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STEM Validation Among Underrepresented Students: Leveraging Insights From a STEM Diversity Program to Broaden Participation

Brian A. Burt, Blayne D. Stone, Rudisang Motshubi, Lorenzo D. Baber

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Abstract

Despite significant efforts to broaden participation in postsecondary science, technology, engineering, and math (STEM) education, students from historically minoritized populations continue to face systemic barriers related to access, departmental climate, and institutional practices. Previous research suggests that campus-level STEM diversity programs often serve as a valuable resource for persistence and completion among students from underrepresented populations. However, more knowledge is needed to better understand how students experience STEM diversity programs and identify with their specific practices and activities, how those practices and activities shape students' experiences, and how the practices, activities, and participation influence how students view themselves as members of the STEM community. Increases in the number of underrepresented students completing STEM degrees would result in new innovations to address world problems, more varied representations of scientists, and more individuals who could mentor future generations of learners. This study of 20 underrepresented students, all of whom participated in the Louis Stokes Alliance for Minority Participation (LSAMP) program, describes the programmatic influences of LSAMP that support students' successful progress within STEM disciplines. Data reveal that: (1) students entered the LSAMP program with self-defined strengths; (2) the LSAMP program provided formal academic support; and, (3) students experienced evolving forms of scientific and identity development. This study centers students' voices to inform educational practices, policies, and future research focused on the persistent need to broaden participation in STEM careers.

Keywords: Undergraduate research experiences (URE), underrepresented students, STEM, broadening participation, validation

STEM Validation Among Underrepresented Students:

Leveraging Insights from a STEM Diversity Program to Broaden Participation

Despite significant efforts to broaden participation in postsecondary science, technology, engineering, and math (STEM) education, students from historically minoritized populations continue to face systemic barriers related to access, departmental climate, and institutional practices (Baber, 2020; Burt et al., 2018; Lane, 2016; McGee & Robinson, 2019). As a result, across multiple STEM sub-fields, disparate outcomes based on demographic background remain. For example, at all levels in postsecondary education, African American and Latinx students are significantly underrepresented in the percentage of degrees awarded in science and engineering (National Science Board, 2016, 2018). For decades, STEM scholars of color have questioned these persistent patterns of underrepresentation of African American and Latinx populations in STEM (Hrabowski, 1991; Malcom, 1990). Thirty years ago, Malcom (1990) noted that while scientists espouse principles of reason and objectivity, historically,

> Differential opportunities were extended in science, independent of talent. Examples abound in which the opportunities for the study of science, the tools needed to do science, and the recognition within science have been handed out based on consideration of race and gender. (p. 247)

The persistent inequality of outcomes among underrepresented students of color and women pursuing STEM education suggests that scientific practices rooted in objectivity and meritocracy are not reflected in the cultural norms of the scientific community. However, previous research suggests that campus-level STEM diversity programs often serve as a valuable resource for persistence and completion among students from underrepresented populations (Baber, 2015; Rincón & George-Jackson, 2016). Program components and facilitators, including program staff and departmental faculty, elevate individual strengths while supporting students during hostile experiences at the campus or department level. Despite some evidence of success for STEM diversity programs, students of color remain underrepresented in STEM fields, suggesting the need to deepen our understanding of their experiences in these programs. Specifically, there is need to identify, from the student perspective, practices and activities that shape experiences and perceptions which lead to persistence and completion in STEM.

The purpose of this study is to examine the intersectional experiences of underrepresented students participating in the one of the largest federal STEM diversity programs—the Louis Stokes Alliance for Minority Participation (LSAMP). Through a qualitative inquiry into program experiences among twenty participations, we investigate programmatic influences of LSAMP that support student progress in STEM. Specifically, we consider the following research questions: How do students participating in a STEM diversity program (i.e., LSAMP) describe initial and continuing engagement with scientific research and professions? In what ways, if any, do emerging identities shape (and reshape) individual perceptions of science? This study centers students' voices to inform educational practices, policies, and future research focused on broadening participation in STEM careers.

Fostering Success in STEM: A Literature Review

Previous research on student experiences in STEM reveals a myriad of individual and contextual factors that contribute to successful outcomes for students from historically underrepresented backgrounds attending both two-year (Bahr et al., 2017; Starobin et al., 2010; Zhang et al., 2019) and four-year institutions (Chang et al., 2014; Dika & D'Amico, 2016; Rincón, 2018). Factors specific to an individual include early exposure to STEM through related activities, pre-college schooling experiences, positive self-efficacy towards science, and resistant attitudes towards normative departmental practices grounded in dominant cultures (e.g., white, male, upper-class). However, factors related to one's context include encouragement from family and teachers, formal and informal academic support, a critical mass of underrepresented students in one's department, and peer-centered networking systems. Collectively, previous studies suggest that underrepresented students' success in postsecondary STEM education is fostered by nurturing existing individual strengths and creating diverse and supportive departmental environments. Based on the extant literature, one intervention that may contribute to broadening participation by leveraging students' individual strengths and creating supportive STEM learning environments is providing opportunities to engage in undergraduate research experiences.

Undergraduate Research Experiences

Literature highlights that participation in undergraduate research experiences (UREs) offers a wide range of outcomes for underrepresented students in STEM, including college retention, undergraduate degree completion, exposure to advanced degrees, and participation in the STEM workforce (Bowman & Holmes, 2018; Linn et al., 2015). Students in STEM UREs experience increased academic confidence, improved research skills, mentorship relationships, a sense of belonging on campus and within their respective STEM field, and deeper conceptual understandings of STEM and the STEM community (Hernandez et al., 2018; Hunter et al., 2007). For instance, Linn and colleagues (2015) found that students who spent 12 months or more in a URE learned new methodological techniques, formulated research questions, accumulated their own data, and interpreted their own findings. In addition, networking with peers and faculty members over an extended period helped them feel more confident in STEM.

Exposure to Graduate School and STEM Careers

Undergraduate students who are exposed to research experiences gain knowledge and research skills needed for graduate school and STEM careers (Craney et al., 2011). For example, Maton et al. (2000) found that underrepresented STEM majors who participated in a scholarly program with research internships attended graduate school at higher rates than other STEM students. This literature suggests that undergraduates' research exposure builds confidence in their abilities, exposes them to what research beyond the baccalaureate entails, and develops competencies necessary for graduate-level work (Burt, 2017; Lopatto, 2007).

To achieve these outcomes, several practices, described below, appear to be common components of UREs: incorporating faculty mentoring, exposure to graduate school and STEM careers, and developing students' STEM identities by encouraging a sense of belonging.

Incorporating Faculty Mentoring

Mentoring has become a national priority (Crisp & Cruz, 2009; Griffin, 2012), especially in STEM fields where students of color remain underrepresented and offering role models is seen as one way to broaden participation (May & Chubin, 2003; Mondisa, 2020; Zaniewski & Reinholz, 2016). Cultural and racial aspects of mentoring relationships have an impact on students' STEM aspirations and overall career trajectories (Byars-Winston et al., 2020; National Academies of Sciences, 2019). Byars-Winston and colleagues' (2020) qualitative study of mentoring relationships in biological sciences found what they characterized as a "culture of silence" regarding race and ethnicity in STEM mentoring relationships and scientific work. The "culture of silence" referred to the perception that STEM is "value free" (Byars-Winston et al., 2020, p. 248), a perspective suggesting that issues related to race or ethnicity are not applicable to STEM activities. They emphasize that speaking about such issues is important in mentoring relationships because they matter to underrepresented mentee students.

Mentoring in STEM can take many forms. In STEM UREs, faculty mentors assist students in all aspects of the research process, help students make connections between what they learn in courses and the work of research, and aid them in understanding their post-baccalaureate options (e.g., graduate school, full-time STEM careers) (Hernandez et al., 2018). For example, in a quantitative study of 291 participants, 47.2% of whom were underrepresented students, Hathaway and colleagues (2002) found that faculty-student interactions not only influenced the educational aspirations of students, but also increased graduate school enrollment and participation in future STEM careers. Further, students who participated in URE programs were more likely to stay in contact with faculty for advice and recommendation letters. For underrepresented students in STEM, positive faculty mentorship relationships can ameliorate some barriers to postsecondary success broadly, and STEM in particular (May & Chubin, 2003).

Developing Students' STEM Identity by Encouraging a Sense of Belonging

Students are better able to see themselves as long-term contributors to the STEM workforce when they participate—and have positive mentoring experiences—in research experiences (Haeger & Fresquez, 2016). Seeing oneself as a member of the STEM community is related to developing a STEM identity. Although still being theorized, STEM identity tends to be described as an individual's self-perception of their connection to the STEM community, both locally (e.g., school/college) and generally (e.g., field of study) (Brickhouse et al., 2000; Burt, 2019; Burt et al., 2018; Carlone & Johnson, 2007).

Illustrating students' STEM identity development, Espinosa's (2011) quantitative study comparing 1,250 undergraduate women of color in STEM to 891 White women showed that peer discussions and experiences outside of the classroom were essential for the development of STEM identity for women of color. Similarly, Charleston and colleagues' (2014) study of 15 participants who identified as African American or Black found that women in particular felt isolated and marginalized in STEM due to their racialized and gendered identities. Not belonging related in part to a lack of community. More specifically, these participants recounted a hostile educational climate where gendered comments were often made by their non-Black women peers (e.g., White and Black men), and a lack of support from faculty members contributed to feeling isolated in STEM. This growing body of research shows the connection between STEM identity and sense of belonging in STEM. It also highlights the importance of providing students with experiences and environments where they can build community in addition to performing their scientist identities in their STEM courses. When students have a strong sense of their science identity, they tend to feel like they belong in their science field and community.

The process of developing a STEM identity is complex for students of color; how they see themselves in STEM is often related to how those within the STEM community respond to them (Robnett et al., 2015; Rodriguez et al., 2019). Research suggests that students' social identities (e.g., gender, race) can influence how they view themselves as belonging in STEM. This is especially true for women and students of color, who receive direct and indirect messages that they do not fit existing models (Archer et al., 2013; Neumann et al., 2016). Further, the "double-bind" experience of racism and sexism is often challenging to navigate for women of color (Ong et al., 2011; Sanchez et al., 2020). The "double-bind" highlights challenges that students pursuing STEM degrees and careers face because of their intersecting identities (e.g., being a woman and holding an underrepresented racial/ethnic identity).

Taken together, these studies suggest that who students are (e.g., social identities of race and gender) is related to how they experience STEM and view their current and long-term participation in the STEM workforce. That is, when students do not feel a sense of belonging in STEM, they may not view themselves as future contributors to the STEM workforce.

Structured Interventions

Several undergraduate programs have been developed to assist in broadening participation in STEM (Daniels et. al, 2016; Scripa et al., 2012). Programs like the Ronald E. McNair Postbaccalaureate Achievement Program (McNair) and Meyerhoff Scholars Program (Meyerhoff) were designed to increase the number of underrepresented students of color obtaining STEM degrees and entering STEM careers. These programs include activities designed to enhance research and academic skills (e.g., study and time management, research writing), provide workshops and seminars to help prepare for graduate education, and create connections with mentors and underrepresented peers (Fries-Britt, 1998; Hrabowski, 2001).

Like McNair and Meyerhoff, the Louis Stokes Alliance for Minority Participation (LSAMP) program was created to increase the number of underrepresented students in the STEM workforce (Baber & Jackson, 2018; Brothers & Knox, 2013). Funded in 1991 as a congressional mandate by the National Science Foundation (NSF), LSAMP is a consortium of two- and four-year institutions across the U.S. Although institutions and alliances—clusters of partner LSAMP institutions within regions—can enact different activities to achieve their goals, the overall program is guided by a model of student retention and practices such as institutional leadership, targeted recruitment, engaged faculty, personal attention, peer support, enriched research experience, bridging to the next level, continuous evaluation, comprehensive financial assistance, and evidence-based approaches) (Baber & Jackson, 2018; Chubin & Ward, 2009; Lane, 2016).

While there is some scholarship on STEM diversity programs, more information is needed on the array of STEM interventions that aid in broadening participation. In particular, knowledge is needed about the specific practices and activities that students engage in while participating in these programs. Such knowledge would contribute to the literature describing how underrepresented students are encouraged into and supported through STEM pathways.

Conceptual Framework

To consider the research questions for this study, we utilized the validation theory framework (Rendón, 1994; Linares & Muñoz 2011), which was developed to examine the experiences of traditionally minoritized students in higher education. Related to Bandura's concept of self-efficacy (1997), validation is defined as a supportive and confirming process initiated by validating agents (mentors, teachers, professionals, peers) who foster academic and interpersonal development. Similar to the concept of self-efficacy, validation theory includes a focus on the individual processing of external signaling about one's capacity to succeed in a particular context. While self-efficacy emphasizes the psychological processing of external signals, validation theory considers the symbiotic relationship between validated self-efficacy and validating forms of signaling in a particular context. Specifically, Rendón (1994) focuses on two forms of validation: academic and interpersonal. Academic validation includes supportive actions that foster academic development, such as learning opportunities that empower students, meaningful feedback on academic work, and individualized tutorial attention. Interpersonal validation includes actions that support personal and social adjustment to institutional settings.

Validation theory serves as a theoretical framework for research focusing on experiences of underrepresented students in higher education (Dowd & Bensimon, 2015; Linares & Munoz, 2011). It challenges the persistence of deficit perspectives in higher education contexts (Harper, 2010) and the related concept of banking pedagogy for knowledge and technical skill development (Adamian & Jayakumar, 2017). As Patton (2016) notes, ideological frames that support racialized oppression reflect ordinary, rather than abhorrent, discourse in higher education. Deeply rooted in forms of patriarchal white supremacy, higher education functions to support the normativity of whiteness, devaluing other sociocultural frames. In contrast, validation theory assumes that students enter the postsecondary environment with varied strengths grounded in previous educational experiences, community culture, and family histories. The validating process acknowledges and amplifies these strengths through educators who proactively serve as institutional resources for students. Validation is particularly valuable for students who experience stressful incongruency between their culturally centered strengths and institutional norms grounded in dominant perspectives—e.g., forms of hypercapitalism, patriarchy, and/or whiteness (Squire et al., 2018). This is particularly important in postsecondary STEM education, which often restricts forms of agency that fall outside "traditional" cultural norms of science. Recent studies have extended the use of validation theory in postsecondary STEM contexts, focusing on STEM identity development among Latinx students (Rodriguez et al., 2019), Black males (Fries-Britt & White-Lewis, 2020), community college students (Johnson et al., 2016), and students transferring from community colleges to four-year institutions (Lopez & Jones, 2017). In this study, we use validation theory to help make sense of students' experiences within the LSAMP program, and their perceptions of the program's validating supports that influence their engagement with science and their emerging scientific identities.

Methods

This study examines the experiences of underrepresented students participating in the Iowa, Illinois, Nebraska Louis Stokes Alliance for Minority Participation (IINSPIRE-LSAMP) program to better understand their engagement with scientific research and professions, and their emerging identities and perceptions of science. This particular STEM diversity program was selected in part because it has created programmatic efforts aimed at broadening participation in

STEM for nearly a decade. In addition, this alliance comprises multiple institutions, including both two and four-year institutions, as well as public and private institutions. Specifically, IINSPIRE-LSAMP connects 15 institutions, including 10 four-year universities and 5 two-year community colleges, across Iowa, Illinois, and Nebraska. Different alliances (i.e., collections of institutions) receive funding to implement various strategies to meet LSAMP's goals. One strategic program the IINSPIRE-LSAMP Alliance offers to broaden participation is the annual LSAMP conference, attended by LSAMP students within the alliance. At the conference, more advanced students present their research in poster or paper formats, and students attend presentations and workshops conducted by STEM practitioners and scholars. Taken together, the diversity of institutional types, from different states, all within the IINSPIRE-LSAMP alliance provided an opportunity to explore how a STEM diversity program can be effective at the individual campus and broader alliance levels.

To address this study's research questions, we conducted interviews with 20 students from the 2017-18 IINSPIRE-LSAMP Cohort. The majority of these interviews were conducted at the conference in February 2018; two were piloted at the principal investigators' (this study's first and fourth authors) campus prior to the conference. To recruit participants, the researchers created and distributed a flyer describing the research team and study goals. Institutional liaisons (i.e., program directors) encouraged their students to participate, and participants encouraged their friends to participate (i.e., snowball sampling) (Merriam & Tisdell, 2016).

After the study received IRB approval and before the start of interviews, all participants completed an eight-item background form. The form included demographic questions to gather contextual information on individual participants and enable comparisons of participants' backgrounds across the sample. Students attended one of eight institutions and were majoring in a field of study considered to be STEM-related (e.g., biology, computer science, engineering, forensic science). Students' educational class levels varied: five identified as being in their first year of postsecondary study, seven in their second year, three in their third year, and five in their fourth year (or beyond). Of the 20 participants, 11 identified as female and 9 as male, and all self-identified with an underrepresented racialized identity. It is worth noting that while females are generally outnumbered by males in many STEM fields (National Science Foundation, 2017), slightly more females participated in our study. Two possible explanations for the greater representation of female participants might be that females outnumber males in the IINSPIRE-LSAMP program, and that more females self-selected to participate in this study. Also worthy of note, because we were interested in part in better understanding students' science identities related to participation in LSAMP, participants were encouraged to identify themselves in ways that made them feel whole. As a result, we do not offer number counts for the race and ethnicity category because of the varied ways that participants identified themselves. For instance, while some indicated being "Black," others listed "African American"; similar patterns occurred for "Hispanic" and "Mexican," and "Asian" and "Pacific Islander." We do not assume that these socially constructed labels are synonymous, as commonly found on most standardized surveys. See Table 1 for self-reported demographics of study participants.

TABLE 1 HERE

After participants completed the demographic form, individual face-to-face, semi-structured interviews were conducted (Merriam & Tisdell, 2016). The interview protocol was designed to understand the effects of participating in the LSAMP program on student experiences, identification with, and long-term involvement in STEM. Because multiple researchers conducted face-to-face interviews, the semi-structured protocol offered standardization but allowed for flexibility to probe for deeper understanding. Interviews, ranging from 30-45 minutes, were digitally recorded, then sent to Rev.com for transcription. We checked the transcripts against the audio to verify that what participants said was accurately captured.

Thematic analysis was used to make sense of the interview data (Braun & Clarke, 2006). In addition, a social constructivist paradigm was used to acknowledge that individuals hold multiple realities, and that there can be multiple truths (Creswell & Poth, 2018). Together, the data analysis method and paradigm allowed us to discover patterns, discuss them with one another, and make explicit connections to existing literature. Each transcript was assigned to two researchers; this strategy offered increased opportunities for peer review (Merriam & Tisdell, 2016). We started by reading through the transcripts, paying particular attention to participants' experiences in STEM, and how their participation in LSAMP influenced other outcomes (e.g., STEM identity, long-term participation in STEM). We coded areas that had the potential to address the research questions, after which we discussed codes from single transcripts, then across the entire data set. After patterns were identified, they were organized into themes.

At all stages of data analysis, we discussed how our individual and collective multiple intersecting identities influenced our interpretations of the data (Peshkin, 1988). This study's authors include two professors and two doctoral students; all are male, and all self-identify as Black (three were born in the United States and one was born outside of the United States). In addition, none of this study's authors hold degrees in STEM; authors' degrees are in the fields of economics, education, English, liberal arts, and psychology. These details about our individual and collective backgrounds matter as they inform how we experience and see the world, and as a result, how we also interpreted the data from this study's participants (Bhattacharya, 2017). During discussions of the data, we regularly talked about how our interpretations were similar and different, and where different, we discussed the nuanced dimensions that led to these differences, usually related to our multiple and intersecting identities.

For instance, we regularly discussed our assumptions about what it meant to be a student in STEM (e.g., isolating, difficult curriculum, lacking same-race and same-gender role models). While these assumptions can be corroborated by existing research (Charleston et al., 2014; Espinosa, 2011; Ong et al., 2011; Sanchez et al., 2020), these conversations were usually had in discussions contrasting our experiences in our respective majors as undergraduate collegians. Acknowledging that not only do we hold different educational backgrounds from our participants, we also discussed how the eras in which we were undergraduates differ from today (e.g., less access to information via the internet; greater or lesser presence of historically underrepresented students at our respective institutions).

Relatedly, we discussed how our gendered and racialized identities (male and Black) in the United States shape how we think about education as an equalizer for systemic oppression in the United States. We share common perspectives that reforming education, and its policies and practices, can help alleviate some of the effects of racism. However, through these discussions, we had to acknowledge our own privilege of traversing undergraduate education and now retrospectively recalling our experiences. In addition, this conversation forced us to interrogate assumptions about how we navigated predominantly White educational spaces, and the potential privileges afforded to men compared to challenges that women may face (e.g., proving that they belong in fields historically dominated by men, like STEM).

Our intentional regular conversations about our positionalities allowed us to consistently interrogate our thinking and assumptions, and where possible, reduce the biases in our analyses of the data. Further, our ongoing peer review (Merriam & Tisdell, 2016) made certain that various perspectives were considered throughout data analysis, and that our findings and themes were thoroughly scrutinized.

Several limitations should be considered. First, students' experiences in STEM vary due to a host of factors, including social identities other than racialized and gendered identities, fields of study, institution type (e.g., four-year public research-intensive, four-year private, two-year), and how LSAMP staff implement programs and practices at their respective campuses. Thus, we were cautious not to generalize across all students but rather aimed to identify patterns in their experiences. In addition, because all students were members of LSAMP, we do not generalize their experiences to other historically underrepresented students in STEM, as LSAMP's programmatic interventions are likely to influence students' experiences in ways that non-LSAMP participants may not encounter. Finally, the LSAMP conference was selected for data collection partly because a critical mass of underrepresented students within the eight-campus alliance would be present. However, it is possible that interviewing students at the same time that they were experiencing the conference could have influenced their immediate thinking about the LSAMP program's contributions to their STEM development. This possibility, similar recency and primacy effects on individuals' short and long-term learning (see for example, Greene et al., 2000), warrants consideration. We were thus careful to identify both complementary and contradictory data, as to not unintentionally lean toward more positive or negative student experiences influenced by their immediate presence at the conference. Despite these limitations, we are confident that this exploratory study captures the wide range of students' experiences.

Findings

Our findings, based on interviews with 20 participants of the LSAMP program, illustrate how participation in the LSAMP program facilitates students' engagement with scientific research and professions, and influences their identities and perceptions of science. Specifically, our data reveal that: (1) students entered the LSAMP program with self-defined strengths; (2) the program provided formal academic support; and, (3) students experienced evolving forms of scientific and identity development. While there is overlap in the findings, we present these patterns separately for better clarity.

Students Entered the LSAMP Program with Self-Defined Strengths

Intervention programs that promote participation in STEM have been shown to have positive outcomes for underrepresented students (Hernandez et al., 2018). However, preparatory programs sometimes have an underlying assumption that underrepresented students do not enter with the necessary skills or strengths to succeed. That deficit-based assumption is counter to the asset-based perspective we took. Our data illustrated several self-defined strengths around STEM that were accessed prior to entering the LSAMP program. Examples included students reflecting upon their personal experiences, which showed a desire for further knowledge, and developing self-interests to motivate their current and future STEM participation. Students often said they were interested in STEM from an early age, before entering college. For example, Rachael, a Latinx female biology major from a four-year private liberal arts college, described being introduced to biology as a child by her parents:

> Both of my parents are doctors…they always introduced me to biology. I was always walking around with them, having the hospital life, because sometimes I had to wait to my parents, or we were in a party and like, "Oh yeah, a patient just showed up. I need to go, I need to be in the hospital." So that I wouldn't be bored, he would take me to see the patients, and listen to patients' hearts. I've been always doing that since I was a kid.

Her personal experience of being in the hospital, and being incorporated into scientific activities (e.g., listening to patients' hearts), exposed Rachael to a related environment with people who shared her cultural identity. For Rachael and other students, childhood experiences of observing other people like them reinforced the possibility that they could work in this environment as well. Rachael emphasized this idea, saying: "I wanted to study STEM since I was nine years old." Likewise, Aretha, a Black female biology major from a four-year private liberal arts college, displayed an interest in STEM at "probably about eight or nine, so elementary."

This interest in STEM at a young age allowed students like Rachel and Aretha to enhance varied strengths as well. For example, Rose, a bi-racial neuroscience major from a four-year institution, summarized her self-motivation: "'Can I really do this?' And you know, you have to face that struggle with yourself every day, but once you get past that, it's just the challenge of how hard the courses actually are, and getting the grades..." Even though college was challenging, and she had occasional moments of self-doubt, Rose understood what it would take to excel. Her self-defined strength appeared to be the capacity to be self-reflective, to process challenges and then determine appropriate steps needed to complete her work. In Rose's example, her internal dialogue, prompted by her motivation, was a form of self-validation of her abilities to succeed in STEM. Other participants also described having internal dialogues as ways to motivate and validate themselves. For instance, Terry, an international Black male student (with an unidentified STEM major) at a four-year public university who was aiming to get into medical school, described having to motivate and tell himself every day that "I need to make it into medical school, again." Terry had been in medical school for two years in a foreign country before coming to the U.S. after he won the immigration lottery. Even though Terry had gotten into medical school before, having that internal dialogue motivated him and validated his belief in himself that he could succeed. Reflective dialogues appear to allow students to tap into their interests for motivational purposes, and independently recognize potential challenges that lie ahead and think about ways to navigate them.

Another student strength was self-awareness. Self-awareness appeared to help students envision their future STEM pathways. For example, students such as Ellie, a biracial female biochemistry major, saw themselves going to "medical school, or graduate school after I finish my undergraduate degree" and were confident in these next steps. Her interest in graduate school and self-confidence connected to her overall future goals. Visualizing herself in graduate school was an important step in validating her belonging in the STEM community. In another example, Mason, a Black male second-year student in biomedical engineering at a two-year public community college, discussed how participating in LSAMP prepared him for conferences and internship interviews. "I remember the last [LSAMP] conference at Indianapolis. I couldn't stand up and speak in front of people. They tell us how to stand, how to speak, how to present yourself if you've got an interview." He explained that being an international student presented challenges, especially because English was not his first language. Mason knew that he needed more knowledge to navigate the challenges ahead of him. Participating in LSAMP allowed him to apply to numerous internship opportunities and to learn to speak publicly, likely making him more confident—and competitive—in interviews and conference presentations.

In addition to self-awareness, students' passion for STEM as a strength was important. One notable example is Rachael, a Latinx female biology major, who described giving a group presentation as an example of how her passion drove and prepared her:

> The thing is that I like exploring and want to be ready for the next task and challenge. I'm always ready for the extra pressure. I remember doing a presentation with a group, and

> then we had a basal serotonin, but in there was no definition. The professor asked, "What is the definition on serotonin?" Everyone in the group was like, "What is serotonin?"...I just looked to everyone, I was like, "You were not expecting this question at all?"…Then I just answered it and the professor was like, "At least someone is prepared"…If I have an interview and I just show them the passion, I know what I can do.

It appears that Rachael's passion prepared her for any challenges that may come her way. Rachael's passion motivated her to learn more so that she could always be ready for any question. Her last statement, "I know what I can do," was a way of validating herself and saying that she is capable of succeeding.

The ways in which students talked about their strengths varied from student to student. Some, such as Mary, a bi-racial forensic science major from a four year-institution, took a developmental approach. Mary summarized her self-motivation ("I feel like I am a basic scientist") and her need to gain more experience in labs and research ("I think I need to learn a little bit more. Just keep learning, do some more research, work with more groups and work in the lab environment more"). Mary was describing the importance of seeing herself as a scientist but also having the desire to learn more in her STEM field. This affirmation and desire to learn more encouraged Mary to see herself in graduate school in the future: "If I end up going to graduate school, I feel like I would be getting my Ph.D. during that time." In this instance, Mary, displayed the confidence and ability to have more than one career option, which allowed her to see herself pursuing multiple career paths that include graduate school in STEM. Even though graduate school was not her only option, Mary visualizing herself in graduate school further illustrates patterns of self-confidence and its connections to future goals.

LSAMP Program Provided Validation through Formal, Academic Support

Across institutions and LSAMP programs, students described positive memories of experiences in the LSAMP program. Collectively, their narratives highlight how the program and each partner institution worked together to create formative learning experiences. Jordan, an African American male fourth-year student studying biology, shared how he was benefitting:

> If it wasn't for LSAMP, I don't know how I would have these resources because I've met so many people, been introduced to so many people that I wouldn't have known. I've gotten a lot of information that I wouldn't have known because a lot of times no one is talking to you about how to prepare for graduate school or medical school or any of that stuff. With LSAMP we're constantly being talked to about it, so I feel a lot more prepared.

In the quotation above, Jordan, who was at a four-year private liberal arts college, highlighted one of LSAMP's key components, exposure to graduate school. But notably, he affirmed an LSAMP practice: consistent and ongoing conversations about graduate school, rather than a one-time workshop. It appears that these ongoing conversations made students feel more confident about the possibility of attending graduate school. Similarly, Heather, a Black female second-year biochemistry major, described benefits of participating in the LSAMP program:

> LSAMP helps you network, which is the biggest thing. It teaches you tools that are otherwise not taught to you. For example, the seminar last night was talking about how to communicate correctly. How to communicate and get your point across or understand different personalities, which is key. Especially when you're trying to collaborate on projects with other human beings.

In her quotation, Heather referenced how attending a seminar on scientific communication at the annual LSAMP conference was beneficial to her future work. Not only did she learn new information by attending that particular seminar, she became more confident in her capacity to communicate about the work she was doing, a valuable competency should she choose to attend graduate school upon graduation (Burt, 2017). Worthy of note, like Jordan, Heather also commented that what she was learning about research (e.g., communicating to interdisciplinary and diverse audiences) had not been taught in other educational contexts (e.g., classroom). These findings suggest that if not for participating in the LSAMP program, some students may not receive important information about navigating and succeeding in STEM pathways.

Diversifying participants' communication skills was not the only program component that made students feel validated. All LSAMP students referred to program faculty as being an asset to their experiences. Specifically, students described experiences where faculty supported their learning and development as researchers. For example, Kylie, a bi-racial second-year student double majoring in biology and Spanish at a four-year private liberal arts college, shared the following:

> Really the most support is being able to just go to my professors and ask them questions. [Faculty mentor] has been super supportive, as well…He's like, "I trained her…I want her to stay because I spent so much time training her." My professors at [my institution], are encouraging me. I feel very supported in LSAMP.

Kylie acknowledged the investment her faculty mentor made to train her. She not only feels encouraged and "super" supported, but also that she can openly ask her professor for help. It also appears that Kylie's support did not rest with one faculty member; she referenced positive experiences with several professors.

Mary, a biracial female fourth-year student in forensic science who attends a four-year private university, asserted that talking to professors alleviated stressful situations. Likewise, Aretha, a Black female, first-year student majoring in Biology, mentioned her professor when discussing a time when she felt encouraged to push herself: “My professor encouraged me to even apply for this internship, even though it was for psychology. He's like, I think you would really enjoy it. And just having that support...that was really cool.” Aretha reflected that she felt supported and encouraged to step outside of her specific area of study. As seen from the illustrative examples above, LSAMP participants across institutions, across class levels (e.g., first year, fourth year) and across fields of study described supportive and encouraging LSAMP program faculty. As documented in the literature (Wilson et al., 2012) being able to ask for help and having faculty support is crucial for the development of underrepresented students, especially those in STEM majors. In the case of LSAMP participants, having a constellation of support from several professors contributed to feeling valued and validated in STEM.

Peer support was also important to students’ feeling validated in STEM. The students' narratives were rich with stories not only of helping each other through classes, homework assignments, and figuring out how to conduct research in the laboratory, but also of how their LSAMP participation helped them develop groups of friends with whom to "hang out" and attend social functions. Mary conveyed that speaking with her peers enhanced her network and motivated her to continue on the STEM path: “It's very good for networking. I like how I can talk with different people who are going through the same thing I am, and…to people who have been through it and have gotten success….It gives me inspiration.” Mary affirmed that she liked being able to “network” and engage with her peers about what she was going through. As stated by Bowman and Holmes (2018), URE experiences tend to provide students with critical thinking and communication skills that aid in their retention. Not only did LSAMP provide opportunities for undergraduates to support one another, it also was effective in connecting them with graduate students. For instance, Terry, a junior and international Black male student (unidentified STEM) described his experience working with a graduate student:

> I think the graduate student I worked with...actually made me like [research]. He was really good at communication. I learned a lot from him. The graduate student was there for me all the time...He helped me prepare my poster. I attended four or five different conferences. And last conference I won first place for the experimental research.

Terry stated that the graduate student in his research lab supported him in various ways while he prepared for a research poster presentation. By participating in LSAMP, students received mentoring, support, and encouragement from peers across different levels (i.e., graduate student, and undergraduate peers) within their URE experience. This intergenerational and interclass-level support contributed to the quantity and quality of relationships within STEM.

Some students said they were able to use LSAMP to launch into other STEM opportunities that contributed to their retention in the field. Mike, a Black male third-year student in electrical engineering at a four-year public university, mentioned that his LSAMP experience led him to the McNair program: "So yeah, I think McNair—I think LSAMP contributed to that somehow, just because that's how I got introduced to research, through LSAMP, and that's how I decided to go to grad school." For Mike, the exposure to research and program staff and faculty provided by LSAMP assisted in his pursuit of and acceptance into the McNair Program. According to Mike, both LSAMP and McNair further solidified his interest in STEM work and influenced his goal to attend graduate school. Not only did he begin pursuing additional STEM opportunities (e.g., more research, conferences, internships), he insisted that his friends from the programs do so as well. This finding is worth noting because Mike not only explained what he individually got from participating in LSAMP, he also described having a friend group that also benefitted. His comments highlight that he wanted to promote and celebrate the collective progress of his peers. This finding is illustrative of students from underrepresented populations, who have been shown to have community-focused and altruistic reasons for pursuing STEM (Burt & Johnson, 2018), compared to their White male counterparts who have been described as being more individualistic and competitive (Seymour & Hewitt, 1997). LSAMP provided students with cohorts of talented, motivated, and supportive peers to learn from and with.

Mason, a Black male second-year student in biomedical engineering at a two-year public community college, also explained how participating in LSAMP opened doors for him to apply for additional research endeavors away from his own university:

> I have applied for different internships at different universities through LSAMP. If I get in, I'll…have a chance to do research….It will help…with the career that I'm going for. It gives me…motivation. Because I see a lot of other people do it, I want to do it.

Because of the foundation of research gained through LSAMP, Mason now saw how he could further his research skills at another research site and felt confident enough to apply for additional research endeavors.

Participation in LSAMP served as a building block for continued participation in STEM-related activities. With increased participation in the STEM community, some students appeared to feel more connected to their STEM field, research, and the potential to remain in STEM. Based on existing literature, it is possible that students felt more confident in and connected to STEM because of their exposure to other talented, high-achieving students from underrepresented backgrounds. This finding relates to the work of Fries-Britt (1998), who found that high-achieving Black students thrive when connected to other high-achieving students. Like those in the current study, the students in Fries-Britt's were in the STEM-focused Meyerhoff program for historically underrepresented students of color. These students were highly capable and motivated to succeed. Like LSAMP, the Meyerhoff program provided structure, practices and activities that helped students make progress, feel valued and see themselves in STEM. Thus, there appear to be cumulative positive effects of participating in (multiple) STEM-related programs, especially those designed for underrepresented students. Most notably, participation helped students to better see themselves as long-term participants in STEM (i.e., STEM identity).

Students Experienced Evolving Forms of Scientific and Identity Development

Throughout their STEM experiences, student participants were self-aware about how they interacted with their various forms of identity. Researchers have noted how students describe their own identities (Kim et al., 2018; Lu, 2015). Students in this study indicated that, at times, they experienced both positive and negative growth. One way in which they experienced growth was through discovering that their identity created barriers for them in their STEM fields. Students in the study often disclosed that they felt barriers existed in relation to their participation and retention in STEM. As an ongoing process of their identity development, students encountered tensions and challenges to their growth. For example, Samantha, an Asian female computer science major at a two-year public community college explained:

> I'm from a different country. The most important thing here is the language and that is really difficult for me. It is a lot of work. I really struggle with the vocabulary. For example, coding in the same words so everybody can use it.

Samantha stated that a barrier for her is the language difference between her home country (Cambodia) and the United States. Samantha's difficulties communicating were not exclusively related to classroom experiences. Rather, she described her limitations to fully participating in STEM activities (e.g., working on team projects, engaging in the research lab) as being due to difficulty translating her native language to English. Rachael, a third-year Biology student at a four-year private liberal arts college, had a similar experience pertaining to her international status. Rachael, who was originally from Brazil, said, “Until last year, I was the only international student who was in biology [aiming for] medical school, and it kind of weirded me so much, like why I'm the only one?” Rachael’s quotation illustrates how being underrepresented—in her case, as an international student—prompted her thinking of her international status as a salient identity in STEM. Being the sole international student in her major made her feel uncomfortable and “weird.” Further, her awareness of her identity made her question her field of study, goal of attending medical school, and sense of self. Her identity in STEM was not validated by the presence of international peers. This highlights how one’s identity within an educational environment can hinder feelings of belonging and validation.

The process of questioning one’s self due to one’s identity did not only apply to Rachael as an international student. Aretha, a Black female also majoring in biology, reflected on her gendered and racialized identities and how they functioned as challenges to thriving in STEM:

> For me, yeah [my identities are challenges]. Just 'cause I'm a minority and I'm a female. But I know that if I keep working hard and proving myself—I know it's harder for a woman of color to get hired in some places just because of how they're perceived, such as maybe the way they act or think. So, I would say that would definitely be a huge challenge just to get through [STEM].

In the quotation above, Aretha realized that she confronts two barriers. She shared her opinion that as a woman who is also Black, she is held to different standards. In addition, she highlighted the role her gender played in how others validated her. She acknowledged that it is difficult for women to succeed in STEM and identified others’ response to her gender as something that she had to overcome. At times, it appeared that she was not describing experiences that she has had, but rather describing what she has come to know about the experiences of women—and Black women, in particular—in today's U.S. society. Her words illustrate added self-pressure to work harder in order to be recognized as legitimate in the STEM community.

When asked if they considered themselves to be a scientist or not, students' responses varied; some accepted a scientific identity, others denied it, and others still were not sure. Cahya, an Asian male studying software development at a public community college, stated: "I don't know—what is a scientist?" Cahya was unsure that the term "scientist" related to his field. Part of Cahya's uncertainty related to a misalignment between what he envisioned scientists to be and the kinds of work and interests he was currently engaged in. Further, he wrestled with whether scientists create discoveries to help others or develop products for financial gain. Mark, a Hispanic male in architecture at a four-year public university, also grappled with the idea of being or not being a scientist: "That's a tough one. Probably not. Well, I guess you could say kind of, 'cause I have to analyze data, which is part of the process." Like Cahya, Mark attempted to make sense of what scientists do, based on his understanding of the research process.

Danielle, an international Black female majoring in environmental science at a four-year private liberal arts college, suggested that to her, becoming a scientist would occur over time and through workload completion: "I don't think I'm a scientist now, but I feel like I will probably never feel like a scientist...I don't think I will ever just sit back and be like, dang, I have done enough." Danielle, who was not yet convinced of her scientific identity, offered a sobering revelation; she might never feel validated as a scientist. This sentiment appears to echo what previous literature suggests about women of color in science and how they may not always feel like they belong within STEM environments (Archer et al., 2013; Neumann et al., 2016).

Danielle seemed hesitant to name herself as a scientist because of the expectation of needing to achieve notable results. This was evident when Danielle stated that maybe in the future when she has “done enough,” she will feel like a scientist, implying that individuals need a certain number of accomplishments or to achieve an unspecified criteria to claim a science identity. Although Danielle indicated that her identity as a scientist was developing, it is possible that she did not yet see herself as a scientist because of the lack of other underrepresented people in STEM.

In contrast to those who were unsure of their scientific identities, some students excitedly shared that they saw themselves as scientists. Ellie, a biracial female majoring in biochemistry at a four-year private liberal arts college, explained how she defined the work of scientists: “Just answering the questions of ‘Why’ and ‘How?’ things work. And finding that tough question that maybe other people have asked but haven't answered.” Ellie’s quotation connects how she sees herself and others labeled as scientists in her field. Asking questions and thinking about the process of “how” and “why” things happen, she is able to assert herself as a scientist. Leonardio, a biochemistry major at a four-year private liberal arts college, had a similar understanding:

> Yes! I just find science very exciting. When you actually figure out how something works. All this time you're sitting there, "Oh, how does this work?" and then you finally figure it out and you're like, "Man, this totally makes sense!" Then you wanna take it even farther, you wanna learn even more about it.

Leonardio shared that science excited him. He explained that understanding “how” something works justifies science. Additionally, Leonardio shared that he had a desire to learn and better understand “how” science works. He went on to say, “I have considered myself a scientist since probably as I entered high school. In my free time I read books on science. I was just always trying to learn more and more about science." Leonardio implied that scientists always want to learn more; they are "inquisitive and have this hunger for knowledge."

In whole, although participants ranged in their understandings of what a scientist was in their field of study and whether they saw themselves as scientist or not, often seeking more appropriate labels to describe themselves, their responses highlighted the complex ways in which they made sense of their scientific identities. Further, these findings highlight a connection between how students view their current scientific identity and what it would take to have a stronger scientific identity (e.g., more years, more research, more scientific accomplishments).

DISCUSSION

Students of color who participate in undergraduate research diversity programs tend to have positive experiences and exposure to STEM, are more likely to attend graduate school, and are more likely to enter the STEM workforce (May & Chubin, 2003). Although existing literature highlights the benefits of STEM diversity programs (e.g., McNair, Myerhoff) for students of color, their underrepresentation in the STEM field and workforce remains constant. In this study, we aimed to focus on one STEM diversity program, LSAMP, and in so doing, gain a more nuanced understanding of how participation in LSAMP facilitates students' engagement with scientific research and professions, and influences students' emerging identities and perceptions of science. The federally funded LSAMP has served as a validating intervention aimed at broadening participation in STEM for individuals historically underrepresented in STEM fields for more than three decades (Baber & Jackson, 2018). With a focus on one LSAMP program from both a campus-level and an alliance-level perspective, we investigated how validating experiences in the LSAMP program contributed to underrepresented students' participation in STEM. Our findings, based on 20 students in various STEM fields of study across eight institutions, shed light on programmatic efforts that provided validating experiences as students transitioned into or matriculated through STEM majors. In particular, there was evidence that some students entered the LSAMP program with strong self-efficacy and validated feelings towards their STEM field. For them, a validating process that encouraged intellectual curiosity and hands-on development of research skills was connected to the identity of being a scientist. Others, however, did not connect themselves to a science identity. This finding is intriguing given that validating activities supporting broader STEM participation aim to foster affective feelings towards students' fields of study and becoming long-term, skilled participants.

While participants described positive experiences in their LSAMP program and its programs and activities, it is unclear why the majority did not yet see themselves validated as scientists. Our findings offer a sober reminder that some underrepresented students, even those already participating in typical scientific behaviors and norms in a STEM environment, may experience a delayed feeling of affective connection with a science identity. Their perceptions of what it means to be a scientist may be rooted in traditional scientific epistemology, which stresses detached observation. For emerging scientists from underrepresented backgrounds, the traditional perspective on objectivity misaligns with experiences of cultural particularism in STEM fields, shaping how they view themselves as participants and how others make them feel as members of the STEM community. Existing research describes how hostility in a STEM community, including microaggressions that underrepresented students face, can make it challenging for students to see themselves validated in STEM (Burt et al., 2019; Burt et al., 2018). Difficulty seeing themselves in STEM might be especially challenging for women of color (e.g., Black women) who are often subjected to "double bind constructs" within STEM (Charleston et al., 2014; Ong et al., 2011; Sanchez et al., 2020). This finding raises questions: Do some students question their science identity, not because of lack of technical confidence, but as a result of observing disconnections between the objective process of scientific inquiry and the subjective culture of scientific communities? Further, does growing into a science identity reflect damaging assimilation or complex resistance? If growth into a science identity is possible, future research needs to investigate this phenomenon, and intervention programs like LSAMP should consider ways to assist participants in developing a science identity. These might include programming and activities to support participants' sense of self and feelings of science identity. Necessary in this recommendation, however, is helping students to reimagine what they perceive a scientist to be. While their perceptions of science and the work of scientists are likely to vary across fields, helping them think about scientific work as an outcome (e.g., a product resulting from research; a community-based, altruistic use of research to help people) might be useful. Additionally, helping them see how their identities *are* examples of those of scientists could increase their self-confidence and validation and reduce their concerns about belonging in STEM.

IMPLICATIONS FOR RESEARCH AND STEM DIVERSITY PROGRAMS

Existing research highlights numerous efforts to broaden participation in STEM fields for historically underrepresented students (e.g., McNair; Meyerhoff) (Fries-Britt, 1998; Hrabowski, 2001; NAS, 2019). More research is needed to identify the unique characteristics embedded in these programs that help students to see themselves as members of the STEM community. While we were able to capture a critical mass of students at the LSAMP conference, more sustained interactions with participants would provide more evidence of the evolutionary nature of students' STEM identities and identification with STEM. Scholars taking this approach might design a study that captures students' academic lifespan in STEM. A study of this nature would follow students from their entry into their STEM diversity program through their graduation from college or graduate school. Granted, this type of study may not capture all of students' experiences and predispositions to STEM (e.g., early interests in STEM; pre-intervention program experiences). However, in efforts to more fully understand how participation in STEM diversity programs influences students' development over time, this longitudinal design focused on the intervention would be beneficial. In addition, this type of research design that captures students' experiences across their academic lifespan could address some concerns of recency and primacy effects (Greene et al., 2000) that might result from one-time interviews or surveys, especially if conducted immediately after an invigorating or detrimental occurrence. Overall, future research that pinpoints the magic of intervention efforts, in conjunction with the existing skills and characteristics students bring with them to campus, will contribute to the development of promising practices for other STEM diversity programs, as well as assist STEM academic departments in reforming their policies and practices to be more inclusive.

The findings from our study also offer implications for STEM diversity programs. Specifically, students consistently mentioned that a highlight of their LSAMP program was its formal, academic support. In diversity programs like LSAMP, formal efforts to increase the participation and academic performance of underrepresented students tend to be intentionally included in their programmatic design (Fries-Britt, 1998; Hrabowski, 2001). This support in our study usually came in the form of mentoring. However, we realized that "mentoring" was being discussed in different nuanced ways. The majority referred to "mentoring" as the programmatic component of LSAMP where a student is assigned a research "mentor"; importantly, in some LSAMP programs, students also referred to their LSAMP program staff as mentors. The research mentor, in particular, held the responsibility of shepherding students through their research experience and exposing students to science and graduate school (Byars-Winston et al., 2020; Maton et al., 2000). However, participants suggested that they needed more mentoring, but not necessarily that which their assigned "research mentor" could provide. That is, while most students did not speak negatively about their experiences with their research mentors, many—particularly women and those from historically underrepresented racial and ethnic backgrounds—described wanting additional mentoring from individuals holding their social identities. This insight from study participants suggests that mentoring around a research project might not be enough for, nor meet the full needs of, students in diversity programs. This might be especially true for those who desire a stronger connection between their social identities and what it means to be a scientist. Similarly, scholarship focused on underrepresented students' mentoring experiences highlights that students who see themselves in STEM are more likely to attend graduate school (NAS, 2019). Diversity programs that facilitate connections to additional mentors—even if informally—that link students' social identities to their scientific field would help validate students' sense of belonging in STEM. Further, this connection between STEM mentors and students' social identities could assist students in seeing themselves as long-term participants in and contributors to STEM. This recommendation supports existing scholarship on the importance of creating mentoring networks (Griffin, 2012), which asserts that no one mentor can provide an individual with everything needed. Instead, students should be encouraged to—and diversity program staff can help to facilitate—build constellations of mentors who can help meet their needs. Based on the needs described by our participants, diversity programs that include this kind of mentoring team might include a research mentor, a mentor to help the student gain a better understanding of graduate school and the application process, and finally, another mentor who might help the student balance the pressures of the academy while holding an underrepresented social identity. Encouraging—and helping to facilitate—formation of a mentoring team might help reduce the pressure on any one faculty member, administrator, or staff member. In addition, encouraging this type of mentoring team might help students to learn how to assess their unique needs and identify human resources to help meet those needs.

Mentoring should also come in the form of peer support. In the present study, some students described having to work harder to be seen and validated because of their identities (e.g., gender, race, international status). It was not evident from our data that the LSAMP program—across partner institutions—offered programming to combat the microaggressions students might face in STEM. However, students regularly described their LSAMP peers as sources of support in navigating isolating STEM communities that were incongruent with their multiple identities. Diversity programs aiming to reduce the impacts of being underrepresented in STEM should incorporate programmatic efforts that connect students with each other. Some studies have shown and discussed how mentors encourage underrepresented students to rely on each other and participate in peer mentoring, emphasizing the roles of peer interaction and forming connections (May & Chubin, 2003; Mondisa, 2020). Such programming—and/or informal interactions—should be framed around support and not competition. That is, the rare opportunities for underrepresented students to interact with each other should mitigate and not propagate the competitive ethos already found within the STEM community (Palmer et al., 2011). Intentional and frequent opportunities for students to see other students who hold similar social identities will further help to validate students' sense of belonging and presence in STEM.

CONCLUSION

Since its inception in the early 1990s, LSAMP has served as a key program for increasing persistence and completion rates among underrepresented students pursuing STEM (Baber &

Jackson, 2018). This study, aimed at examining the practices and activities that contribute to broadening participation of underrepresented students within one LSAMP alliance (IINSPIRE-LSAMP), discovered patterns of positive experiences among students historically marginalized by normative practices in postsecondary STEM education. As opposed to focusing on deficit perspectives around individual dispositions, institutions would be better served by leveraging insights offered from this study's findings and scaling sustainable practices and activities students identified. To be clear, although much of the focus of this study was on the programmatic elements of students' LSAMP programs, students were not empty vessels upon arriving to college. That is, many were self-aware of their existing strengths. Effective LSAMP practices, then, validated and further nurtured those strengths. These practices, which were not necessarily LSAMP-based program goals, might have been created by individual LSAMP administrators. Leveraging this insight with a validation-centered philosophy, STEM educators should consider how to more consistently help students see their strengths. Helping students see their strengths, especially when transferable to their STEM practice, may help to improve and/or further strengthen their science identities.

One strength mentioned by some participants was the ability to navigate in STEM despite obstacles. We are not suggesting that students should have to negotiate obstacles in STEM (e.g., racism, sexism, underrepresentation). In fact, we argue that the flat rate of growth in broadening participation in STEM for historically underrepresented populations is in part due to the obstacles they encounter. Centering a validating educational process throughout students' STEM pathways (both in the curriculum and co-curriculum) may allow students to bring their whole beings to their desired STEM profession. By more intentionally validating students, this suggested change to STEM education would challenge the impersonal culture of postsecondary STEM education that is neither fully meritocratic nor value neutral.

Table 1

Self-Reported Student Demographic Information

Pseudonym	**Institution**	**Age**	**Race and/or Ethnicity**	**Gender**	**Academic Status**	**Academic Major**
Aretha	4-year private	19	Black	Female	Freshman	Biology
Cahya	2-year public	41	Asian	Male	Sophomore	Software
Danielle	4-year private	19	African (Nigerian)	Female	Freshman	Environmental Sciences
Ellie	4-year private	18	African American & White	Female	Freshman	Biochemistry
Heather	2-year public	24	Black	Female	Sophomore	Biochemistry
Jordan	4-year private	23	African American	Male	Senior	Biology
Juan	2-year public	24	Mexican	Male	Sophomore	Conservation
Kylie	4-year private	19	Hispanic & Caucasian	Female	Sophomore	Bio & Spanish
Leonardio	4-year private	19	White & Hispanic	Male	Freshman	Biochemistry
Marissa	4-year public	25	Black African	Male	Senior	Mechanical & Materials Engineering
Mark	4-year public	23	Hispanic/Latinx	Male	Senior	Architecture
Mary	4-year private	21	White & Puerto Rican	Female	Senior	Forensic Science
Mason	2-year public	21	Black	Male	Sophomore	Biomedical Engineering
Matthew	4-year public	23	Pacific Islander	Female	Senior	Mechanical Engineering
Mike	4-year public	23	Black	Male	Junior	Electrical Engineering
Rachael	4-year private	20	Latinx	Female	Junior	Biology
Rose	4-year private	19	Bi-racial	Female	Sophomore	Neuroscience
Samantha	2-year public	27	Asian	Female	Freshman	Computer Science
Susan	4-year private	19	Black & Hispanic	Female	Sophomore	Pre-Vet
Terry	4-year public	23	Black	Male	Junior	STEM

REFERENCES

Adamian, A. S., & Jayakumar, U. M. (2018). Mutual engagement in spaces of tension: Moving from dialogue toward action across multiple contexts. *The Educational Forum, 82*(3), 335-350. https://doi.org/10.1080/00131725.2018.1458359

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171-194. https://doi.org/10.1080/14681366.2012.748676

Baber, L. D. (2020). Color-blind liberalism in postsecondary STEM education. In E. O. McGee & W. H. Robinsin (Eds.), *Diversifying STEM: Multisiciplinary Perspectives on Race and Gender (19-35)*. New Brunswick: Rutgers University Press.

Baber, L. D. (2015). Considering the interest-convergence dilemma in STEM education. *Review of Higher Education*, *38*, 251-270. https://doi.org:10.1353/rhe.2015.0004.

Baber, L. D, & Jackson, J. (2018). From the edge of success to the center: Development of LSAMP alliances, 1987-2017. *IINSPIRE LSAMP Research Brief, 2*. Ames: Iowa State University. http://www.iinspirelsamp.org/wp-content/uploads/2016/11/Quantitative-Research-Brief_2018.pdf

Bahr, P. R., Jackson, G., McNaughtan, J., Oster, M., & Gross, J. (2017). Unrealized potential: Community college pathways to STEM baccalaureate degrees. *The Journal of Higher Education*, *88*(3), 430-478. https://doi.org/10.1080/00221546.2016.1257313

Bhattacharya, K. (2017). *Fundamentals of qualitative research: A practical guide*. Routledge.

Bowman, N. A., & Holmes, J. M. (2018). Getting off to a good start? First-year undergraduate research experiences and student outcomes. *Higher Education*, *76*(1), 17-33. https://doi.org/10.1007/s10734-017-0191-4

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77-101.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching*, *37*, 441–458. https://doi.org/10.1002/(SICI)1098-2736(200005)37:5<441::AID-TEA4>3.0.CO;2-3

Brothers, E., & Knox, B. (2013). Best practices in retention of underrepresented minorities in Science, Technology, Engineering, and Mathematics (STEM) in the Tennessee Louis Stokes Alliance for Minority Participation (Tennessee LSAMP). *Journal of Intercultural Disciplines, 11*, 71.

Burt, B. A. (2017). Learning competencies through engineering research group experiences. *Studies in Graduate and Postdoctoral Education, 8*(1), 48-64. https://doi.org/10.1108/SGPE-05-2017-019

Burt, B. A. (2019). Toward a theory of engineering professorial intentions: The role of research group experiences. *American Educational Research Journal, 56*(2), 289-332. https://doi.org/10.3102/0002831218791467

Burt, B. A., & Johnson, J. T. (2018). Origins of STEM interest for black male graduate students in engineering: A community cultural wealth perspective. School Science and Mathematics, 118(6), 257-270. https://doi.org/10.1111/ssm.12294

Burt, B. A., McKen, A., Burkhart, J., Hormell, J., & Knight, A. (2019). Black men in engineering graduate education: Experiencing and coping with racial microaggressions within the advisor-advisee relationship. *Journal of Negro Education, 88*(4), 493-508. https://doi.org/10.7709/jnegroeducation.88.4.0493

Burt, B. A., Williams, K. L., & Smith, W. A. (2018). Into the storm: Ecological and sociological impediments to Black males' persistence in engineering graduate programs. *American Educational Research Journal, 55*(5), 965-1006. https://doi.org/10.3102/0002831218763587

Byars-Winston, A., Leverett, P., Benbow, R. J., Pfund, C., Thayer-Hart, N., & Branchaw, J. (2020). Race and ethnicity in biology research mentoring relationships. *Journal of Diversity in Higher Education, 13*(3), 240–253. https://doi.org/10.1037/dhe0000106

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *44*(8), 1187-1218. https://doi.org/10.1002/tea.20237

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching*, *51*(5), 555-580. https://doi.org/10.1002/tea.21146

Charleston, L., Adserias, R., Lang, N., & Jackson, J. (2014). Intersectionality and STEM: The role of race and gender in the academic pursuits of African American women in STEM. *Journal of Progressive Policy & Practice*, *2*(3), 273-293.

Chubin, D. E., & Ward, W. E. (2009). Building on the BEST principles and evidence: A framework for broadening participation. In M. K. Boyd & J. L. Weseman (Eds.), *Broadening participation in undergraduate research: Fostering excellence and enhancing the impact* (pp. 21-30). Council on Undergraduate Research.

Craney, C., McKay, T., Mazzeo, A., Morris, J., Prigodich, C., & De Groot, R. (2011). Cross-discipline perceptions of the undergraduate research experience. *The Journal of Higher Education*, *82*(1), 92-113. https://doi.org/10.1080/00221546.2011.11779086

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry & research design: Choosing among five approaches* (4th ed). Sage

Crisp, G., & Cruz, I. (2009). Mentoring college students: A critical review of the literature between 1990 and 2007. *Research in Higher Education*, *50*(6), 525-545. https://doi.org/10.1007/s11162-009-9130-2

Daniels, H., Grineski, S. E., Collins, T. W., Morales, D. X., Morera, O., & Echegoyen, L. (2016). Factors influencing student gains from undergraduate research experiences at a Hispanic-serving institution. *CBE—Life Sciences Education, 15*(3), ar30. https://doi.org/10.1187/cbe.15-07-0163

Dika, S. L., & D'Amico, M. M. (2016). Early experiences and integration in the persistence of first- generation college students in STEM and non- STEM majors. *Journal of Research in Science Teaching*, *53*(3), 368-383. https://doi.org/10.1002/tea.21301

Dowd, A.C., & Bensimon, E. M. (2015). *Engaging the "race question": Accountability and equity in U.S. higher education*. New York, NY: Teachers College Press.

Espinosa, L. (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review, 81*(2), 209–241. https://doi.org/10.17763/haer.81.2.92315ww157656k3u

Fries-Britt, S. L. (1998). Moving beyond Black achiever isolation: Experiences of gifted Black collegians. *Journal of Higher Education, 69*(5), 556-576. https://doi.org/10.1080/00221546.1998.11775151

Fries-Britt, S., & White-Lewis, D. (2020). In pursuit of meaningful relationships: How Black males perceive faculty interactions in STEM. *The Urban Review*, 1-20. https://doi.org/10.1007/s11256-020-00559-x

Greene, A. J., Prepscius, C., & Levy, W. B. (2000). Primacy versus recency in a quantitative model: Activity is the critical distinction. *Learning & Memory*, *7*(1), 48-57.

Griffin, K. A. (2012). Black professors managing mentorship: Implications of applying social exchange frameworks to our understanding of the influence of student interaction on scholarly productivity. *Teachers College Record, 114*(5), 1-37.

Haeger, H., & Fresquez, C. (2016). Mentoring for inclusion: the impact of mentoring on undergraduate researchers in the sciences. *CBE—Life Sciences Education, 15*(3), ar36. https://doi.org/10.1187/cbe.16-01-0016

Harper, S. R. (2010). An anti- deficit achievement framework for research on students of color in STEM. *New Directions for Institutional Research*, *2010*(148), 63-74. https://doi.org/10.1002/ir.362

Hathaway, R. S., Nagda, B. A., & Gregerman, S. R. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study. *Journal of College Student Development*, *43*(5), 614-631.

Hernandez, P. R., Hopkins, P. D., Masters, K., Holland, L., Mei, B. M., Richards-Babb, M., & Shook, N. J. (2018). Student integration into STEM careers and culture: A longitudinal examination of summer faculty mentors and project ownership. *CBE—Life Sciences Education*, *17*(3), ar50. https://doi.org/10.1187/cbe.18-02-0022

Hrabowski III, F. A. (1991). Helping gifted Black males succeed in science. *Journal of Health Care for the Poor and Underserved*, *2*(1), 197-201. https://doi.org/10.1353/hpu.2010.0384

Hrabowski III, F. A. (2001). Communications-The Meyerhoff Scholars Program. *Notices of the American Mathematical Society*, *48*(1), 26-28.

Hunter, A. B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36-74. https://doi.org/10.1002/sce.20173

Johnson, J. D., Starobin, S. S., & Santos Laanan, F. (2016). Predictors of Latina/o community college student vocational choice in STEM. *Community College Journal of Research and Practice*, *40*(12), 983-1000. https://doi.org/10.1080/10668926.2016.1204963

Kim, A. Y., Sinatra, G. M., & Seyranian, V. (2018). Developing a STEM identity among young women: A social identity perspective. *Review of Educational Research*, *88*(4), 589-625. https://doi.org/10.3102/0034654318779957

Lane, T. B. (2016). Beyond academic and social Integration: Understanding the impact of a STEM enrichment program on the retention and degree attainment of underrepresented students. *CBE-Life Sciences Education 15*, 1-13. https://doi.org/10.1187/cbe.16-01-0070

Linares, L. I. R., & Muñoz, S. M. (2011). Revisiting validation theory: Theoretical foundations, applications, and extensions. *Enrollment Management Journal*, *2*(1), 12-33.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science*, *347*(6222), 1261757. https://doi.org/10.1126/science.1261757

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education, 6*(4), 297-306. https://doi.org/10.1187/cbe.07-06-0039

Lopez, C., & Jones, S. J. (2017). Examination of factors that predict academic adjustment and success of community college transfer students in STEM at 4-year institutions. *Community College Journal of Research and Practice*, *41*(3), 168-182. https://doi.org/10.1080/10668926.2016.1168328

Lu, C. (2015). Finding los científicos within: Latino male science identity development in the first college semester. *Journal of College Student Development*, *56*(7), 740-745. https://doi.org/10.1353/csd.2015.0069

Malcom, S. M. (1990). Reclaiming our past. *The Journal of Negro Education*, *59*(3), 246-259.

Malcolm, S. M., Hall, P. Q., & Brown, J. W. (1976). *The double bind: The price of being a minority woman in science* (N. 76-R-3). American Association for the Advancement of Science.

Maton, K. I., Hrabowski III, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. *Journal of Research in Science Teaching, 37*(7), 629-654. https://doi.org/10.1002/1098-2736(200009)37:7<629::AID-TEA2>3.0.CO;2-8

May, G. S., & Chubin, D. E. (2003). A retrospective on undergraduate engineering success for underrepresented minority students. *Journal of Engineering Education*, *92*(1), 27-39. https://doi.org/10.1002/j.2168-9830.2003.tb00735.x

McGee, E. O., & Robinson, W. H. (Eds.). (2019). *Diversifying STEM: Multidisciplinary perspectives on race and gender*. Rutgers University Press.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation (4th edition).* Jossey-Bass.

Mondisa, J. L. (2020). The role of social capital in African American STEM mentoring relationships. *Journal of Women and Minorities in Science and Engineering*, *26*(2),125-

153. https://doi.org/10.1615/JWomenMinorScienEng.2020022267

National Academies of Sciences, Engineering, and Medicine. (2019). *The Science of Effective Mentorship in STEMM*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25568.

National Science Board (2016). *Science and engineering indicators 2016*. NSB-2016-1. https://www.nsf.gov/nsb/publications/2016/nsb20161.pdf

National Science Board (2018). *Science and engineering indicators 2018*. NSB-2018-1. National Science Foundation. https://www.nsf.gov/statistics/indicators/.

National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering*. https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_178246.pdf

Neumann, M. D., Lathem, S. A., & Fitzgerald-Riker, M. (2016). Resisting cultural expectations: Women remaining as civil and environment engineering majors. *Journal of Women and Minorities in Science and Engineering*, *22*(2), 139-158. https://doi.org/10.1615/JWomenMinorScienEng.2016013949

Ong, M., Wright, C., Espinosa, L., & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard Educational Review*, *81*(2), 172-209. https://doi.org/10.17763/haer.81.2.t022245n7x4752v2

Palmer, R. T., Maramba, D. C., & Dancy, T. E. (2011). A qualitative investigation of factors promoting the retention and persistence of students of color in STEM. *The Journal of Negro Education*, 491-504.

Patton, L. D. (2016). Disrupting postsecondary prose: Toward a critical race theory of higher education. *Urban Education*, *51*(3), 315-342. https://doi.org/10.1177/0042085915602542

Peshkin, A. (1988). In search of subjectivity. One's own. *Educational Researcher*, *17*(7), 17-21. https://doi.org/10.3102/0013189X017007017

Rendón, L. I. (1994). Validating culturally diverse students: Toward a new model of learning and student development. *Innovative Higher Education*, *19*(1), 33-51.

Rincón, B. E. (2018). Does Latinx representation matter for Latinx student retention in STEM? *Journal of Hispanic Higher Education*. https://doi.org/10.1177/1538192718820532

Rincón, B. E., & George-Jackson, C. E. (2016). STEM intervention programs: Funding practices and challenges. *Studies in Higher Education*, *41*(3), 429-444. http://dx.doi.org/10.1080/03075079.2014.927845

Robnett, R. D., Chemers, M. M., & Zurbriggen, E. L. (2015). Longitudinal associations among undergraduates' research experience, self- efficacy, and identity. *Journal of Research in Science Teaching*, *52*(6), 847-867. https://doi.org/10.1002/tea.21221

Rodriguez, S., Cunningham, K., & Jordan, A. (2019). STEM identity development for Latinas: The role of self-and outside recognition. *Journal of Hispanic Higher Education*, *18*(3), 254-272. https://doi.org/10.1177/1538192717739958

Sanch*ez,* M. E., Hypolite, L. I., Newman, C. B., & Cole, D. G. (2020). Black women in STEM: The need for intersectional supports in professional conference spaces. *The Journal of Negro Education*, *88*(3), 297-310.

Scripa, A. J., Lener, E. F., Gittens, C. B., & Stovall, C. (2012). The McNair Scholars Program at Virginia Tech: A unique model of librarian mentoring. *Virginia Libraries, 58*(3). https://doi.org/10.21061/valib.v58i3.1224

Seymour, E., & Hewitt, N. M. (1997) *Talking about leaving: Why undergraduates leave the sciences*. Westview Press.

Squire, D., Williams, B., & Tuitt, F. (2018). Plantation politics and neoliberal racism in higher education: A framework for reconstructing anti-racist institutions. *Teachers College Record*, *120*(14), 1–20.

Starobin, S., Laanan, F. S., & Burger, C. J. (2010). Role of community colleges: Broadening participation among women and minorities in STEM. *Journal of Women and Minorities in Science and Engineering*, *16*(1), 1-5. https://doi.org/10.1615/JWomenMinorScienEng.v16.i1.10

Wilson, Z. S., Holmes, L., Degravelles, K., Sylvain, M. R., Batiste, L., Johnson, M., McGuire, S. Y., Pang, S. S., & Warner, I. M. (2012). Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate STEM disciplines. *Journal of Science Education and Technology*, *21*(1), 148-156. https://doi.org/10.1007/s10956-011-9292-5

Zaniewski, A. M., & Reinholz, D. (2016). Increasing STEM success: A near-peer mentoring program in the physical sciences. *International Journal of STEM Education*, *3*(1), 1-12. https://doi.org/10.1186/s40594-016-0043-2

Zhang, Y. L., Adamuti-Trache, M., & Connolly, J. (2019). From community college attendants to baccalaureate recipients: A planned behavior model for transfer students in STEM fields of study. *The Journal of Higher Education*, *90*(3), 373-401. https://doi.org/10.1080/00221546.2018.1536935

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