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Sticking with STEM: Who Comes, Who Stays, Who Goes, and Why?

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Leveraging Cultural Wealth, Identities and Motivation: How Diverse Intersectional Groups of Low-Income Undergraduate STEM Students Persist in Collegiate STEM Environments

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Abstract: Grounded in a conceptual framework incorporating intersectionality, motivation, self-determination, and self-efficacy, this empirical study investigated how individuals' identities, mindsets, and resources in educational environments intentionally cultivated to support their decision-making, development, and connections in the science community, can significantly increase the recruitment, persistence, and success of low-income, academically talented science students from diverse backgrounds. Several factors—academic performance in coursework, self-image, self-agency, financial support, and social integration in the science culture—continue to significantly impact student retention and persistence in STEM disciplines. Many of these factors are negatively affected based on a students' intersecting identities, which can be detrimental to their academic success if not addressed. We found that additional considerations to factor in concerning low-income students from diverse backgrounds that is pertinent to supporting their persistence and success in the postsecondary STEM educational context.

Keywords: low-income students; intersectionality; motivation; self-efficacy; self-determination; social agency; higher education; STEM education

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1. Introduction

The national goal of increasing the proportion of students from diverse low-income families succeeding in science, technology, engineering, and mathematics (STEM) education and research enterprise remains paramount to advancing STEM fields in the United States. However, more than simply having the opportunity to engage in postsecondary STEM education is required. Students must consider the costs and the resources needed to enroll and persist in postsecondary education. According to The National Postsecondary Student Aid Study, there are many equity gaps in postsecondary education, including with regard to students from low-income households [1]. Many college aspirants, particularly individuals from low-income families, identified lack of sufficient financial resources as one of the most significant hurdles affecting their ability to pursue postsecondary education. Further, statistics show that approximately 43% of students from all racial and ethnic groups identified as low-income [1]. In particular, students identifying as Hispanic, Black, and American Indian or Alaska Native had the highest numbers identifying as low-income at 52.9, 54 and 59.8 percent, respectively. These jarring statistics affirmed by existing studies illuminate the truth that educational journeys and social mobility attainment can vary significantly by race, ethnicity, gender, and financial resources for various student groups [2–4]. Students from low-income backgrounds and who identify as Black or Hispanic are more likely to leave college without obtaining a credential compared to their White and Asian counterparts.

Layered with the context of socioeconomic status impacting educational attainment, the continued trend of underrepresentation of individuals from diverse racial and ethnic backgrounds in certain career fields continues to bring into focus the layered challenges impacting these groups. In particular, science, technology, engineering, and mathematics (STEM) disciplines show a continued trend of underrepresentation of women and individuals from diverse racial and ethnic backgrounds [5–7]. The 2023 Diversity and STEM report released by the National Center for Science and Engineering Statistics (NCSES) illuminated the disparities based on gender and race and ethnicity within the U.S. STEM workforce (see Figure 1) [8]. Certain racial and ethnic and gender groups are significantly underrepresented in specific STEM fields in science and engineering, while other groups are significantly overrepresented. For instance, women are significantly underrepresented in S&E occupations, which are typically jobs that require a bachelor's degree, in five major categories: (1) computer and mathematical scientists, (2) biological, agricultural, and environmental life scientists, (3) physical scientists, (4) social scientists, and (5) engineers. Women are overrepresented in S&E-related occupations, such as health care workers, S&E managers, S&E precollege teachers, technologists, and technicians, which are a subset of STEM occupations that require STEM skills and expertise, but are not classified in the five main S&E categories [8]. When investigating the statistics in Figure 1 through the lens of race and ethnicity, notably, white individuals represent over 60% of the S&E workforce in all occupation categories. In comparison, Black and Hispanic individuals represent between 8 and 10% of the S&E workforce, which is also a lower percentage than their representation in the general population. Such statistics and reports beg the question of why some groups are successful in some STEM occupations while others struggle to increase their representation. This concerning landscape assessment of science and engineering fields presents educational leaders with the task of evaluating the policies, values, pedagogies, and resource distribution in their institutional environments that continue to be inequitable against groups vulnerable to attrition.

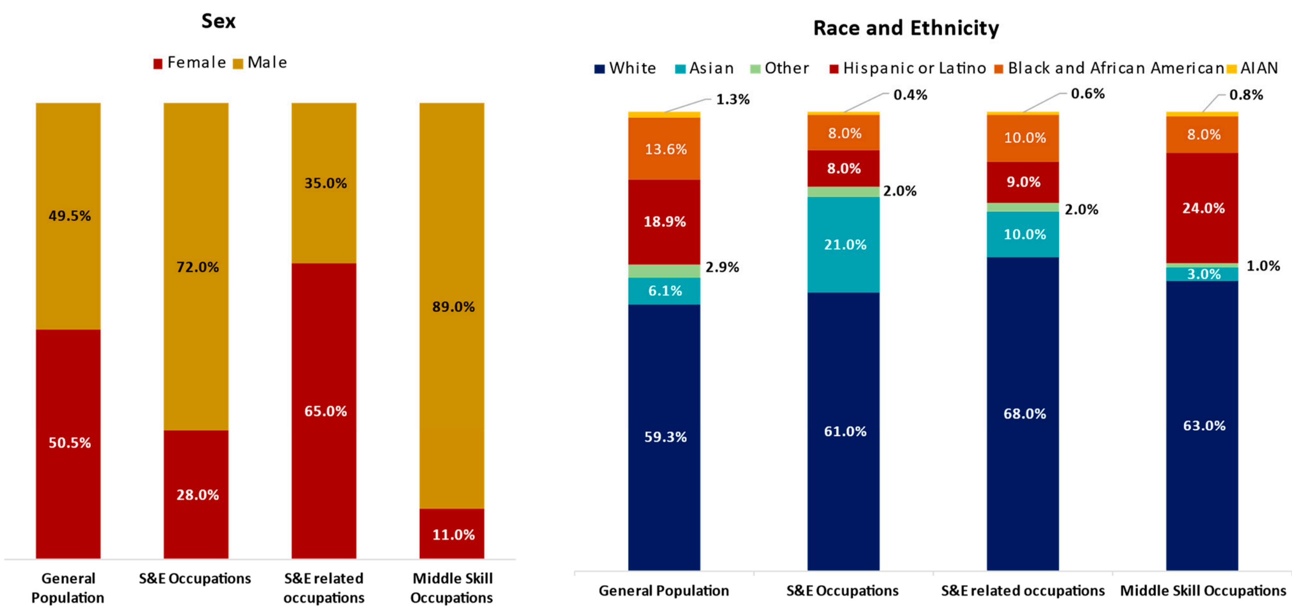

Figure 1. Characteristics of the U.S. STEM workforce ages 18–74, by occupation: 2021.

Earlier studies investigating the disparity between population groups and their participation in STEM disciplines identified several significant barriers to the participation of historically underrepresented groups in STEM fields, particularly a lack of a sense of belonging, a lack of science identity, and a lack of career pathways identified for the prescribed major [9–12]. However, a longstanding notion foundational to the discourse regarding the disparity between groups has perpetuated the view that the deficit depends solely on the student's abilities, without factoring in the role that STEM culture and environments can play in their access to resources and community. This traditional thinking and these attitudes towards understanding who participates in STEM and who exits STEM do not provide a complete picture of the educational experience of individuals from diverse backgrounds. Centering on the individual's knowledge and abilities without factoring in the systematic and structural powers at play severely underestimates the impact of the educational environment and the exclusionary undertones implied by traditional thinking and approaches to addressing these challenges [13,14].

In recent years, there has been an increase in empirical research studies and critical scholarship that has critiqued the traditional notions and dominant narratives of STEM culture. In particular, scholars have challenged the notion of the deficit solely lying with the individual and have provided substantial evidence that many of these challenges are perpetuated by systematic and structural policies, practices, and ideologies interwoven into the fabric of the STEM enterprise [15–19]. Further, scholars have posited that to broaden STEM participation for marginalized groups, we must critically disrupt the dominant STEM culture and narrative rooted in white and male dominance [20–22]. There are structural and systematic biases that preferentially encourage students from dominant groups and those who are well-resourced, i.e., in terms of finances, positions of power, and influence. Among the studies discussing the need for disrupting deficit discourses in STEM educational contexts, Castro has highlighted that many existing STEM recruitment and retention programs frame their targeted student population with deficit descriptions such as "underprepared" and "at risk" and typically focus solely on the student's deficit [15]. This study brings to light a critical, foundational step for educational equity, starting with challenging the language and labels we use to describe marginalized students. Like many others, this study shows how inequities are foundational and interwoven in educational contexts and must be redressed to support all students interested in pursuing a career in STEM.

Throughout the higher education literature centered on STEM disciplines, scholars have shown that science identity, sense of belonging, access to role models and mentors, social capital and agency, and other factors contribute to undergraduate success and the development of a science identity [9,23–29]. Within STEM disciplines, it is increasingly critical to acknowledge the importance of cultivating educational spaces that promote inclusivity for all individuals, particularly persons that have traditionally been excluded. These studies suggest that meaningful interventions can support the persistence of students with talent and the motivation to learn science. Scholars have urged application of the collective power of the STEM faculty and education discipline researchers to work together to advance the STEM enterprise. Within the discourse on collaboration and change for STEM education, Wilson-Kennedy underscores that "the cultivation of talent in the STEM community belongs to and is the responsibility of the community. . . we must collectively work together to address systemic barriers" [30]. To support this scholarship and sense of belonging and to broaden participation in STEM fields, the National Science Foundation and many other federal, state, and non-profit organizations have offered their support, resources, and advocacy for investigating and improving the experiences of vulnerable populations to broaden their participation in the STEM enterprise, specifically examining the impact of the STEM culture on their persistence and graduation outcomes to shed light on the structural and systemic inequities stunting the growth of these populations [31,32].

The Present Study

Our study is centered on understanding how diverse intersectional groups of undergraduate students pursuing science and mathematics majors utilize and leverage their identities, mindsets, skills, agency, and resources in STEM environments to establish connections to their scientific community that encourage them to remain in their STEM field. The central research question guiding this study is: How do diverse intersectional groups of low-income undergraduate STEM students describe their experience navigating and persisting in their postsecondary STEM environment?

2. Conceptual Framework

Fundamentally, this empirical study investigates how an individual's identities, motivation and self-efficacy can be supported by intentionally reimagining STEM postsecondary spaces to foster a sense of belonging and to support science identity development for low-income populations and marginalized and historically excluded backgrounds. The conceptual framework utilized to situate this study was adapted from integrating intersectionality theory and three strands of motivation theory (self-determination theory, self-efficacy, and intrinsic and extrinsic motivation) (See Figure 2). Utilizing these theoretical underpinnings strengthens our ability to investigate and understand how diverse groups of low-income students leverage their identities, skillsets, and resources to develop their science identity and social agency in the scientific community. Further, we couple these theories to depict the positive impact of high-impact educational practices when situating an individual's abilities in environments that are intentionally designed to foster and support their science identity and social agency development.

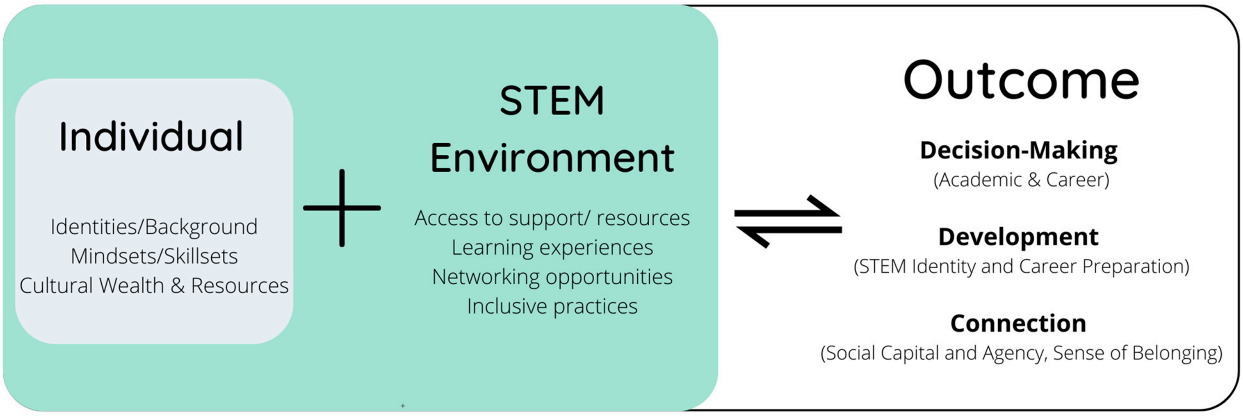

Figure 2. A Conceptual Model Integrating Individual and Environmental Conditions Necessary to Yield Desired Outcomes for Undergraduate Science Students.

The first element of the equation in the conceptual model focuses on the elements an individual possesses prior to entering the academic environment. In particular, this model highlights identities and background (demographic characteristics—race, ethnicity, gender, socioeconomic status, religious affiliation, first-generation status), mindsets and skillsets (motivation, self-efficacy, self-determination), and cultural wealth and resources. Salient to each individual is their unique background and identities, which, intertwined, shape their experiences—also known as intersectionality. Coined by Kimberly Crenshaw, mainly focusing on African American women, the term intersectionality was initially used to describe the combination of a person's social identities which overlap, interplay, and combine to produce different forms of oppression and empowerment [33,34]. Creshaw's work has since expanded to explore how individuals experience multiple oppressive forces based on their different, overlapping identities, such as class, race, gender, ability, sexual orientation, etc. This study of the interplay of overlapping identities enables us to better understand how to combat interwoven injustices in the human experience. In STEM education, intersectionality theory is used within research studies as a frame for understanding the complex lived experiences of individuals from marginalized groups in order to facilitate equity in education and the overall STEM enterprise [35–40].

Further, studies investigating power and oppression in social identities have shown that individuals from dominant identity groups seldom understand or are aware of the experiences of those individuals from marginalized identity groups [41–44]. Individuals in dominant groups can consciously or unconsciously invalidate the experiences of individuals from non-dominant groups due to a myriad of reasons, including inability to relate because of a lack of experience with oppression and lack of recognition of differences, among others. For instance, STEM fields such as engineering, physics, and the computer sciences have been known to be, and remain, traditionally white and male-dominated. Individuals from non-dominant groups, such as women and racial and ethnic marginalized groups, encounter numerous systematic and structural barriers when attempting to participate in such fields [45–48]. As such, our understanding of the human experience requires more thoughtful discussion and understanding of the complexities and intersections of power and oppression experienced by an individual, particularly in educational contexts that are often binary and traditional and do not always account for the nuanced nature of the human experience, which can severely discredit and inhibit their ability to persist.

In addition to the identities and backgrounds of individuals, this conceptual model brings into focus the mindsets and skillsets developed to support individuals' goals and aspirations. Our research utilizes three strands of motivation theory (self-determination theory, self-efficacy, and intrinsic and extrinsic motivation) as elements of our conceptual framework, particularly for its focus on understanding and centering the individual [28,49–52]. These elements provide a vital context for elevating the individual or student voice. Motivation in the dominant STEM culture is ascribed to individuals based on interpretations of persons in power. Our usage of motivation theory with cultural wealth disrupts traditional notions in disciplines and frames the student voice to highlight the goals, mindsets, and assets that students bring to their experiences in STEM.

Intrinsic and extrinsic motivation are established predictors of personal action [50,53–56]. Intrinsic motivation is doing an activity for its inherent satisfaction rather than for some separable consequence. As Deci and Ryan articulated, "when intrinsically motivated, a person is moved to act for the fun or challenge rather than because of external products, pressures, or rewards. . . in contrast, extrinsic motivation is a construct that pertains whenever an activity is done in order to attain some separable outcome" [53] (p. 56). Studies have shown that intrinsically motivated individuals are more likely to expend copious amounts of effort on an activity they enjoy, whereas extrinsically motivated individuals exert energy in a task or activity linearly according to what they perceive the return on investment will yield. While the perceived value gained differs, intrinsic and extrinsic motivation ultimately foster investment in the task at hand.

Self-determination theory (SDT) seeks to articulate the connection between motivation and one's ability to be self-determined. This broad framework presents a meta-theory of how social and cultural factors support or inhibit an individual's sense of initiative and volition. Existing research has posited that the highest quality forms of motivation and engagement are determined based on the individual's autonomy (the need to feel ownership of one's behavior), competence (the need to produce desired outcomes and to experience mastery), and relatedness (the need to feel connected to others) [50–52]. The optimal occurrence of these three conditions promotes an individual's creativity, persistence, and performance in an activity. For instance, research has shown that an individual's perceived competency in work-related activities increases their motivation and engagement [50,53].

Self-efficacy, a foundational element of theories of motivation, refers to an individual's belief in their own ability, knowledge, and skills to accomplish personal goals. Their self-efficacy is developed through personal performance accomplishments, vicarious learning, social influences, and physiological and affective states [54–56]. Studies have highlighted self-efficacy as a predictor of a student's motivation, engagement, and persistence in STEM scholarly activities [57–59].

The second element of the equation in the conceptual model is the collegiate and STEM environment context. In particular, the environment context highlights the role that learning experiences, opportunities to build community with peers, knowledge and access to resources, and inclusive STEM environments play in shaping an individual's science identity, sense of belonging and, ultimately, their persistence in their STEM discipline. The climate and culture of STEM disciplines play a significant role in students' sense of belonging and science identity development. Notably, the incorporation of recognized high-impact educational practices and learning experiences in STEM curricula and culture have been proven to aid in cultivating spaces that foster a sense of belonging and science identity [26,60–62].

In addition to understanding the optimal conditions of the educational environment, it is also important to understand the ways in which the individual and environment interplay together in a unique way to produce desired outcomes. Studies have shown that high-impact educational practices provide students with the opportunity to engage in a variety of ways to bolster their social connections, skills development, and self-efficacy, among other qualities [57,63–68]. Several additive educational practices can be incorporated to reimagine curricular and co-curricular experiences, such as living learning communities, communication training, summer intensive bridge experiences, and exposure to professionals in their specific fields, among others, that can promote the persistence of science students, particularly those from vulnerable groups [65,69,70].

We posit that an individual's background and motivations for STEM are supported and encouraged in STEM learning environments that foster a sense of belonging and science identity, so that there are expected outcomes and results affirming their persistence in STEM. In particular, our conceptual model highlights the outcomes achieved are decision-making (academic choices supporting the actualization of a career in the STEM field), development (science identity development, social agency development, research and technical skills development) and connection (within the institution and the science community). The outcomes achieved show how situating an individual's abilities, skills, and resources in environments intentionally cultivated to support their growth significantly affects their willingness and ability to persist in STEM.

2.1. Key Concepts

In addition to presenting the conceptual framework, this section will define several key terms fundamental to situating this study.

2.1.1. Community Cultural Wealth

We utilize the term community cultural wealth (CCW), which refers to the six assets that individuals from marginalized populations utilize to navigate educational environments [71]. Tara Yosso expanded on Bourdieu's work on cultural capital to provide a more inclusionary approach to understanding the cultural assets possessed by marginalized groups [71]. We chose to utilize the term community cultural wealth as our scholarship actively seeks to decenter ideologies that promote deficit approaches, maintain the status quo, and perpetuate inequities impacting individuals from marginalized populations.

2.1.2. Science Identity

As defined by Carlone and Johnson, science identity refers to the factors that affirm an individual's belief that they are a scientist. The three factors are their performance (engagement in relevant scientific practices), recognition (recognizing oneself and being recognized by others as a science person), and competence (knowledge and understanding of science content) [9].

2.1.3. Social Agency

Social agency is an individual's capacity to have the power and resources to fulfill their potential in their community [72]. In the context of this study, we posit that the combination of the individual in a supportive STEM environment can assist in cultivating their social agency in the scientific community. As a result, individuals experience a sense of ownership and the power to engage and navigate the science community successfully.

3. Methods

3.1. Participants and Research Setting

This study employed a qualitative case study approach to explore the formation of science identity and social agency among low-income, academically talented undergraduate science students from diverse backgrounds. Case study research allows researchers to comprehensively understand complex issues within their real-world context [73,74]. Case study research explores real-life, bounded cases through multiple forms of data. The setting of the research study was a large, research-intensive public university in the Deep South region of the United States. Within this college of science, approximately 1500 undergraduate science majors are enrolled across seven academic programs. About 16% of the undergraduates identify as members of a historically underrepresented racial and ethnic group.

The target population of this research study was science and math students who currently participate in or who participated in a scholarship program for students with significant academic talent and financial need from Fall 2020 to Spring 2023. The rationale for engaging this specific participant pool was the diversity in the group and the opportunity for access to collect interviews and other data sources for collection and triangulation. The term diverse group in this study is defined as individuals with differences in race, ethnicity, socioeconomic status, religious belief, sexual orientation, academic pursuits, and life experience, among others.

Table 1 summarizes the profiles and demographics of the participants in this research study. The participants included five women, four men, and one non-binary individual. The academic classifications of the group ranged from sophomores to graduating seniors. The racial makeup of the group was Asian, Black/African American, and White. All the participants identified as low to moderate income in their socioeconomic status. Four participants identified as first-generation students—neither parent had attended college or a university. The students actively participated in several high-impact educational practices and engagement opportunities that holistically supported and encouraged their academic and social integration into scientific and university culture.

Table 1. Participants' profiles.

Pseudonym	Classification	STEM Discipline	Gender	Race/Ethnicity	First Generation
Marie	Junior	Biological Sciences	Woman	Black or African American	N
William	Junior	Physics-Astronomy, Mechanical Engineering	Man	White	N
Alex	Junior	English Literature (previously Physics)	Non-binary	Two or more races (White and Asian)	Y
Irene	Junior	Biological Sciences-Marine Biology	Woman	Asian or Pacific Islander	N
Louis	Sophomore	Microbiology	Man	White	Y
Ruth	Sophomore	Microbiology	Woman	Black or African American	Y
Mary	Sophomore	Mathematical Statistics	Woman	White	N
Rachael	Sophomore	Biological Sciences (Pre-Med)	Woman	White	N
Malcolm	Senior	Biochemistry (Pre-Med)	Man	Black or African American	Y
Davis	Senior	Biological Sciences	Man	Asian	N

3.2. Data Collection and Analysis

Aligned with the case study methodology, we collected multiple forms of data, inclusive of documents and interviews [75]. We posit that the collective evaluation of these data points paints a detailed picture of our scholars' experiences, particularly giving a more in-depth understanding of how they developed and utilized their science identity and social agency in connection with their involvement in the mentoring scholarship program to integrate into their scientific community. The primary sources of data collected in this study were one-on-one, semi-structured interviews. The interviews lasted approximately 45 min and were conducted through the Zoom video platform. The interview protocol for this study can be found in the Supplementary Materials. Each participant provided verbal informed consent prior to participating in the research study. This study was approved by the Institutional Review Board at a research university in the Deep South region of the U.S. Participants were assigned pseudonyms to ensure their identity remained confidential and to provide a means of reference in the findings and discussion portion. The interview protocol questions for the research study were developed from the conceptual framework. In particular, the questions explored participants' transition to college, social agency development, science identity formation, participation in curricular and co-curricular experiences, and their perceptions of race and gender within the science community. The interview protocol questions are provided in the Supplementary Materials.

In addition to interviews, the researchers evaluated each participant's success metrics collected yearly. The success metrics included grade point average (G.P.A), professional development engagement, awards/honors, and individual development plan development and progress. This study's third source of data was annual evaluation reports provided by the external program evaluator. The annual evaluation report provided an overall summation of the program's efficacy in relation to outcomes, student and staff feedback and suggestions for areas of improvement. We posit that the collective review of these data points paints a detailed picture of our scholars' experiences, particularly giving a more in-depth understanding of how they developed and utilized their science identity and social agency in connection to their involvement in the mentoring scholarship program to integrate into their scientific community.

The data analysis process was grounded in an inductive coding strategy that allowed the researchers to identify patterns and assign codes to concepts of interest in the interview data [76,77]. The first step in this analysis process was reading through the transcripts to ensure accuracy, to correct grammatical errors, and to gain an initial understanding of each participant in the case study. Next, each transcript was uploaded into the Dedoose qualitative analysis software for coding. Each transcript was open-coded using an inductive strategy: reading and interpreting raw data to develop themes and concepts via interpretations based on data [74]. In this phase, the codes produced are tentative and subject to evolve and change as the analysis continues. After initial open-coding of all transcripts, the first iteration of the codebook was completed. In subsequent rounds of axial coding and refining the codebook, the final codebook was completed, which included 76 codes.

The reporting of the data analysis was two-fold. We conducted a narrative analysis to understand how participants interpreted their own lives through their identities as they navigated the academic and social environment in college, utilizing multiple data sources, including student metrics, evaluation reports and interview data, to deepen our understanding of each participant and the context of their environment [78,79]. Secondly, we examined the data across the group by identifying relationships and patterns across the ten participants. Utilizing these groupings of relationships and patterns, we labeled the emerging themes shared by the participants [80]. The final themes presented in the results section are the key outputs produced by the identified patterns or trends between the participants' experiences. We utilized peer debriefing sessions and concept mapping throughout the study development, implementation, and execution phases to ensure trustworthiness [81,82].

3.3. Researchers' Positionality

Our individual research agendas and collective interests focus on justice, equity, diversity, and inclusion (JEDI) systemic change, and education models in chemistry education. We investigate topics regarding faculty and student recruitment, retention, and success in STEM. The first author is a Black woman, a postdoctoral fellow in chemistry education at a public PWI. As a trained forensic scientist and qualitative educational researcher, her lived experiences as a student and professional have informed her scholarship and practice, which examines the narratives and lived experiences of historically excluded and marginalized populations, particularly investigating critical points in their transition to and navigation of the STEM educational pipeline. The second author is a faculty member in chemical education research and practice and an administrator within the College of Science at a PWI. As a leader on almost $30 million in extramural support from NSF, NIH, USDoEd, and philanthropic agencies, she has designed and implemented over 20 education projects, which have employed mentoring models to create and test development structures that cultivate self-efficacy and agency, particularly for groups historically underrepresented in STEM. Her research centers on studies of the persistence of individuals from all backgrounds in STEM higher education and careers, with a primary focus on faculty and student recruitment, retention, and success. Her lived experience as a woman of color in STEM influences her passion for studying students from diverse backgrounds and their pathways in STEM higher education and careers.

4. Results

The data analysis revealed three salient themes that emerged across the ten participants in relation to the central research question. We found that our participants discussed the ways in which their intersecting identities significantly shaped how they were navigating their collegiate STEM experience. Additionally, we found that our participants attributed their persistence in their STEM discipline to their motivation sources (intrinsic and extrinsic), support from their community (peers and mentors), and intentional engagement in academic activity and access to well-resourced environments (academic and social opportunities).

4.1. Intersecting Identities Significantly Shaping Their Collegiate Experience

As participants discussed navigating their educational experience, many of them discussed an awareness of the realities of the privilege and oppression of their intersecting identities as they moved through academic and social spaces. In particular, each participant described the most salient identities they were most conscious of as they navigated their educational spaces. In our discussions about the ways in which their identities were shaping their collegiate experience, Ruth, a Black woman and first-generation college student in her sophomore year of the microbiology program, shared her experience of developing awareness when she participated in a panel discussion during her freshman year about being Black at a predominantly white institution. She explains:

> *I was on a panel last year about being black and the PWI, and how you felt about that... after that panel I started seeing things I didn't really notice before... like the fact that an average class has about two hundred people and there is usually only maybe ten to fifty of us [Black people]... if there's ten of us here, we tend to group together based on that [race]... but then sometimes I think about this underlying thing which is in a job force only one of us can succeed.*

Ruth also discussed the dichotomy she experienced when she sought out a Black science-based organization:

> *I am a member of a Black science-based organization. I went to a couple of events, and it was really cool to see so many people in my major, who looked like me ... however, when I talked to my aunt, she said try not to get pigeon hole into just going to black organizations, because whenever you graduate, or you go into the workforce. Everyone's*

not going to be black and you want to have experiences outside of that [being Black], and not just be so uncomfortable in branching out because of that [race].

Conversely, Malcolm, a Black man and first-generation college student in his senior year of the biochemistry program, shared how the representation of Black and Brown students has increased since his freshman year at this institution. For him, the growth in these specific student populations has become a form of motivation for his persistence.

From freshman year to now, there is a lot more color around campus. . .Sometimes I'd be the only black or minority person in a classroom. . . I would notice it, but it wouldn't be that big of an issue. Now, when I go into class, there's a bunch of other black and brown people, and it makes me feel good. . . even against odds and what anyone else thinks they're doing this too, which drives me. I don't want them to feel like they're alone in this, so I'm going to keep going too.

In addition to the discussion about race, other participants focused on the dichotomy of their identities in academic and social spaces and how their academic spaces seemed neutral and erased their identities and human essence. Irene and Alex discussed how their experience navigating their identities was much more challenging socially than academically. Irene, a South Asian woman in her junior year of a biological sciences, marine biology concentration program, discussed how identifying as South Asian and Hindu was most apparent in the social settings of her collegiate experience. Particularly, she shared how she was negatively impacted by being in an institution with a dominant Christian student population:

There are a lot of people here identifying as Christian. . . so my religious identity and growing up Hindu has definitely impacted my social experience here. . . there are a lot of Christian-centered organizations and a lot of Christian-centered talk in some classes. . . it affected it a little negatively, just because I grew up in a very diverse community. . . Here everyone is either Catholic or Protestant and if you don't like fit that, it can be a little isolating. . . but in terms of feeling supported in my academic life, that's never affected me. . . people don't bring up religion in my Bio lab.

While Irene appreciates the neutrality of her STEM academic space, Alex, a White and Asian non-binary person and first-generation college student in their junior year of the English literature program and formerly in the physics program, interpreted the neutral approach of their STEM academic environment as an erasure of their identities and put more of an emphasis on their ability to produce quality work as the determinant of their value. Alex shared: "*The physics department faculty were very supportive of my identity and my transition. . . however I always say being queer in STEM is a double-edged sword because, on the one hand, your identity doesn't really matter that much, and it just depends on the quality of the work that you put out. . . But, on the other hand, there isn't necessarily an explicit validation of identity. . . I think that both helped and hurt.*

Louis, a first-generation, White queer man with a speech disability in his sophomore year of the microbiology program, eloquently discussed the intersectionality of privilege and oppression experienced through his identities.

To start off with being first-gen. I don't feel like I'm good enough sometimes, and like I don't deserve a spot at college. . . I come from a disadvantage background, and it puts me in a spot where I feel like they have advantages. I'm going to kind of let them keep having those, and I'm going to sit back. . . As a queer person. . . I feel isolated sometimes because it's hard to judge someone's acceptance of me. . . I don't bring up certain things about myself, because I don't know how they'll react and it's a safety thing. . . which kind of leads me to not having any full interactions, because that's such a big part of me. And I'm a white man. I acknowledge that I'm a white man and the privilege that comes with that. . . I also have a speech impediment. . . It's kind of hard for me to communicate. I also hold back sometimes if someone's not taking the time to understand or if people are going to make fun of it.

Conversely, students from dominant identity groups did not explicitly view their experience through their own identities of race, ethnicity, gender, and religion but rather through the lens of being low-income or being accepting of others' differences. Particularly, Davis, an Asian man in his senior year in the biological sciences program, shared his sentiments about the work ethic as the main factor influencing his educational experience:

> *I've interacted with a lot of people of different races, genders, genders, and like classes as me… I've learned to just respect people. For me, my race, class or gender do not limit me from what I want to be because it's about mindset, you know. I feel like it's about your grind. The harder you work, the more opportunities you have.*

Similarly, William, a White man in his junior year of physics and mechanical engineering programs, shared that his focus was not on identities but instead on connecting with peers over the shared student experience in the collegiate environment:

> *Every time I walk into an environment on campus, there's a wide variety of different types of races, genders and religions and a lot of different types of people. I think that's a great thing. I don't really feel I get that effect of there's too little or too much of this one specific group… it kind of blends to the point where I look past that stuff [identities]… I think we're all students trying to make it through our days so how can we help each other, or how can we share experiences, or get to know each other, and our differences, and all the stuff that makes us the same.*

Rachael and Mary, White women in their sophomore year in the biological sciences and mathematical statistics programs, respectively, discussed identities from the perspective of accepting others without acknowledging how they view their education journey through their own identities. For instance, when asked how her identities or perceptions of race, class, or gender have shaped her experience, Rachael said, *"I wouldn't say it has influenced it as much… I'll talk to anybody. It doesn't bother me. It's nothing wrong with your identity… everybody's unique."*

4.2. Motivation Powering Their Pursuits

In a discussion about their educational experience in their STEM academic program, participants explored and shared several topics and concepts rooted in actively remembering their motivation to pursue science. All the students discussed some degree of intrinsic motivation and self-reliance as the primary driving force for their direction and success academically. For all the students, their intrinsic motivation was cultivated from a belief in self, curiosity, and interest in the specific science discipline and achieving their definition of success. When asked to share their definition of success that motivated them to pursue their goals, three common themes emerged from their definitions of success: (a) accomplishing their goals; (b) being able to comfortably live the life that they envisioned for themselves; and (c) progression in developing their skills, abilities, and knowledge. Louis and several others brought into focus how their progression to becoming better was a demarcation of their success on their journey to their career. Specifically, Louis reflected on how he viewed his academic progression as a source of affirmation and motivation:

> *I reaffirm myself … that's why a lot of my validation comes from academics because there's an active scale … it's a double edge because sometimes, for example, I was struggling with organic chemistry, but for me, I'm succeeding because I understand more than I thought I would. In reality, I may not be my best, but I'm succeeding because I'm passing the class.*

In addition to their shared attributes of motivation and success, several participants discussed another layer to their motivation to pursue their career path: their commitment to serve and support their communities and society at large. Malcolm, Irene, and several others, stated that their motivations were rooted in their desire for civic responsibility to their communities. It is this connection to something greater than self that these participants found a source of fuel to their motivation to pursue their science degrees. Malcolm shared that his motivation was rooted in creating access for individuals from underserved and economically disadvantaged backgrounds and encouraged him to be persistent in his pursuit of becoming a neurosurgeon with experience in hospital administration.

> *I want to create more access for folks... people shouldn't have to risk the quality of their life even more so getting surgery... I definitely do want to go into the policy and procedures... I find there is a large disconnect between the admin and the people that are actually practicing medicine when the admin has not been in the doctor's shoes, and they're trying to implement things that they think could work instead of things that they've seen in practice... I want to limit the need for spinal surgery to begin with, and then, if someone does need spinal surgery, I want to develop methods that are going to reduce the risk associated with it.*

Similar to Malcolm, Irene conveyed that one of her motivations to pursue a career in environmental science was being able to connect science to society through educational resources. In particular, she discussed her love for documentaries and the ways in which documentaries are used to educate the general population about complex science matters. "*Film (documentaries) is what made me want to go into environmental science... it was seeing really good documentaries or seeing TV personalities like Steve Erwin... That's what I think connected me to nature. When documentaries like plastic ocean came out... these environmental documentaries really attracted me. I've always really liked what they did in terms of public outreach about bringing the science to large-scale audiences.*"

For others, their motivation to persist in their STEM programs was fueled by an initial curiosity in their specific discipline and motivated their initial pursuit, while the opportunities, freedom, and encouragement to explore and refine what their career path could be fueled their motivation and enthusiasm to continue to persist and navigate their educational experience. William, Louis, and Ruth all discussed the ways in which their persistence in their specific discipline had been sparked by their initial curiosity and sustained by their ability to refine their path to their own niche. For instance, William's childhood love for sci-fi movies piqued his interest in physics. Once he came to start his education journey, he added an engineering major to allow him to bring his theoretical physics training to life through an engineering design background. He explained, "*When I was a lot younger, I would always watch the sci-fi movies... I set my path initially for just purely physics, but then I started realizing that I wanted to go into a field where I could do more design and try to apply these concepts... realized that in order to get that design background, you would ideally, you'd want to have an engineering background*".

4.3. Community and Connection Matters

A notable commonality among all participants was their active engagement in various academic and social opportunities that supported their sense of belonging in the science and university community. As the students shared about their engagement outside of classes, they discussed participating in at least one student organization and one academic experience (i.e., conferences, undergraduate research, shadowing, etc.). Table 2 represents data from the student metrics collected on their participation in undergraduate research, academic organizations, social organizations, and academic co-curricular experiences for the ten students in this study. Utilizing a ranking scale from the activity with the highest participation to the lowest participation, science-related academic organizations, undergraduate research, and social organizations were the top three engagement activities in which most participants engaged. Notably, all the participants reported participating in at least one science-related academic organization.

Table 2. Engagement in Specific Academic and Social Activities.

Engagement Activity	Total Participation	Percentage
STEM-Related Academic Organizations	10	100%
Undergraduate Research	7	70%
Social Organizations	7	70%
STEM Conference Participation	6	60%
STEM Conference Presentations	5	50%
Shadowing/Internships	3	30%

When asked about their engagement experiences, many participants discussed how their participation in various engagement activities had supported their personal and professional growth, provided a community of like-minded peers, and affirmed their sense of belonging in the science community. Davis, Mary, and Rachael discussed at length the positive impact that their engagement outside of the classroom had in supporting them. For Davis, his engagement in academic and social opportunities had been the linchpin in his persistence in his discipline. He expounded, "*These experiences give me like a buffer between science classes because I feel sometimes science can be a little bit overwhelming no matter how interested you are in the subject… It gives me an opportunity to destress and come back better than ever, ready to focus, ready to take on science.*" Further, when discussing his social connections, he shared his appreciation for his peers, "*It's so necessary for the college experience. I don't think I would have made it… The people in the program are already accomplished people. I talk to them about stuff, and conversational pieces are in the back of my head… I wanted to be around like-minded people and to be able to engage in that type of space*".

Davis, Rachael, and Mary shared how engaging with peers in social settings had been one of the highlights of their collegiate experience to help them balance the rigor of being a science major. Rachael explained, "*… doing fun activities definitely helps lighten the load and makes this experience feel a little better. For instance, we went bowling, and I had an exam the next day, but I like planning ahead, and I was like, I'm still going to this event because It's going to be a nice relaxation before having to go take an exam.*" Mary shared how her engagement with her peers had served as extrinsic motivation to persist in STEM. "*Having people doing similar things like me or making sure that I'm staying on track has definitely motivated me to keep working at this degree and to keep up with my other friends in STEM. Also, to not let people down, you know… Its motivation being around similar like-minded people*".

In addition to being in a community with like-minded peers, students who participated in undergraduate research discussed the ways in which their ability to understand the course content and growth in their research skills and academic decision-making were significant benefits of this opportunity. For instance, William participated in a summer undergraduate research experience, the summer before his sophomore year, and shared: "*I did my research after my freshman year….everything I had to learn in the research project over that summer was stuff that I was going to be learning in courses down the road… I'm still coming across content I learned in that research experience that's coming up in the courses I'm taking now… it's extremely helpful getting involved in research.*" For Irene, her undergraduate research experience had strengthened her research skills and supported her career plans and actualization in her STEM field.

> *Everything I've done outside of the classroom has been pushing me in this direction that I think I've always been headed, which is like just wanting to do something either service-oriented, or for climate change, or something that feels urgent… Everything is set to give me skills that I will apply in the future… It's really been good to know that I can see how this was applied in the lab.*

5. Discussion

The purpose of this present study was to explore the ways in which low-income undergraduate science students from diverse backgrounds describe navigating their post-secondary educational experience, particularly the contexts, skills, and supports that have encouraged their persistence to remain in their desired STEM field. Particularly for our ten participants in this study, their educational journey was investigated with a focus on their intersecting identities and how these intersecting identities shape how they connect with peers, access resources, engage in activities, develop skills, and actualize their place within the science community. Considering the experiences shared by the ten students, several streams of understanding emerged to answer the central research question guiding this study.

Foundational in this study, our participants shared the identity of being classified as low-income in terms of socioeconomic status. Through conversations with the students, we found that many of them shared similar work-ethic philosophies that their hard work can pay off and their goals would be met. Their sentiments affirmed the common societal belief that individuals from low-income backgrounds can achieve upward economic and social mobility with their hard work [2–4,83]. While this belief may be a common assumption, research has shown that individuals from low-income backgrounds face and consistently contend with prolonged challenges that impact their ability to achieve economic stability, particularly those from marginalized racial and ethnic groups.

The existing literature asserts that the dominant culture and narratives in STEM disciplines prefer individuals who identify as either white, Asian, male, cisgender, or a combination [20–22]. As such, individuals from these identity backgrounds are more likely to achieve their desired goals and careers in STEM. Conversely, those individuals departing STEM disciplines are the students from non-dominant groups in STEM. In this present study on low-income science students, we, too, found evidence of the dominant culture and narratives in several of our participants. Also, we noted stark differences in the participants' navigation of their academic environments through the lens of race, ethnicity, gender, and religion, and how the intersection of these identities shaped their ability to navigate academic and social spaces and actively shaped their development, connection, and persistence in their STEM discipline. For instance, the Black women in this study discussed how operating in academic spaces with their Black identity at the forefront produced feelings of inadequacy, lack of belonging, and unequal performance expectations. The White women in this study did not even acknowledge their whiteness as a salient identity when navigating their educational spaces and often took the approach of blindness to diversity when discussing and engaging with diverse groups of people in their academic and social settings. Aligned with existing studies on student perceptions of their identities in the science community and specific disciplines, we know that students from historically underrepresented groups can experience feelings of inferiority, tokenism, unequal performance expectations, and not belonging at higher rates than their counterparts [62–66]. As students navigate their educational experience through the lens of their intersectional identities, they often navigate oppressive systems, policies, and practices that perpetuate inequities and barriers for marginalized groups. As such, it is imperative to account for nuanced considerations and, in some cases, the layering effect of their intersectional identities, when supporting students in STEM disciplines.

Regarding motivation powering their pursuits, Deci and Ryan suggested that motivation for one's goals should be self-directed and grounded in one's reasoning as the most satisfying and successful approach to success and accomplishment [53]. Aligned with existing studies and theoretical frameworks centered on motivation, self-efficacy, and self-determination [51,53,58,59,84], our participants affirmed the importance of one's motivation and self-efficacy to pursue and actualize their educational and career goals regardless of the challenges one encountered. Several participants discussed extrinsic motivation connected to civic responsibility—a calling more significant than themselves—usually to their communities, families, and the betterment of the human experience. In line with extrinsic motivation, our participants' self-defined success goals and additional external elements encouraged and supported their success to date and, in the long-term, influenced their desired end goal of success [50]. Motivation in this context not only supported the students in focusing their attention on their personal goals but encouraged several of them through the inspiration of their communities. These varied sources of intrinsic and extrinsic motivation were notable factors that supported and encouraged their persistence in STEM.

This study also brings to the forefront how consequential inclusive, affirming, and welcoming environments are in supporting the persistence of low-income, diverse student groups in STEM. The existing literature clearly articulates the importance of connection to peers and faculty and how engagement in academic and social activities outside of classes is valuable for developing their social agency and strengthening their relationship with the science community [16,19,85–88]. When exploring the impact of peer support and motivation, many of the participants discussed the value and benefits of being in a community with peers with similar goals and pursuits. Many of the students in this study discussed the benefits of having financial support for tuition and engagement opportunities and how access to such opportunities was critical to developing their social and professional networks that enriched their educational experience. The students highlighted that being in a community of peers with similar goals provided a source of motivation, increased their sense of belonging, and expanded their access to social networks, opportunities, and resources. Their participation in various engagement activities also supported their career and academic decision-making, career preparation, research skills development, and sense of belonging.

Across our participants' extracurricular engagement experiences, we noted that several of them discussed their engagement in STEM academic organizations connected to one or more of their salient identities. The desire to be in identity-centered educational spaces was four-fold: representation of professionals in their field, expansion of their social network, supporting their academic and career decision-making outcomes, and being in a space that affirmed an identity or intersecting identities seen as a barrier in the larger educational setting. For instance, the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE) is an organization with the expressed purpose of supporting the development and training of Black scientists in academic, development, leadership, and philanthropic endeavors throughout college, and careers in chemistry and chemical engineering. Our findings further affirm the importance for STEM environments to be intentionally cultivated to foster a sense of belonging and to promote inclusivity for students from diverse backgrounds, linking increased engagement in the STEM curricular and extracurricular experience to increased persistence in the STEM discipline [11,12,67,89,90].

Limitations

The participants' sensemaking of intersectionality varied significantly across the group. While most of them could list their salient identities, we recognize that our participants varied in their understanding of how their identities shaped the navigation of their STEM academic experience. As such, including a secondary interview in the research design would be beneficial to investigate the concept of intersectionality and to support our participants' sensemaking process more comprehensively.

6. Conclusions

Our study explored how diverse low-income students leverage their identities, skillsets, and resources within supportive STEM academic environments. Students enter postsecondary educational spaces with unique identities and backgrounds, mindsets and skillsets, cultural wealth, and resources. Our research shows the importance of the relationship between low-income diverse student groups and their academic environment for their persistence in their STEM discipline.

Looking deeper at low-income populations, we acknowledge that it is not a "one size fits all" approach. Much of the rhetoric surrounding low-income populations focuses on their work ethic as the sole determinant of success. However, our participants' interviews and narratives illustrate clearly that additional considerations must be considered when supporting the success of diverse low-income students, particularly regarding how their intersectional identities, skillsets, and resources are acknowledged and engaged in the collegiate environment. Their stories illuminate that their persistence in their STEM discipline is primarily attributed to their motivation sources (intrinsic and extrinsic), support from their community (peers and mentors), and intentional engagement in academic activities and access to well-resourced environments (academic and social opportunities). Thus, one implication of this study is for leaders and professionals supporting diverse students in STEM to actively consider how they are accounting for and factoring in students' identities, skillsets, and resources to best support them in developing a sustainable STEM ecosystem to encourage their persistence in STEM collegiate environments through to the STEM workforce.

As scholars, practitioners, and leaders in the STEM enterprise addressing the call for broadening participation, we encourage consideration of the realities of low-income students and other marginalized groups when establishing initiatives and engagement opportunities. For instance, participation in supplemental science-based activities has been long touted as beneficial to strengthen credentials and connection to the science community at little to no cost. However, we present two critical considerations for low-income populations. The first is that several immersive opportunities, such as conference participation and international undergraduate research experiences, are typically available to students with the time and financial resources to participate. The second is that many low-income students support themselves financially through college and, therefore, do not have the time to engage in supplemental activities. With this context in mind, we implore STEM program leaders to consider how their initiatives can be equity-minded. An example is the provision of dedicated funding sources for economically disadvantaged students to support their engagement in professional development and science-based activities. This approach removes the financial burden and potential stigma low-income students may experience regarding finances and encourages their involvement in learning experiences similar to their well-resourced counterparts.

Finally, our research encourages using high-impact educational practices adapted to account for the diverse student populations our institutions serve. In addition to the guidance on high-impact educational practices, we also posit that consideration can be given to program operation, logistics, cultural competence, and accessibility, among others. For instance, undergraduate research experiences are considered a high-impact educational practice. When designing such experiences for students with marginalized identities, we offer the following considerations as examples: paying undergraduate researchers, provision of culturally relevant training approaches, and connection to a mentor. It is incumbent that educators and leaders consider how we can intentionally and thoughtfully engage students who have the desire and willingness to pursue their desired STEM career path.

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