraduate students in STEM disciplines at a major, public R1 institution, specifically a Hispanic-serving institution with a majority minority student population. Our focus includes a broad range of underrepresented students, with a particular interest in identifying barriers and facilitators to their participation in graduate education and STEM careers.

Participants were recruited from the undergraduate STEM population at the University of New Mexico using email invitations, campus flyers, and direct recruitment by instructors. Recruitment materials highlighted the study's focus on students from underrepresented backgrounds in STEM and included clear instructions for participation. Informed consent was obtained verbally at the start of the focus group session, following participants' review of the consent form.

To date, one focus group session has been conducted, consisting of two African American, freshman undergraduate students. Participants self-identified as members of underrepresented groups in STEM, representing different disciplines. It is worth noting that both students reported familial and social capital, thus likely representing near ideal outliers for understanding institutional deficiencies given their existing capital prior to entering higher education helped them overcome barriers other students may not have.

The focus group was conducted in-person in a reserved meeting room. The session lasted approximately 65 minutes and was moderated using a semi-structured discussion guide designed to elicit insights into participants' educational experiences, perceptions of support systems, and future educational and career aspirations in STEM. A list of questions asked is available in Table 1. Discussions were audio-recorded to ensure accurate data capture, and detailed notes were taken by a member of the research team during the session. Audio recordings were transcribed verbatim and anonymized to protect participant confidentiality. All identifiers were removed during transcription to ensure participants' privacy.

Table 1: Deductive Codes and Their Associated Explanations and Focus Group Questions

Code	Explanation	Focus Group Questions
Aspirational Capital	Reflects the motivation, dreams, and long-term goals that drive students to succeed despite systemic barriers.	- What were your initial thoughts on entering a STEM field as an undergraduate?
		- Why did you select your particular field?
		- What are the most critical factors influencing your future career and educational decisions?
Linguistic Capital	Refers to the abilities and cultural knowledge that students develop through communication, storytelling, and multilingualism.	- How does your personal identity intersect with your experience in engineering?

Familial Capital	Captures the emotional, logistical, and cultural support provided by family and community.	- How have your cultural values and community connections impacted your career aspirations?
Navigational Capital	Refers to students' ability to maneuver through institutional systems and overcome structural challenges.	- Why did you select your particular field?
		- How aware are you of the research experiences available on campus?
		- What support or resources have been most helpful for you in your undergraduate program?
Resistant Capital	Represents the strategies students use to challenge and resist systemic inequities and biases.	- How does your personal identity intersect with your experience in engineering?
Social Capital	Encompasses the networks and relationships that provide access to resources and opportunities.	- How aware are you of the research experiences available on campus?
		- What support or resources have been most helpful for you in your undergraduate program?

Data analysis followed a thematic approach, combining deductive and inductive coding strategies to identify key patterns and themes in the data. Deductive codes were drawn from the research questions and grounded in Yosso's CCW framework, which emphasizes the various forms of capital underrepresented students leverage to navigate systemic barriers. These codes provided a structured foundation for the analysis, ensuring alignment with the study's theoretical framework. Inductive codes, on the other hand, emerged during the initial review of the focus group transcripts, allowing for the identification of unanticipated themes or patterns unique to participants' experiences.

This dual coding approach enables a nuanced exploration of how underrepresented students experience STEM pathways, drawing on both predefined categories and participant-driven insights. While this initial focus group session offers valuable preliminary findings, the small sample size limits the generalizability of results. Future focus groups will aim to include a broader participant base, offering a more comprehensive understanding of the challenges and opportunities these students encounter. The deductive codes used in the analysis, along with their definitions and corresponding focus group questions, are summarized in Table 1.

Results

This study investigates how underrepresented students in STEM leverage different forms of capital to navigate their educational pathways. Through deductive and inductive coding, we identified two primary themes, aspirational capital and familial capital, as central to the students' persistence and goals. Additionally, inductive analysis revealed emergent themes of reliance on external capital and a significant gap in institutional support for first-year students.

Aspirational Capital

Aspirational capital, which encompasses students' long-term goals and intrinsic motivation to succeed, was a dominant theme across participants. Students articulated a strong sense of purpose, often tied to clear career objectives and a desire for financial stability. For example, one participant shared:

> *"I knew I wanted to be financially stable in the future… I found anesthesiology really interesting after looking into it, and it's something I've been focused on since fifth grade."*

Similarly, another participant described early formative experiences in middle school that solidified their passion for engineering:

> *"I've wanted to be a mechanical engineer ever since middle school… building a submarine out of PVC pipe and wiring during a robotics competition made me fall in love with the subject."*

For these participants, their aspirations were shaped by early exposure to specific career paths, which motivated them to pursue rigorous academic goals. However, the data suggest that this aspirational capital stems predominantly from personal experiences and external influences rather than institutional engagement or support. This reliance on non-institutional factors raises questions about the role of universities in fostering and sustaining students' long-term motivations.

Linguistic Capital

Linguistic capital refers to the abilities and cultural knowledge that students develop through communication, storytelling, and multilingualism. Although not explicitly a focus of the participants' responses, elements of linguistic capital can be inferred from their emphasis on communication skills and their reflections on interpersonal dynamics.

One participant highlighted the importance of reading non-verbal cues and developing advanced communication skills, especially in professional contexts:

> *"You kind of learn how to read whether they're really being genuine or… being sarcastic. I think that kind of gets you further in the world because… you have to communicate."*

This insight reflects the participant's ability to adapt to complex social and professional environments, leveraging their linguistic capital to navigate interactions effectively. Such skills are vital in STEM fields, where collaboration and interdisciplinary work often require nuanced communication.

Additionally, participants discussed how group projects and peer interactions in their academic environments fostered a sense of connection and engagement, further cultivating their communication abilities:

> *"Studying with one another is fun. It's how you build connections… it makes it easier to learn or take interest in your major."*

These reflections suggest that linguistic capital plays a role in facilitating both academic success and a sense of belonging, as students use their communication skills to build networks, access resources, and enhance their learning experiences. While linguistic capital was not directly discussed in the context of multilingualism, the participants' stories emphasize the value of interpersonal communication as a bridge to professional growth and personal resilience.

Familial Capital

Familial capital emerged as a crucial support system for participants, providing emotional, financial, and logistical assistance. Families were portrayed as foundational to students' persistence, often stepping in to address gaps in institutional support. One participant reflected on the encouragement they received from their family:

> *"My dad sent me a message today: 'You're in the home stretch. Get plenty of rest. Do your best on the assignments.' They've been pressuring me all through high school, but it's gotten me here."*

Another participant emphasized the collective nature of their family's support:

> *"My family's been a huge factor… we've created a group connection, with cousins and aunts all in college at the same time, supporting each other through this process."*

Financial contributions from family also played a significant role in facilitating participants' transitions to college. One participant recounted:

> *"I received $7,000 during my graduation party… it was the first time I cried over how much my family values education."*

This level of familial engagement underscores its importance as a form of external capital that bridges gaps in institutional resources. However, both participants high levels of familial capital also highlight how the deficiencies in institutional assistance

Resistant Capital

Resistant capital, reflecting students' strategies for challenging systemic barriers, was evident in participants' reflections on identity and resilience. One participant, a Black LGBTQ woman, shared how her identity shaped her experiences in STEM:

"Being a Black woman in STEM, especially LGBTQ and masculine presenting, has its challenges… but going through those challenges strengthens you as a person."

She elaborated on how connections with peers of similar backgrounds provided strength and solidarity:

"The connections I've built with people of color have been really strong because they've had personal experiences… those experiences strengthened me as a person."

These comments highlight the dual nature of resistant capital: while systemic inequities pose significant obstacles, they also foster resilience and empowerment through shared experiences and solidarity among marginalized groups.

Furthermore, a *notable* portion of participants did not directly mention systemic barriers at all. This absence could indicate either a lack of awareness about systemic inequities or a tendency to normalize such challenges as part of their lived experience. It is also possible that the participants' focus on external support systems, such as family and mentors, has overshadowed a direct acknowledgment of institutional barriers, suggesting a gap in institutional accountability for addressing inequities.

Navigational Capital

Navigational capital, or the ability to maneuver through institutional structures, emerged as an area of struggle for participants during their first semester. Many expressed uncertainty about accessing resources and opportunities, such as research programs. One freshman participant reflected on this challenge:

"I've seen emails about research groups, but I haven't joined yet. I'm still learning about the campus and how things work."

Similarly, another freshman participant described a lack of institutional guidance:

"I haven't found anyone here like the mentors I had in high school… My old teacher is still checking in on me, but on campus? Not yet."

These quotes illustrate how participants are still developing the skills and knowledge necessary to navigate the university environment, underscoring the need for institutions to provide clearer pathways and support during the first year.

Social Capital

Social capital, which includes the networks and relationships that provide access to resources and opportunities, was underdeveloped among participants during their first year at the institution. While students expressed an awareness of its importance, much of the social capital they

described stemmed from pre-college experiences rather than interactions within the university environment.

For example, one participant shared the lasting impact of a middle school teacher who introduced them to engineering:

> *"My teacher in middle school inspired me to pursue engineering. Without him, I wouldn't have known where to start… he really set me on this path."*

On campus, however, participants found it difficult to establish similar relationships. For instance, a participant explained:

> *"I haven't met many faculty or staff in person… most of my interactions have been online or administrative."*

Peer networks were identified as a potential source of social capital, particularly through group projects. However, those connections remain largely nascent and are chiefly with fellow students. One participant remarked:

> *"Studying with one another is fun. It's how you build connections, and it makes it easier to take interest in your major."*

These findings suggest that while participants value social capital and recognize its importance, the institution has not provided sufficient opportunities for them to cultivate meaningful relationships with faculty, staff, or peers. This lack of structured social integration may hinder students' ability to access the resources and guidance necessary for academic and professional development.

Reliance on External Capital

An inductive theme that emerged from the data was participants' reliance on external sources of capital—family and pre-college networks—to navigate their early college experiences. This reliance highlights the limited role of the institution in providing transitional support for first-year students. For example, one participant described their initial difficulty navigating and using campus resources:

> *"I've seen emails about research groups, but I haven't joined yet. I'm still learning about the campus and how things work."*

Similarly, another participant noted the absence of mentorship opportunities on campus:

> *"I haven't found anyone here like the mentors I had in high school. My old teacher is still checking in on me, but on campus? Not yet."*

These quotes illustrate how external networks, rather than institutional resources, are currently sustaining students through their early college transitions.

Institutional Gaps in Support

Participants frequently contrasted the supportive environments they experienced in high school and earlier with the lack of institutional guidance during their first semester. One participant reflected on the impact of their middle school teacher:

> *"My teacher in middle school inspired me to pursue engineering. Without him, I wouldn't have known where to start… but here, it's different. I haven't met many faculty or staff in person."*

The absence of institutional mentorship and accessible resources creates a gap that forces students to rely on external support. Another participant highlighted this disparity:

> *"My family is the reason I'm still here. The school hasn't really helped much yet."*

This lack of early engagement risks leaving students disconnected from institutional opportunities, such as research experiences and professional development. Participants reported little to no awareness of campus research opportunities and indicated that they had not yet accessed meaningful institutional mentorship or guidance. As one participant explained:

> *"I'm just trying to settle in, but I haven't had the chance to get into [research opportunities] before."*

Emergent Themes of Identity and Belonging

An additional theme that surfaced during inductive coding was the role of identity in shaping participants' experiences in STEM. For example, one participant described the intersection of their racial, gender, and sexual identity with their experiences in engineering:

> *"Being a Black woman in STEM, especially LGBTQ and masculine presenting, has its challenges… but it's been a learning experience."*

This participant also highlighted the resilience required to navigate systemic biases:

> *"It's not fun to be judged by the color of your skin or what you wear… but going through those challenges strengthens you as a person."*

These insights reveal the complex ways in which identity and systemic barriers intersect, influencing students' sense of belonging and persistence.

Discussion

This study provides valuable insights into how students underrepresented in STEM leverage various forms of capital—familial, aspirational, navigational, resistant, and social—within the framework of Yosso's Community Cultural Wealth [1]. The findings highlight both the strengths and vulnerabilities of these students as they navigate their academic pathways at a Hispanic-serving R1 institution. Notably, participants demonstrated a strong reliance on familial and aspirational capital while expressing significant challenges in building navigational and social capital within the university environment. These findings underscore critical gaps in institutional support and point to opportunities for targeted interventions.

Aspirational and Familial Capital as Pillars of Success

Aspirational and familial capital emerged as dominant themes, reflecting the resilience and motivation students derive from their personal goals and family networks. Participants articulated clear career aspirations, often tied to financial stability and long-term success. Early exposure to STEM fields, facilitated by family and pre-college mentors, played a pivotal role in shaping these aspirations. Familial capital, in particular, provided emotional and financial support that sustained students through the challenges of transitioning to college. For example, participants frequently referenced the encouragement of family members and the tangible contributions of extended family networks. These findings align with prior research on the critical role of familial encouragement in fostering persistence among underrepresented students [6], [8].

However, the reliance on familial and aspirational capital also underscores an institutional gap. This is further evident given the participating students were notably high in both forms of capital, implying lack of institutional support or social capital investment is likely larger for students who lack adequate social and familial capital prior to starting their undergraduate journey. While these forms of external capital are vital, they are not substitutes for robust institutional support. Universities must recognize the value of these assets and create environments that build upon them, providing complementary resources to further empower students.

Challenges in Navigating Institutional Structures

Navigational capital was less developed among participants, with many expressing uncertainties about how to access resources such as research opportunities and mentorship. This challenge was particularly pronounced among first-year students, who noted the absence of structured guidance and accessible institutional pathways. Participants compared their current experiences with the supportive environments they encountered in high school, where mentorship and clear academic pathways were more readily available. This lack of navigational capital risks leaving students underprepared to take full advantage of the opportunities available at a research-intensive institution.

The findings suggest that universities need to proactively facilitate the development of navigational capital, particularly for first-year students. Strategies such as structured onboarding programs, faculty-student mentorship initiatives, and clearer communication of research opportunities can help bridge this gap.

The Role of Identity and Resilience

Resistant capital emerged through participants' reflections on their identities and experiences with systemic inequities. One participant, a Black LGBTQ woman, highlighted the dual role of identity as both a source of challenge and empowerment. Connections with peers who shared similar backgrounds provided solidarity and strength, illustrating the importance of peer networks in fostering resilience. However, the absence of explicit acknowledgment of systemic barriers by other participants raises questions about whether these challenges are being normalized or inadequately addressed by institutional structures.

Universities must acknowledge and address the systemic inequities that underrepresented students face. Creating inclusive environments where students feel safe discussing their experiences is crucial for fostering a sense of belonging and empowerment.

Limitations

This study's findings are limited by the small sample size, as they are based on a single focus group with two participants. While their experiences provide valuable preliminary insights, they cannot be generalized to the broader population of underrepresented STEM students, especially those with different identities and backgrounds. The data reflect the perspectives of two first-year students at an early stage in their academic journeys, leaving questions about how these experiences may vary across the student population or even change over time.

Additionally, the reliance on self-reported data in a group setting may not fully capture the complexities of participants' experiences, particularly regarding sensitive topics like systemic barriers and identity. A larger and more diverse sample is necessary to ensure that findings reflect a wider range of perspectives and are applicable to other underrepresented student populations.

While the study identifies gaps in institutional support, it does not delve deeply into the specific policies, practices, or structural factors that contribute to these deficiencies. For instance, the study highlights a lack of mentorship opportunities and guidance for first-year students but does not examine the broader institutional strategies or resource allocations that might explain these gaps. Future research could include interviews with faculty, staff, and administrators to better understand the institutional context and identify actionable solutions.

Conclusion

This study highlights the multifaceted challenges and opportunities that underrepresented students in STEM encounter during their academic journeys. Aspirational and familial capital

play pivotal roles in sustaining students' persistence and motivation, but the institution's failure to provide sufficient navigational and social capital limits their ability to fully engage with available opportunities. Furthermore, participants' reliance on external support systems underscores the need for universities to take a more active role in fostering student development.

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