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The Pursuit of STEM: Factors Influencing Minority Entrance and Persistence

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ABSTRACT

Continual underrepresentation of racial/ethnic and female students in STEM has spurred research on the factors that inhibit and support their entrance and persistence in the field. Although informative, prior studies are limited by their focus on undergraduate students and by their tendency to examine the isolated, rather than interactive, effects of individual-, interpersonal-, institutional-, and societal-level factors. Thus, this study relies on interview data from 18 minority and/or female graduate students in STEM to explore how individual-, interpersonal-, institutional-, and societal-level factors interact with one another to influence the students' STEM entrance and persistence. Findings suggest there are important interactive effects, but they differ for STEM entrance and STEM persistence. Implications for racial/ethnic diversity and female representation in STEM are discussed.

Keywords: STEM education, STEM entrance, STEM persistence, underrepresented students

INTRODUCTION/BACKGROUND

Science, technology, engineering, and mathematics (STEM) fields have traditionally been—and continue to be—dominated by White men (McGee, 2016). Thus, while the educational attainment of minority students within STEM has improved in recent decades, women and students of color continue to be underrepresented (Rincón & Rodriguez, 2021; Valla & Williams, 2012). Such underrepresentation has spurred scholars to examine not only the factors that impact entrance into STEM fields, but also the factors that impact persistence and eventual degree attainment. For instance, existing research suggests that institutional resources, including clubs and tutoring centers, can influence STEM entrance, while an individual's feelings of belonging and self-efficacy can influence STEM persistence (Rainey et al., 2018). This focus on both institutional and individual-level effects is important because it suggests that the factors impacting minority student STEM participation are likely quite varied.

In fact, interpersonal- and societal-level factors also matter for minority student STEM participation (Xie et al., 2015), and they, along with individual- and institutional-level factors, likely interact with one another, thereby impacting minority student STEM participation in complex and nuanced ways. Yet, however, existing research has not examined the degree to which individual-, interpersonal-, institutional-, and societal-level factors interact to affect STEM entrance and persistence. Moreover, existing research tends to focus on undergraduate students, and while it is possible to examine both entrance and persistence with that demographic, we contend that discussions with graduate students will allow for a deeper exploration of persistence processes.

Thus, this study relies on interview data from 18 underrepresented STEM graduate students in universities throughout California. It also uses the socio-ecological model of behavior as a backdrop for examining how individual-, interpersonal-, institutional-, and societal-level factors influence underrepresented students' efforts to enter and persist in STEM. We demonstrate that these factors do interact but the interactive processes differ for entrance and persistence, and that has important implications for racial/ethnic diversity and female representation in STEM.

LITERATURE REVIEW

The Socio-Ecological Model

The socio-ecological model of behavior suggests that human actions are influenced by overlapping factors occurring at the individual-, interpersonal, institutional-, and societal-level of influence (Bronfenbrenner,

1977; Kilanowski, 2017). More specifically, individual-level factors are those that impact a person on a personal level. Within an educational context, individual-level influences could include a person's beliefs about their own abilities in a particular area of study. Interpersonal-level factors focus on how relationships impact a person's decisions. For example, relationships between students and their parents, peers, and teachers can support or hinder educational attainment. Institutional-level factors focus on how institutions impact an individuals' decisions. Universities are, by definition, institutions that can impact students' success in STEM subjects. For example, the availability of scholarships, fellowships, and research experiences can assist students along their STEM journey, while the absence of those things can hinder entrance or persistence. Finally, societal-level factors look at how social norms and culture impact a person's decisions. Within an educational context, it is possible that existing social norms and prejudices might inhibit some people's willingness to pursue certain types of degrees. For instance, research suggests that, in general, minority students are less likely to pursue STEM degrees, in part because existing stereotypes create uninviting educational environments for them (Martin, 2016).

The socio-ecological model's emphasis on individual-, interpersonal-, institutional-, and societal-level influences offers an important framework for examining the factors that influence students' educational trajectories. Because it accounts for interactions within these levels of influence, it is particularly useful for drawing attention to how factors at one level can impact factors at another level. Moreover, although existing research has explored the independent effects of individual-, interpersonal-, institutional-, and societal-level factors on underrepresented students' STEM entrance and persistence, few studies have done more than allude to the interactive effects. Thus, this study uses the socio-ecological model to explicitly draw our attention to the interactive effects that impact minority students' entrance into and persistence in STEM.

STEM Entrance and Persistence

Research on minority student entrance into and persistence in STEM is plentiful (Arcidiacono et al., 2016; Dewsbury et al., 2019; Hurtado et al., 2010). Such research suggests that although educational attainment has improved for minority students, they continue to be underrepresented in STEM and the associated disciplines reflect predominantly White and masculine culture (McGee, 2016; Rincón & Rodriguez, 2021; Valla & Williams, 2012). Existing research also points to a number of individual-,

interpersonal-, institutional-, and societal-level factors that positively and negatively influence minority student STEM entrance and persistence.

Individual-Level Influences: Characteristics of the Student

First generation, low-income, female, and racial/ethnic minority students are less likely to pursue and persist in STEM fields (Martin, 2016; Xie, et al., 2015). This is often due to financial burdens, lack of familiarity with STEM, feelings of inadequacy, and the belief that they don't belong in STEM. For instance, the more affordable tuition, flexible scheduling, and open enrollment policies associated with community colleges make them attractive to many underrepresented students (Jackson et al., 2013; Wang & Wickersham, 2018), but students who begin STEM studies in community colleges are less likely to enter four-year institutions later and are less academically prepared if they do transfer to a four-year university (Cohen & Kelly, 2020; Long & Kurlaender, 2009; Park et al., 2020; Wang, 2015). Women and students of color are also less likely to see themselves represented in STEM, which contributes to lower feelings of self-efficacy and heightened concern that they do not belong in STEM (Alade et al., 2021; Cheryan et al., 2013; Seron et al., 2015; Steinke, 2017). These kinds of negative individual-level beliefs are associated with lower levels of academic success (Heilbronner, 2011; Rainey et al., 2018; Sax et al., 2015). Notably, while these studies focus predominantly on students' individual-level characteristics, they also implicate institutional- and societal-level factors (e.g., community college resource availability, female representation in STEM). The socio-ecological model asks us to think more concretely about these interactive effects.

Interpersonal-Level Influences: Support from Networks

Interpersonal support, especially from parents and teachers, has also been shown to influence students' STEM trajectories. Emotional and financial support from parents is often critical for a student's ability to pursue a degree in STEM (Bravo & Stephens, 2023; Dotterer, 2022; Šimunovic & Babarović, 2020; Wilkins-Yel et al., 2022). Even when parents can't provide extensive financial support or existing knowledge about educational institutions, the values they impart to and the expectations they have for their children can motivate them to consider a STEM degree (Dewsbury et al., 2019; Russell & Atwater, 2005; Strayhorn, 2015). Relatedly, teachers often provide information about STEM-related opportunities that parents and underrepresented students would otherwise not know about (Bicer et al., 2020; Chelberg & Bosman, 2019; Valla & Williams, 2012). For instance,

teachers often expose students to STEM-related hobbies, science clubs, and summer camps that provide positive STEM socialization (Hite et al., 2019; Stearns et al., 2016). Teachers also help enhance students' academic preparation by offering advanced coursework, after school clubs, and supplemental information sessions for students (Cantu, 2012; Leoni et al., 2023).

These efforts by parents and teachers are important because they impact students' own feelings of STEM self-efficacy. Positive and encouraging messages from individuals in a student's network serve as powerful motivators for entrance into and persistence in STEM (Bryson et al., 2024; Dewsbury et al., 2019; Harris et al., 2023; Russell & Atwater, 2005)—but ironically, so too can negative and discouraging messages. Although unsupportive interpersonal interactions can reduce feelings of self-efficacy and hinder students' STEM trajectories (Sax et al., 2015; Seron et al., 2015), they have also been shown to benefit STEM trajectories by motivating students to overcome the negative judgements they encounter (Collins, 2018; Jackson et al., 2013; Rainey et al., 2018). The socio-ecological model helps draw our attention to the important ways interpersonal supports interact with students' individual-level characteristics to impact STEM entrance and persistence.

Institutional-Level Influences: Academic Preparation

While teachers often provide important interpersonal resources for students, high schools provide important institutional resources. For instance, the availability of advanced math and sciences courses as well as STEM-related extracurricular activities (e.g., field trips, guest speakers, clubs), encourages STEM entrance not only by piquing students' interest in STEM fields, but by providing the academic preparation necessary to gain admission into undergraduate programs (Bettencourt et al., 2020; Crisp et al., 2009; Xie et al., 2015). Students' grades, GPAs, and standardized test scores factor heavily in admission decisions, and students are more likely to be high achieving on each of these measures when their schools provide resources and experiences that promote their STEM knowledge (Bicer et al., 2020; Saw & Agger, 2021; Stearns et al., 2016).

As was true with respect to interpersonal networks, academic experiences interact with individual-level beliefs, such that positive experiences increase feelings of self-efficacy, boost confidence, and bolster the likelihood of underrepresented students entering and persisting in STEM (Conger et al., 2021; Dweck, 1986; Tyson et al., 2007). When academic institutions fail to provide resources for students, the students are less likely

to follow a STEM trajectory (Barker et al., 2023; Bettencourt et al., 2020; Xie et al., 2015). That may partially explain the link between community college attendance and lower STEM persistence. Many first generation, low-income, and racial/ethnic minority students start their STEM studies at community colleges in an effort to bolster their high school academic records (Park et al., 2020; Wang & Wickersham, 2018). Because community colleges often have fewer resources available (Long & Kurlaender, 2009; Wang, 2015), students start their STEM journeys disadvantaged and that often results in lower STEM persistence overall (Cohen & Kelly, 2020; Van Noy & Zeidenberg, 2014).

Societal-Level Influences: Cultural Stereotypes

Existing stereotypes about STEM tend to exclude racial/ethnic minorities and women from the STEM narrative (Alade et al., 2021; Cheryan et al. 2013; Seron et al., 2015). Not only do cultural stereotypes suggest STEM is predominantly for White, male students, they also suggest minority and female students lack the intellect necessary for success in STEM (McGee, 2016; Meador, 2018; Riegle-Crumb & King, 2010). Consequently, underrepresented students continually face racial bias, gender hierarchies, microaggressions, and institutional barriers that imply they do not belong in STEM (Allen et al., 2022; González-Pérez et al., 2020). These negative societal influences often cause students to either doubt their capabilities (Pronin et al., 2024; Sax et al., 2015) or overwork themselves in order to prove their competence (Carlone & Johnson, 2007; McGee & Martin, 2011). The stress associated with either situation makes entrance and persistence in STEM less likely (Heilbronner, 2011; Rainey et al., 2018). Overall, then, societal-level stereotypes interact with individual-level factors to affect minority students' self-perceptions, as well as others' perceptions of these students and the resources made available to them. The socio-ecological model of behavior draws our attention to these interactive effects.

In summary, prior studies suggest that underrepresented students' entrance into and persistence in STEM is influenced by numerous factors, including student characteristics, support networks, academic resource availability, and cultural stereotypes. And while these factors—and others at the individual-, interpersonal-, institutional-, and societal-level—interact with one another in complex ways, existing research has not yet examined all of these factors simultaneously or fully explored the important ways they interact with one another to influence minority student STEM entrance and persistence. This study fills that gap.

RESEARCH METHOD

Sampling and Data Collection Procedures

This study uses interview data with racial/ethnic minorities and/or female students who were pursuing a graduate degree in STEM in 2022. Our study focuses on graduate students for two reasons. First, most research examines minority student STEM entrance and persistence by relying on data from high school and/or baccalaureate students—research on minority graduate students in STEM is exceptionally rare (Bryson et al., 2024; Wilkins-Yel et al., 2022). Second, and most importantly, we contend that a graduate student population allows us to examine persistence in a deeper way because such students represent individuals who persisted in STEM through the baccalaureate and beyond. In short, because most studies focus on students who have not yet achieved a STEM degree, they are more limited in their ability to fully examine issues of persistence.

Participants were recruited from California universities using flyers, emails, social media postings (i.e., Facebook, Instagram, and LinkedIn), and purposive sampling techniques. These efforts generated interest from 29 individuals, 18 of whom agreed to and completed an interview. Using a semi-structured interview guide, participants were asked to comment on their STEM journey. Specifically, they reported on the factors that (1) initially piqued their interest in STEM, (2) contributed to their STEM entrance as undergraduate students, and (3) contributed to their persistence into graduate studies. Interviews were conducted and recorded through Zoom. The Zoom audio files were downloaded, initially transcribed using the dictation feature on Microsoft Word, and then checked for accuracy and corrected, when necessary, by the first author. Interviews were transcribed verbatim but for the purposes of clarity and brevity, common speech fillers (e.g., "um," "like," "you know") have been omitted from quotes included in the study results. Interviews averaged 77 minutes in length, with a range between 38 and 143 minutes. All study protocols and primary data collection procedures were approved by the [authors' university's] Institutional Review Board.

Analytic Strategy

To allow for an emergent research process, data analysis utilized qualitative coding techniques consistent with grounded theory and the constant comparative method (Charmaz, 2014; Glaser, 1965). Qualitative analyses are particularly helpful for exposing patterns within interview data (Creswell, 1998; Denzin & Lincoln, 1998). As such, the authors created, refined, and applied a set of open codes to the data by reading each transcript three times. These codes were then grouped into both axial categories and

overarching themes (Straus & Corbin, 1998). For instance, open codes such as "financial assistance" and "emotional care" were part of the axial category "family support," and axial categories such as "family support," "teacher support," and "peer support" were part of the broader theme "interpersonal factors." In total, the four overarching themes for these data corresponded to the four levels of influence associated with the socio-economic model (individual-, interpersonal-, institutional-, and societal-level influences).

Coding and theming was initially completed by the first author and then reviewed by the second author. Discrepancies in coding were discussed and, when possible, resolved during the discussion. When the authors were unable to resolve differences of opinion, both sets of codes were applied to the data. This ensured that the greatest nuance and widest interpretation of the interviews was captured in the finalized data. Upon completion of coding, the authors created coding tables, wrote lengthy research memos, and referred to existing theory in order to identify and interpret patterns in the data.

Participants

Of the 18 STEM students interviewed for this study, 11 (61%) were female, 7 (39%) were male, and none identified as non-binary. Thirteen (72%) were in a PhD program and five (28%) were in a master's program. Although most students were pursuing degrees in the life sciences, there was considerable variation in students' subject areas. Specifically, three participants (16%) were pursuing degrees in the physical sciences (e.g., Chemistry and Biophysics), 11 (61%) in the life sciences (e.g., Environmental Science, Ecology, Biological Oceanography, etc.), one (6%) in the health sciences (e.g., Nursing), one (6%) in mathematics, one (6%) in civil engineering, and one (6%) in computer science programming.

Regarding the racial/ethnic demographic of participants, more than half identified themselves as Latino/a: eight (44%) were Latinas and four (22%) were Latinos. Additionally, three (16%) participants identified themselves as Filipino/a, one (6%) identified as Asian, one (6%) identified as Black/Nigerian, and one (6%) identified as White. Importantly, although White and Asian populations are not considered underrepresented in STEM, the participants who identified themselves as such were also women and therefore qualified for this study.

RESULTS

These data suggest that throughout a minority student's STEM journey, individual-level and societal-level factors often interact to serve as barriers to STEM entrance and persistence. The ability to overcome these

barriers frequently hinges on the interpersonal- and institutional-level supports to which students have access. Interestingly, though, the way these factors interact differs for STEM entrance and STEM persistence. Table 1 summarizes each of these relationships.

Table 1

Interactive Relationships

	STEM Barriers	STEM Entrance	STEM Persistence
Interactions	Societal stereotypes X Individual beliefs	Interpersonal support X individual beliefs Institutional support X Interpersonal support	Institutional support X Individual beliefs Individual effort X Interpersonal support Interpersonal support X Individual beliefs

Interactive Effects That Serve as STEM Barriers

Demographic factors, especially first-generation status, race, and gender, disadvantage underrepresented students from the outset, as do cultural stereotypes about who belongs in STEM. Together these factors hinder feelings of belonging and lessen self-efficacy. This interactive effect came up frequently among the interviewees. For instance, a Latino PhD student in chemistry said stereotypes about "science people" initially convinced him he wasn't a "science guy." He noted, "I would say that [the] thing that kind of deterred me from science [was]…I just felt like that wasn't for people like me, you know? The people who do science are smart people, right? Like [they're] just amazing, [they're] beautiful at math." Similarly, a Latina PhD student in computational biology said she struggled with a "confidence issue" because she did not feel she was "good enough to stay in math." Others noted that hearing people say things like "it's not for you" or "it's not people like you that should be doing this" made them feel very "discouraged" to pursue STEM. In short, societal-level stereotypes interacted with students' individual-level self-perceptions and caused them to doubt their fit within STEM.

Female students also reported having their knowledge and intellect continuously questioned by others, which impacted their own feelings of

belonging: “They make you feel bad, if that makes sense? Whether you're aware of it or not, I think they have more of an effect on how you feel and that has an effect on how you work.” Similarly, racial and ethnic minority students said it was “difficult…envisioning [themselves in STEM]” because the typical scientist is “a White male.” With so few role models to emulate, minority students often felt compelled to “just kind of accept…there are science people in the world and there are non-science people in the world,” and the science people are “really different” from them.

Importantly, however, the STEM students in this study were eventually able to overcome the stereotypes and feelings of self-doubt. A Latino Master’s student in civil engineering said, “I eventually got to a point where I was like, ‘You know what? There's nobody there that I can…see in this role; maybe I just have to be that person.’” How did students make this transition? It had a great deal to do with the interpersonal- and institutional-level supports that were available during their STEM journeys. Sometimes these supports worked independently of each other and sometimes they interacted with each other and/or students’ individual-level beliefs.

Independent and Interactive Effects Influencing STEM Entrance

Interpersonal Supports. Parents and teachers were crucial sources of support for students. When parents and teachers showed an interest in what the students were working on and encouraged their efforts, students felt empowered to pursue collegiate-level STEM studies. For instance, a Latina PhD student recounted her father’s reaction when she told him she was going to pursue psychology instead of neuroscience because psychology “would be a safe zone.” Her father said “You’ve never been scared; nothing should hold you back” and that helped “wipe away [her] fear” about “going for it.” Parents were also sometimes able to offer financial support for their children.

A White female PhD student said, “I ended up taking the ACT eight times. Eight! Obviously, they’re expensive. I was very lucky that my parents were willing to [pay for] that,” and an Asian female PhD student said, “[My parents] paid for my whole undergrad career…so that gave me opportunities to just study really hard, not have to work a job, and [be able to] take internships [even if they] didn’t pay.”

Teachers encouraged students’ interests by exposing them to the possibilities in STEM. A Black male PhD student in computer science recounted his high school computer science teacher bringing a computer gaming textbook to class: “He opened up the book and he pointed to a bunch of programming languages and goes, ‘You know the game you’re playing

right now? You can actually write it for yourself.'" This interaction was pivotal in helping the student believe he could pursue a career in computer science. A current Latina PhD student in biochemistry noted that a high school teacher recommended her for a summer research program at a local university. This experience, although challenging, was the impetus for her STEM journey: "Even then my understanding of science was not strong enough for me to be able to follow what we were doing, … a lot of it went over my head, but what I knew [was] I really liked doing all the hands-on bench work." The following year the student gained entrance into a baccalaureate STEM program.

Having access to teachers with existing knowledge about STEM and higher education proved vital for many of these students. Teachers frequently helped them with their college applications and entrance exams by offering extra study sessions, tips for selecting undergraduate programs, and general application guidance. According to a White female PhD student in environmental science, "If you don't have either someone directly close to you in academia who can connect you to someone who knows the process better, or if you don't get lucky with a mentor, you're just out of fucking luck and that's the really hard truth of it."

Importantly, these discussions illustrate that interpersonal supports had both independent and interactive effects on STEM entrance. They provided students with opportunities and knowledge they otherwise would not have had, and they changed students' own beliefs about their STEM capabilities. Both outcomes increased the likelihood that these students would pursue a degree in STEM.

Institutional Supports. Support from teachers was based on more than their personal desire to help. The more institutional resources teachers had available to them, the more they were able to offer to students. In this way, institutional and interpersonal supports interacted with one another and worked in tandem to promote STEM entrance. Specifically, students attending schools with advanced placement courses, living in communities with STEM-related summer camps, and/or residing near universities with outreach programs were more likely to gain entrance into STEM, in part because of their teachers' efforts to make them aware of these opportunities.

Access to these types of resources was crucial because "then [students] have people to talk to and [they] can see what [STEM] is really about." These resources were also "really good at [giving students] a list of jobs…and the industries [they] can work in," and having that knowledge was important for fostering interest in STEM. One Latino PhD student said that

learning about job prospects was vital because it helped him realize that a person working in STEM is "not just a dude with a lab coat in a lab somewhere; it's more than that."

Institutional support also came in the form of financial assistance. Although some parents were able to help with college costs, many were not. Thus, students talked a great deal about applying for "scholarships" and "fellowships," looking for programs that were "affordable," and finding ways to not "burden" their families or put themselves "into debt." In fact, students frequently had to preference program cost over program reputation when deciding which undergraduate school to attend. As a Latina PhD student noted, "I applied to a range of schools. There were some private schools, there were UCs [University of California schools], and there were a couple of CSUs [California State Universities]. I got into all of them except for one, and I chose to go to [this university] because I got a scholarship." Another Latina Master's student recounted running carwashes to raise the money she needed for tuition while she awaited the passage of Deferred Action for Childhood Arrivals (DACA):

> [My undergraduate university] was like, "If you don't pay the first quarter, then you can't come."… I wanted to wait it out till DACA came in because then [the university was] gonna pay for me, but they were like, "if you don't come the first quarter, we can't enroll you and you're gonna have to miss this year." So, I had to find a way to get the money for tuition, for the first quarter…I barely made it with just enough for the first quarter.

In short, without the financial aid associated with DACA, this student would not have attended college or entered STEM. Thus, as was true for interpersonal supports, institutional factors had both independent and interactive effects on STEM entrance. Advanced placement courses, community resources, and scholarships were important in and of themselves, but they also worked in conjunction with teachers' efforts and students' growing understandings of their own place within STEM.

Independent and Interactive Effects Influencing STEM Persistence

Persistence in STEM was also affected by interpersonal and institutional supports that worked separately and in tandem. Interestingly, however, an additional interactive effect arose when considering STEM persistence—students' own efforts were crucial for mobilizing interpersonal supports, especially those that could be provided by peers.

Institutional Supports. Institutional-level factors in the form of tutoring and supplemental instruction (SI) programs helped students achieve success in their classes. For instance, when discussing a key to success, a Latino PhD

student noted, “For me, a big thing was [my undergraduate university] has this program called SI, supplemental instruction, where…you can go to a mini discussion kind of class and ask questions from a senior student who’s taken the class and excelled in the class.” Similarly, a Latina PhD student in biochemistry said, “If it was not for those [SI] classes, I really don’t think I would have been able to succeed.”

One reason tutoring programs were so impactful was they helped students find the confidence they needed to persist in STEM. According to a Latina PhD student in molecular cell biology:

> I remember coming into the first [tutoring] session and I still just didn’t know what was going on. [The tutor] really took the time to stay with me and explain things, and by the end of the class, I was one of the top performing students. Then, the quarter after that, I was actually tutoring OChem to the students who were taking it at the time. So, I just feel like that kind of just shows you [that] you can start off thinking you’re not gonna know anything…[and] you’re going to fail and then you just completely turn it around. I feel like that happened to me at so many points in my undergrad career...so my motto [became] “I don’t know how I’m gonna do this, but I know I’m gonna do it.” I feel like that just stuck with me throughout this entire process, even [to] where I am now. Sometimes I’m still like, “I don’t know how I’m gonna get this presentation done or this experiment to work, but I know it’s gonna happen eventually.”

Thus, tutoring resources not only provided independent academic support, but also interacted with students’ self-perceptions by showing them they were capable of succeeding in a topic they initially worried about failing. This positive experience contradicted the common notion that individuals have to be a “natural” in STEM, and in so doing, it not only bolstered students’ feelings of self-efficacy, it promoted their persistence in STEM.

Unexpectedly, students also noted that their persistence in STEM was influenced by the emotional support they received from their institutions. What is interesting here is the focus on the actions of departments and research labs rather than specific instructors. For instance, one Latina PhD student noted that it was her experience in a research lab that ultimately pushed her toward graduate school:

> During my undergrad, [in] my last year, I joined a research lab, and they were super supportive. They would ask me all the time what my plans were after I graduated, and I didn’t have any plans. So in that lab they were able to keep me a year after I had finished my

undergrad, just to do some work and [to] get a little bit of experience in research to see if I liked it and if I wanted to do grad school.

Prior to this experience, the student did not believe she was ready for graduate school. Similarly, a Latina PhD student in computational biology shared, "The math department was super excited just to find out where I was interviewing, and they were people that I just talked to about the programs [I was] considering…. They were definitely rallying for [me], which was really nice." Others said that without the help their departments and research labs provided with respect to "graduate applications" and "personal statements," they "don't know if [they] would have gotten into any [program]." Once again, then, we see that institutional factors were not only independently helpful for students via the opportunities and encouragement they provided, they were also helpful in solidifying students' belief in themselves.

Interpersonal Supports. Interestingly, the impact of interpersonal support on STEM persistence differed markedly from its effect on STEM entrance. Whereas STEM entrance was strongly affected by the independent and interactive effects of resources offered by parents, teachers, and institutions, persistence was more strongly tied to support from peers and students' own efforts to mobilize that support. For instance, students frequently asked peers for assistance with graduate applications and studying for the Graduate Record Examination (GRE). They also noted how important it was to "find a mentor that's one or two years older than you" and make an effort to understand "what they're applying to [and] what things they are getting involved with." One White female PhD student described relying on an older peer to help find potential advisors for her PhD program: "He told me how to write the emails to introduce myself, he helped me edit my CV. [He was a] godsend. Literally, I would not be in a PhD program today if it was not for him and I mean that."

It appears, then, that as underrepresented students' STEM journeys progressed, they spent a considerable amount of time actively seeking out help from friends rather than waiting for offers from teachers. In this way, interpersonal supports interacted with individual-level factors to promote STEM persistence. And that was true for more than just the instrumental help associated with applications and GRE preparations. Students also sought out friends for emotional support and a "listening ear." That was especially true when their gender or minority status made them question their belonging in STEM. A Latino Master's student in civil engineering recounted:

> I was questioning: "What am I doing? What am I doing in this program? How did I even get in?" So, I reached out to [an]

> organization for Latinos in STEM…and I talked to them…. We had this serious conversation where I was like, "Dude, I'm having imposter syndrome and I don't know how to deal with it," and he was like, "That's okay, it happens."

And a Latina student working on her master's degree in nursing said: I joined a Latina sorority, and they were my biggest support system; [they were] like my family away from home. And they had a lot of resources too because the older sisters or the alumni were super helpful in just navigating the system and finding…resources [like] recycling books, recycling study material, telling me which professors to take and which ones not to take. That was super helpful. And then just getting through the classes with my sorority sisters—we would help each other out and be in study groups, and we would push each other and motivate each other.

Having similar others to connect with was so crucial for students' experiences in STEM that many built their own networks when pre-existing groups were not available. For instance, a Latina PhD student in biochemistry said that because of her struggle to find community as a racial/ethnic minority, she started a chapter of The Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) at her graduate institution:

> I started a SACNAS chapter just 'cuz, for me, that was another community that I felt I could go to. [It's a place] where you can bring your culture and your science background, and a lot of people are going through the same things that you are in terms of imposter syndrome or applying to fellowships or things like that. Because of that, I wanted to have [SACNAS at my graduate university].

Similarly, an Asian female PhD student in ecology helped restart and expand a club for underrepresented students. She noted, "I'm helping restart…a club that provides community for people from underrepresented backgrounds…. It's hard for grad students to find community with each other…. I want to provide that community for those people."

As these quotes illustrate, the effects of interpersonal supports were often felt because the students made a concerted effort to connect with similarly situated peers. Rather than merely being recipients of interpersonal support, as was commonly the case for STEM entrance, students relied on their own agency and the help of others to ensure their persistence in STEM. In short, they actively mobilized help from peers and that allowed them to meet the challenges associated with moving forward in STEM. Importantly, this is not to say that support offered from parents or teachers was not important for STEM persistence.

Students did discuss faculty and parents encouraging them to pursue graduate studies or assuring them that their work was important. Nonetheless, peers were discussed much more frequently and thus the interaction between students' individual-level efforts and interpersonal supports seemed more critical for STEM persistence. As one Latino PhD student noted, "You need friends. You need somebody to kind of make the moment pass, you know? That you can have a beer with [and] you can talk shit with. Something like that...that's helpful, that's super helpful." Ultimately, these students persisted in STEM and came to believe that their work was "doing good for the world," "bringing people together," and "making progress [for] the planet itself." Knowing that made them feel like they finally belonged in STEM.

DISCUSSION AND CONCLUSIONS

Using the socio-ecological model as a backdrop, this research set out to examine the degree to which individual-, interpersonal-, institutional-, and societal-level factors interact with one another to influence marginalized students' (e.g., racial/ethnic minorities and women) entrance and persistence in STEM. Prior research has demonstrated that individual- and societal-level factors, such as race, gender, and cultural stereotypes, often serve as barriers to STEM entrance (McGee & Martin, 2011; Meador, 2018; Sax et al., 2015; Seron et al., 2015). Similarly, existing studies have pointed to the importance of interpersonal and institutional factors for promoting STEM entrance and persistence (Bicer et al., 2020; Cantu, 2012; Dotterer, 2021; Šimunović & Babarović, 2020; Valla & Williams, 2012). Although important and informative, these studies have rarely discussed the way these factors interact with each other. Instead, the interactive effects have been assumed or merely alluded to.

Our explicit exploration of the interactive effects illustrates that individual-, interpersonal-, institutional-, and societal-level factors do work together in complex and nuanced ways that vary over time. Specifically, societal-level stereotypes about who belongs in STEM influence students' own self-perceptions, causing them to doubt their fit in the discipline. Cultural stereotypes and self-doubt, thus, work together to create barriers to STEM entrance.

It is possible for students to overcome this self-doubt, but the interactive effects that make this possible appear to differ slightly for STEM entrance and STEM persistence. During a student's high school and early college years, they will be most apt to consider entering STEM when they have interpersonal encouragement from parents and teachers that undercuts their self-doubt. In short, they must be able to see themselves in STEM, and

they need to have positive experiences in the field that bolster their beliefs in their own abilities. This is much more likely to happen when institutional supports, such as advanced placement courses, clubs, and summer camps, are available in their schools and communities. When these kinds of resources exist and teachers encourage students to participate in them, students feel empowered to enter STEM. Thus, STEM entrance is seemingly influenced by the way interpersonal-, institutional-, and individual-level factors interact with one another. Notably, however, at this point in a student's STEM journey, they seem to be largely passive beneficiaries of the supports and resources offered to them by others–but that changes with time.

Once students have entered STEM, interpersonal and institutional supports that bolster their self-perceptions remain important, but they also begin to exhibit agency by actively seeking out resources and support for themselves. In short, rather than continuing to be passive recipients of help from others, they actively mobilize help from peers, find mentors, and even build large-scale support networks (such as clubs) if they do not already exist. This suggests that students' own efforts have as much to do with STEM persistence as the interpersonal and institutional supports they continue to make use of. This is not to say that students entering STEM lack agency, but it does appear that their successful entrance into the field is strongly influenced by the efforts of others, while STEM persistence is influenced by students actively seeking out the supports and resources needed to ensure their continued success, especially in the form of help from peers.

IMPLICATIONS

These findings are important because they highlight the ways individual-, interpersonal-, institutional-, and societal-level factors interact to affect underrepresented students' STEM entrance and persistence. They also suggest that the processes that foster STEM entrance differ from those that foster persistence, and that has important policy implications. For instance, because minority students generally do not see STEM as a path they can take unless they receive encouragement from authority figures, it seems clear that parents, teachers, schools, and communities need to continue to provide, and perhaps even expand, resources and experiences that will foster students' STEM self-efficacy. Students also need exposure to role-models in STEM, perhaps via guest lectures, field trips, and units of study dedicated to minority scholars. Ultimately, helping students see themselves in STEM is a crucial first step to getting them there.

Importantly, persisting in STEM requires more than access to encouraging words and institutional resources. While those things are

certainly important, these data suggest that access to the emotional supports that come from similar-others is also crucial. And while the students in our study took it upon themselves to foster these connections, teachers and institutions could facilitate this process through the creation of clubs, networking events, socializing spaces, and so forth. In short, providing supports for students' emotional, psychological, and/or social well-being is critical for their persistence in STEM, especially as they enter post-baccalaureate education.

LIMITATIONS AND FUTURE RESEARCH

Our study is not without limitations. For instance, the racial diversity in our study is limited–there were very few participants who identified as Black and none who identified as Native American. Moreover, participants were drawn from a pool of students attending universities only in California. Consequently, it was not possible to investigate whether entrance and persistence strategies differed by race or region of the country. Future research should use additional and more varied groups of students to further explore how individual-, interpersonal-, institutional-, and societal-level factors impact minority students' STEM entrance and persistence. Future research should also seek to verify these results with a representative, quantitative sample. For now, though, this study offers important preliminary insights into the interactive effects that impact STEM entrance and persistence among marginalized students.

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