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Pulled In or Pushed Out? Underrepresented Minority High School Students Describe Socio-environmental Factors Shaping STEM Persistence and Post-Secondary Plans

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Abstract

Introduction

This research applies the Phenomenological Variant of Ecological Systems Theory to understand the persistence of racially underrepresented minority (URM) youth in STEM pathways. URM youth aspire to STEM careers at the same rate as White peers [1], but Black and Latinx students leave STEM disciplines at nearly twice the rate of White students [2]. As a result, the STEM workforce does not reflect the country's diversity. Literature reveals key socioenvironmental factors in the exosystem (STEM curriculum, qualified STEM teachers), the mesosystem (mentorship opportunities, family and peer support), and the microsystem (STEM interest, math self-efficacy, STEM outcome expectations and choice goals, and math achievement) that contribute to low-persistence of URM youth in STEM education and careers. However, few studies investigate this problem in a pre-college population, analyze interaction across levels of the system, and emphasize marginalized students' lived experiences through phenomenological approaches.

Methodology

This study examines socioenvironmental experiences that shape persistence in a year-long after-school algebra-for-engineering program, interest in STEM careers, and post-secondary plans. Interviews from three cohorts (n = 25) between 2021 and 2024 in a large urban district addressed the following research questions: RQ1) How do students describe experiences in school-based math and science coursework? RQ2) What are students' plans for postsecondary STEM pathways? RQ3) What are differences between high- and low-persisting students in the algebra-for-engineering program regarding mesosystem and microsystem factors?

Results

Interviews revealed an accumulation of weak math and science school experiences yet overall high math self-efficacy, STEM interest, and strong family support. Most students described ambitions to attend college and focus on "getting good grades" at present, yet participant post-secondary plans ranged considerably between firm, burgeoning, and vague. High-persistence students differed most starkly from low-persistence students regarding mentorship opportunities (namely pragmatic support), STEM identities (consolidated identities across home, school, and extracurriculars), and coordinated school-based post-secondary planning. Notably, students with these supportive mesosystem factors clustered at two of nine schools. Low-persistence students described weak bonds with teachers or understaffing, limited peer support, haphazard curriculum, and delayed or altogether absent advising. This study highlights emergent themes as well as outliers (i.e., students with high-persistence yet weak mesosystem supports) who navigate structural, school-based tensions ("y'all, how did we all just pass this with no teacher?").

Conclusions

These qualitative findings help illuminate surprising quantitative findings from the same project: comparing treatment and control groups, the algebra-for-engineering program had no significant effects on math self-efficacy, STEM interest, or STEM outcome expectations [3]. However, students in the treatment group had significantly higher levels of STEM choice goals. This study explores how those post-secondary goals develop, pointing to modifiable socio-environmental factors relevant to urban program developers, school administrators, and policy makers interested in supporting flourishing STEM ecosystems. (Keywords: Pre-college, Engineering, Race/Ethnicity, Socio-economic Status)

Introduction

Despite significant efforts nationally to diversify STEM fields, underrepresented minority (URM) youth are less likely to pursue and persist in STEM subjects in high school, college, and careers than White and Asian peers [4], [5]. For URM youth in U.S. high schools, math performance—specifically in algebra—is a significant barrier to success. In Baltimore City Public Schools (City Schools), a majority African American and low-income district [6], algebra proficiency in high school lags, impacting on-time graduation, access to higher level math and science courses, and success in college courses [7]. In 2023, only 6.5% of students were deemed proficient on the algebra state assessment [8]. In close partnership with City Schools' Mathematics Office, educators and researchers from the Johns Hopkins Whiting School of Engineering, Notre Dame of Maryland University, Morgan State University, and American University designed, implemented, and rigorously evaluated an algebra-for-engineering afterschool program.

Baltimore Online Algebra for Students in Technology (BOAST), funded by the National Science Foundation (Grant No. DRL-2005790), expands math learning time and opportunities to develop mastery and confidence in algebra through an applied problem-based curriculum. While a mixed methods experimental design evaluates program effectiveness [3], this study responds to calls for qualitative inquiry into adolescents' pre-college experiences of STEM programs, emphasizing Black and brown students' voices [9], [10]. Moreover, while barriers to participation were intentionally minimized and incentives included (i.e., field trips, free snacks, letter of recommendation) all three years of the program, participation and persistence overall were low. The purpose of this study is to understand the differences between high-persisting and low-persisting BOAST students with regard to mesosystem factors (peer support, mentoring, family support) and microsystem factors (STEM interest, STEM identity, math self-efficacy, and STEM choice goals). Institutional Review Boards at City Schools, Johns Hopkins, and Notre Dame of Maryland University reviewed and approved this study.

Theoretical Framework

This research incorporates Social Cognitive Career Theory (SCCT) [11] and Phenomenological Variant of Ecological Systems Theory (PVEST) [12].

Social Cognitive Career Theory

SCCT is a theoretical framework that describes four interrelated aspects of career development: 1) how academic and career interests develop, 2) how educational and career choices are made, 3) how academic and career success is obtained, and 4) how satisfaction in the workplace (or classroom) is experienced [11]. SCCT assumes that stronger self-efficacy, outcome expectations, and personal goals contribute to higher interest, choice, and performance (refer to Figure 1). SCCT is a leading theory for explaining educational attainment outcomes and persistence in STEM. However, literature points to unanswered questions about the adequacy of the SCCT model with diverse demographic groups [13]. Thus, this study incorporates a qualitative, phenomenological approach to expand upon the SCCT baseline constructs.

Phenomenological Variant of Ecological Systems Theory

PVEST merges ecological systems theory [14] with classic phenomenology. PVEST centers adolescents' agency in shaping and determining both environment and behavior [15]. PVEST contends that adolescents form situational identities in response to perceived risks (such as stereotypes and biases) and supports, potentially promoting positive adaptive identities [12], [16]. Figure 2 shows how key SCCT constructs map onto a PVEST framework based on a literature review [17].

Methods

Participants

City Schools students (ninth to eleventh grades) from nine participating schools with bourgeoning interest in engineering who completed Algebra I with a C- or better were eligible. Students participated in a hybrid algebra-for-engineering afterschool program with an in-person instructor, attended field trips to the university, and watched high-quality role model videos featuring diverse STEM professionals. Across three years, interviews with 25 students were collected.

Data Sources

Interview questions (Appendix A) probe for information about student participation in BOAST and barriers to involvement; experiences in school-based math and science courses; goals after high school; and whether/how they discuss career plans with friends, family, and adults at school. The protocol, adapted from an existing protocol [18], was originally written to augment quantitative research measures (such as student surveys, data from the Learning Management System, and achievement data) and gather insight into socioenvironmental factors impacting BOAST participants. This interview protocol was revised before Year 2, for example to acquire more consistent math self-efficacy ratings and re-order questions for fluidity. Interviews were conducted one-on-one in person or via Zoom. Digital audio recordings were transcribed and coded using Nvivo analytical software.

Data Analysis

The First Cycle of coding [19] highlighted SCCT theory-derived constructs (Table 1). In the Second Cycle, language used by participants themselves (also known as *in vivo* coding) was added. A codebook (Table 2) was used consistently across all transcripts and a color-coded table of the data (Table 3) visualized patterns. Thematic analysis [20] was then applied to extrapolate major themes from these codes.

Table 1

Three Iterations of Analysis

First Iteration – Initial Codes		
RQ1	**RQ2**	**RQ3**
Minimal teacher support	College-aspirant	Peer support
COVID Impact	Work	Mentoring
No hands on	Military	Counseling/career advice
Want harder math	Dream job	School culture
Pathway, CTE, special program	Not thinking about future	School resources/staffing
Achievement	Avoid math	Family support
	Internship	STEM interest
	Doubt	STEM identity
		Math self-efficacy
		STEM outcome expectations/choice goal
		Persistence (high, low)
Second Iteration – Initial and Emergent Codes (in italics)		
Teacher Quality	Type of plan	Mesosystem factors
No teacher	College-aspirant	Peer support
If the teacher's cool	Work	Family support
Curriculum	Military	Counseling, mentoring, advising
COVID Impact	*STEM extracurricular*	*Limited peer support*
No hands on	*Concrete short-term plan*	*Limited family support*
Hands-on, real-world	Dream job	*Limited counseling, mentoring, advising*
Jealous	*Skills*	Microsystem factors
Achievement	*Self-awareness*	STEM interest
I got the grade	*STEM-related choice goal*	STEM identity
Pathway, CTE, special program	Avoid math	Math self-efficacy
Struggling	Not thinking about future	*Procrastination*
I just love math	Doubt	Persistence
		High
		Medium
		Low
		Outlier

Third Iteration – Final Themes		
RQ1	**RQ2**	**RQ3**
Theme 1: Achievement First, Interest Second	Theme 1: College Aspirations? Get Good Grades	Theme 1: Enabling Factors
Theme 2: Teacher Quality	Theme 2: Vague, Burgeoning, and Firm	Theme 2: Coordinated Planning Clusters by School
Theme 3: Uneven Access and Learning Loss		

To support consistency in the analytic process, and adequately answer RQ3, the codebook was adjusted for more discrete differentiation and operationalization of high, medium, and low levels. Table 2 includes this codebook derived in the final stage and applied uniformly to all transcripts.

Table 2

Codebook Ranking Schema for Mesosystem and Microsystem Factors

Construct	Low (red)	Medium (yellow)	High (green)
Peer Support	Peer support absent or negative influence on student	Peer support limited, primarily to emotional support	Peer influence includes pragmatic, emotional, and/or academic support
Mentorship Opportunities	No adult at school with whom student discusses post-secondary plans	One adult at school identified who discusses post-secondary plans or provides support	One or multiple adults who discuss post-secondary plans and provide emotional, psychosocial, and/or academic encouragement into STEM pathways
Family Support	No family member with whom student discusses future plans	Family member(s) provide emotional support	Family member(s) provide various types of support (emotional, spiritual, pragmatic, etc.)
Math Self-Efficacy	Rating 0-3, or narrative description indicates no/low confidence	Rating 4-6, or narrative description indicates some confidence in some math classes	Rating 7-10, or narrative description indicates confidence in all math classes
STEM Interest	Limited passion or interest in science or math content	Some interest, describes STEM content that intrigues or excites	Exuberant interest, describes STEM content that thrills and excites
STEM Identity	Limited STEM identity; student does not	STEM identity is split across communities of	STEM identity is consolidated across

	describe affiliation with STEM ("science-type") people	practice at home, school, and extracurricular activities; student describes some affiliation with STEM people	communities of practice at home, school, and extracurricular activities; student describes strong affiliation with STEM people
STEM Choice Goals	Non-STEM career goal	N/A	STEM-aligned career goal identified
STEM Persistence	Completes limited or no work (at the time asked), though may attend field trip and watch role model videos	Completes some work (multiple modules, but not all, at the time asked), and may attend field trip/watch role model videos	Completes all work (all modules, at the time asked), including field trips and watching role model videos

Trustworthiness

Trustworthiness for the study was increased by utilizing peer debriefing and maintaining an audit trail throughout data analysis [21]. Once themes were derived, member-checking of codes and themes was utilized to validate the researcher's conclusions [22]. Moreover, data were reviewed numerous times searching for disconfirming evidence and outliers [19].

Results

The experiences of 25 mostly Black students who participated in BOAST between 2021-2024 contributed to the findings. The empirical findings for the study are organized by research question in this section. Themes for each research question are presented with illustrative quotes and interpretation.

RQ1 – Students' Experiences in School-Based STEM Coursework

The first research question asked, "How do students describe experiences in school-based STEM coursework?" Three themes emerged: Achievement First, Interest Second; Teacher Quality; and Uneven Access and Learning Loss. Each theme is expounded upon in this section.

RQ1 Theme 1: Achievement First, Interest Second

The theme of Achievement first, Interest Second includes the following codes: I got the grade and I just love math. Students overwhelmingly described their experience in school-based math classes by the grade received or the ease with which they completed coursework. For example, Leon from Delta said, "Me with math classes, I'd say I've been pretty good with math. I've passed all of them for so far." Kyra from Alpha described, "Math class? So being here since sixth grade, I've always been good at math, and I've always been able to get an A+ or just an A."

Kyra elaborated on strategies to succeed: “So in class really, if you just pay attention carefully and listen and get all the notes done, you’re good. So, it’s not really that difficult or stressful for me.” Ailani from Beta responded, “I always had a B or a A. I’ve never had a bad grade.” When pushed to describe what she finds enjoyable about science, she vaguely responded, “I don’t know. I find a lot of things enjoyable.” Students who performed well in STEM courses defined their experience primarily by passing (i.e., “Achievement First”)—requiring coaxing to further describe what they were learning, how they were learning, and how interested they were in those subjects (i.e., “Interest Second”).

Some students reported reasons for why they struggled to achieve high grades, typically related to attendance. Kamilah from Gamma described, “The past two quarters I haven't really been showing up, so my grades have been suffering. I went from like a 3.5 GPA to a 3.0... Math is first period, and I'm usually always late.” In this school district, missing the first period class is not rare, primarily due to transportation issues and long bus routes to schools. Halle from Delta, on the other hand, described how complicated he finds math class: “It's a complex process of how you got to break stuff down... You got to do this, then you got to do this... But if this is not correct, then you got to go back and do it all a different way.” Halle felt “intimidated by everything” he was required to learn and remember for tests and “overwhelmed by school.” He also confessed:

> And to be honest, I slept in class a few times. Not proud of it, but probably [I’ll try this year] not to do that too, like I did in Geometry last year. Pay attention more because I do want to learn math. I like math, it’s just sometimes it can get complicated.

Halle expressed interest in math but felt overwhelmed and disconnected when it was too complicated. The majority of students defined their experience in math by letter grade, or—like Kamilah—by attendance. This focus on achieving success or just pushing through reflects an understanding of school as a site of compliance rather than deeper learning [23].

Some students were outliers to this theme, first speaking to passion or interest in the subject. These students described interest in problem solving, the relevance drawn to their lives, and joyousness in math. Lennon from Beta explained why he liked math class: “Calculations, the numbers. How many numbers it can go up to. I just like math.” Zara from Zeta similarly described:

> The thing that I love about doing math is that once you’ve found out what you can do and how you can solve this, and you can actually get the answer right, it feels good. And knowing that you’re right and this is the right answer... I feel great because of that!

Problem solving was satisfying for Zara. Halle from Delta, when prompted why he likes Algebra, replied “I just find pleasure when I know I’m able to solve it.” Besides Zara and Halle, most students more readily described interest in content or enjoyment related to science rather than math coursework. For example, Giovanni from Beta described ho-hum enthusiasm: “Math classes have been just math classes, honestly.” However, he responded, “science classes have been interesting with experiments... and just learning about how things work and tick.” Similarly, Gabriella described limited enthusiasm for math, “But I like the little labs we do [in science],

mixing chemicals" and Avon noted, "last year I did some experiments, and it was pretty cool." This theme of Achievement First, Interest Second captures the dominance of extrinsic motivation (i.e., achievement) over intrinsic motivation (i.e., interest). On the one hand, this may be developmentally "typical" for high school age students. On the other hand, this cultural paradigm may be a value fostered and perpetuated by present-day school systems.

RQ1 Theme 2: Teacher Quality

The theme of Teacher Quality includes the following two codes: if the teacher's cool and no teacher. Only a small handful of students described relationships with teachers defined by trust, respect, and inspiration. For example, Mavis described the skill of his teacher:

> In Mr. W's class it's like, I don't want to sound over exaggerated, but it's [like you] enter into a spaceship. Like he takes you on a journey of how you find the solution to the most complicated looking questions that you'll see in your life. And then when he explains it it's like, that's not so hard. I could have done that.

Mavis described how this skillful teacher facilitated learning of challenging problems, instigating feelings of competence and confidence. Similarly, Leon directly linked math enjoyment and teacher quality:

> I mean, if the teacher's cool, then the math is cool. If I'm in a math class and I like the teacher, I'll enjoy the class more. If I don't like the teacher, I'll still do the work, but I wouldn't enjoy it as much.

For both students, effective instruction by teachers with appealing personalities led to understanding, which yielded greater satisfaction. Zara highlighted the particular qualifications of her teacher: "My physics teacher, he majored in chemical engineering. So, I really love how he always talks about his experience. So, I really like that. I really like that major." In rare circumstances, teachers not only built content knowledge, but also shared personal life stories, information about college majors, and work experience that brought content to life. Flo acknowledged the trusting, mutual relationship she formed with her teachers:

> The teachers, they're really nice. So having a nice bond with your teacher is really good as well. And, also, you know, like turning things in on time, because it's not typical for them [laughs]. You know, they already graded the worksheets, and now you're turning it in late...

Flo described her own responsibility in a bidirectional teaching and learning relationship. This maturity and reflection on one's own agency as a learner were rare among interviewees.

Alarmingly, a large cluster of students described absent, unavailable, uncaring, or poorly skilled teachers. Ailani from Beta described math class as challenging "because the teacher I have at the moment, she doesn't break it down to what the kids need." When asked if there's anything Avon does not like about math class, his favorite subject, he said, "The teacher, I guess?" More explicitly, Avon described a transactional relationship with school:

> I really don't like school, I don't like the system about it. I just like the fact, I come to school not just to mess around with my friends or hang out with my friends, I come here to get my education, like all kids should do.

Avon agreed with the interviewer's summary of his words that the teacher greatly impacts whether he likes the class or not.

More concerning, Shamya described having no teacher for part of the year (SY 2021-2022): "We had a teacher in the beginning of the school, I was doing really, really good, but she actually quit." To fill the vacancy, the school offered substitute teachers and the class was instructed to learn virtually on Imagine Math, an online curriculum. Shamya reflected, "but that really doesn't help me. And because I don't have a teacher, I can't ask questions the way I want to." While the pandemic strained all school systems, students from 2023-2024 continued to describe absent or poorly skilled teachers. Maisie, also from Omega, stated, "I wanted to do that [try an engineering class], but they didn't have a biomedical teacher."

Other students described teachers who only seemed interested in pushing students through the pipeline, rather than deeply learning. For instance, Sylvia, also from Omega, described her chemistry teacher: "Well, in chemistry, he would give us the answers and then write down [copies]... And then after that, we would watch a video about whatever he was teaching us." This lack of skillful math and science teachers is particularly alarming for these students, all of whom described health-related STEM choice goals (i.e., ultrasound or radiology, pharmacy, nursing). Poor instructors yielded low cognitive engagement with the content, low social engagement with peers in the class, and emotional disengagement [24].

RQ1 Theme 3: Uneven Access and Learning Loss

The last theme, Uneven Access and Learning Loss, includes the following codes: COVID impact, hands-on, real world, no hands-on, struggling, and jealous. Student experiences revealed heterogeneity across the district; however, students with higher-quality instruction did cluster at specific schools. Students at Schools Beta and Zeta reported hands-on, project-based learning, and learning linked to real world applications. For example, Raphael at Beta described:

> My current teacher for the science stuff, he has a lot of hands-on lessons and he thoroughly explains everything and makes sure that we get it. And the examples that he uses are about everyday things. And then as the lesson goes on, it gets more advanced. And that makes it easier to digest and understand what's happening and how this translates to the real world.

Additionally, Zara from Zeta reported: "I do like doing the stuff that was happening in my class, all the investigations, DNA stuff... I like the hands-on activities [because]... I'm more interactive, I learn more when I'm doing visual representation, instead of just [being told], 'oh, this is what you're supposed to do, okay, you're done, that's all." Moreover, Zara reported that when "I don't know what I'm doing and I'm struggling with something, it does get frustrating sometimes. I do ask the teachers about what I'm doing, and then they'll tell me." Not only did Raphael and Zara

experience hands-on learning, but the instructors checked for understanding, made sure it was contextualized to real world applications rather than purely theoretical, and the learning progressed in difficulty. They *did* science, rather than learning *about* science.

Students from Omega diverged from students at Beta and Zeta in their accounting of curricula. For example, Sylvia described how disconnected and uninspiring class felt

> What I find enjoyable is nothing, honestly. I used to love math… I don't even get instructions, honestly. They really just tell me the answers. Well, you kind of solve them first. And because we have a lot of people in our classes, they usually just go up to the board and just start solving them. So, I don't really have to... Sometimes I have to wait for them to finish solving them because I already saw them first. But other times, when I don't really know the answer, I'm usually just letting them answer it and then I get the answers.

Sylvia perceived teachers as feeding answers to students, skipping past skill-building and conceptual understanding. Sylvia buoyed her confidence by pointing out her letter grade but otherwise expressed feeling deflated ("school is just tiring now") and avoidant of the subject she used to love. When prompted to describe how the number of math courses would affect her decision on a college major, she said, "I want to avoid math, but I know I can't, because going into pharmacy, you would need to count..." A handful of students perceived other students receiving curricula or hands-on learning differentially, their accounts tinged with envy. For example, Maisie from Omega stated:

> So, ninth grade biology, we didn't do anything. But now it's a new school year, except for I don't have biology anymore. The ninth graders that's in the biology class is doing some with fish and microscopes, and I was a little jealous, because I couldn't do that either.

Maisie was perturbed by a vague sense of unfairness, yet unsure how to act on that feeling. She further explained:

> They pick and choose what they want to do each year. It kind of sucks, because it's a small school too, so we didn't really get to do a lot of stuff. And back when I was in middle school, we went on a lot of field trips about biology and stuff. Now we don't really go on any field trips at all.

Maisie's complaint about science classes focused on a lack of input into engaging activities, reporting wasted time and not enjoying classes.

A subset of students described the gaps or learning loss during COVID years. Kyra from Alpha reported:

> So, biology, I had it last year, but we didn't really do anything. We didn't really have a teacher for the first quarter or so, and the teacher we did have, they kind of went with the Apex work [online education] and that wasn't really fun.

Shamya, interviewed in 2022, in particular aired grievances:

> I used to enjoy math, but once COVID started, I guess, me being at home for three years, I really knocked a lot of my skills and stuff off that I had when I was still in school in person. So, I guess that chunk away from school really knocked me off of really being a good student in math... And then algebra, they gave me a 60. So, I was like, 'How did I pass this and I didn't know any of it?' A lot of students was like, they passed. I'm like, 'Y'all, how did we all just pass this with no teacher?' Nobody had answers, they was just like, 'We don't know.' And I was just like, 'Okay, I'm not going to say nothing.'

Shamya reflected full awareness of being shepherded through the system, with little accountability for understanding content. Since peers did not seem eager to highlight this failure, she indicated complacency ("I'm not going to say nothing") and later admonishment of her school administration:

> So, I'm just like, 'You guys [admin], do y'all see how bad we are struggling in school right now?' Honestly, I failed one class in ninth grade, but I was able to do it in summer school and bring it back up… I'm just like, 'If I fail English and math this year, what are you guys going to do?' And they was like, 'Oh, we can allow you to take it at...' I don't want to take summer school… I feel like y'all basically blaming us. We fail in these classes and y'all know we don't have a teacher. What are we supposed to do? And we had midterms for the school year. I took their English and algebra one. I was surprised that I passed the English one.

In conversation with administrators, Shamya felt administrators did not take responsibility for leadership failures or provide adequate support structures for her success. Credit recovery was the only option, which she perceived as blame or punishment. This district-wide strategy for credit recovery echoed in other students' statements. For example, Daniel from Kappa could not persist in the BOAST program because he had to take credit recovery after school after failing his first period chemistry class.

While COVID pandemic closures exacerbated access to modalities of learning, this luck-of-the-draw lack of uniformity in curricula extends before and after the pandemic. Avon, interviewed in 2023, reported that last semester, "I didn't have math." School districts undergo reforms, including adopting new curricula, or shifting from a year-long to semester-long math course. Students perceive some of these changes as benefiting others while they are left out. Students were aware that they could make it through high school without proficiency; while the majority of students acquiesced to this system focused on herding students to graduation, students like Shamya urgently desired more support and investment, attempted to channel her agency, and found the responses unsatisfactory.

RQ2 – Students' Plans for Postsecondary STEM Pathways

The second research question asked: "What are students' plans for postsecondary STEM pathways?" Student responses to long-term goals (i.e., dream job at 30-years-old) and short-term plans and actions (i.e., college visits, STEM extracurricular activities, etc.) in pursuit of that goal

were coded. The long-term goals that students described as viable, attainable STEM careers included being a marine biologist, robotics engineer, computer engineer, electrical engineer, welder, rocket engineer, nurse, ultrasound technician, and radiology technician. Twenty of 25 students described STEM-related professions (including health professions). The following section describes patterned responses resulting in the following themes: College Aspirations? Get Good Grades and Vague, Burgeoning, and Firm Goals.

RQ2 Theme 1: College Aspirations? Get Good Grades

The codes college-aspirant and good grades revealed that the majority of students desire to attend college (two- or four-year), guided by a mixture of internal motivation, parental expectation, or peer influence. For example, Kyra said, "So, I didn't really think college was for me... But my mom thinks I should go to a college and do something that involves chemistry and biology. Because right now... I'm actually doing pretty well in it [chemistry]." Giovanni similarly expressed indecision:

> If I had to give a percentage, I think 65% of me wants to go to college because of the opportunities, maybe the experience and just because I've had a family member that I really look up to go to college, the rest of me kind of doesn't want to because it just wants a break from working... day in and day out.

Both students ultimately shared that they were likely college bound. Other students, like Maisie, Avon, and Damario, shared solidified college plans. Damario stated, "I want to go to college because I want to learn more things." Avon said, "I mostly just wanted to do it [BOAST] for college. I'm going to college, I'm interested in going there." Given current debates about the value of college particularly for low-income students [25], this enthusiasm for higher education for either practical job training or intellectual growth was marked. Only two students aspired to join the military or navy and two to trade school.

To reach college, most students emphasized maintaining or getting strong grades in the short-term. Gabriella, who felt she would study special education, stated, "I need to get good grades in school, try my hardest, don't let the negative thoughts get to me, talk to people about it to make sure that's really what I want to do..." Giovanni stated his short-term steps to get to college: "Just overall making sure that my grades are good enough so that if I don't have the money I may get like a scholarship." Students varied considerably in their knowledge of specifics (i.e., what type of coursework might be part of a degree, when and how students select majors). For example, Lennon was not aware what a college major meant. Three students (tenth and eleventh graders Damario, Daniel, and Jordan) had not even been on a college campus until the BOAST program; they wanted to go but held no vision of that reality from real life.

Concerningly, a handful of students, like Kyra, Leanna, and Raphael, surmised that they'd figure out college application at the end of twelfth grade or later. Raphael outlined his plan after graduation:

> Well, after graduation I want to either take a year off and learn how to survive on my own and then secure the money I need to go to college and prepare myself for the real world.

> And then after that, I would like to go to college and start setting up stuff and making connections and relationships with people who will help me throughout my career.

This delayed planning is worrisome given the support and resources—albeit inconsistent—available to students when in school (i.e., access to guidance counselors, support with college applications, etc.). Moreover, low-income students are at risk for lower college graduation rates [25] racking up debt and not earning degrees. It is true that low-income high school students do not receive adequate guidance in US schools [26]: the majority of high performing students from low-income schools lack information about college options, leading to missed opportunities to apply to selective universities that are more likely to provide higher amounts of financial aid than two-year and less selective four-year colleges. However, this information gap is only exacerbated when students are completely on their own, outside of educational support systems.

Other students lacked clarity whether college was within reach based on mediocre grades, poorly understood entrance criteria, or financial constraints. Daniel, from Kappa, expressed hesitation about attending college contingent upon financial options:

> I feel like I might, but like I said, it's a matter of if I can. It's a matter of if I can. And if I had the requirements to do anything or go to college or anything, then I definitely will. I definitely will, if I can.

Daniel expressed discernable desire yet a limited understanding of college access, affordability, and his own options. Financial precarity increased focus on the here-and-now, a need or desire to work rather than invest in long-term goals. Marcus and Kamilah, both from Gamma, aspired to attend college but described the prevailing mentality of their school environment. Marcus stated:

> Students? They don't really care for their futures. They're okay with being on the streets, selling drugs and all that. Or just working at McDonald's. They don't really care for future problems or any of that.

Kamilah, also from Gamma confirmed, "Most them [my friends] not trying to go to college anyway." While they were engaged in BOAST to support their college aims ("Because I needed extracurricular activity for college," according to Marcus), their college aspirations were colored by this social influence and financial preoccupations. Research indicates that financial stress is a primary factor for low-income URM students leaving college [25]. In summary, the majority of students did desire to attend college, but most exhibited significant knowledge gaps in next steps and, thus, delayed planning.

RQ2 Theme 2: Vague, Burgeoning, and Firm Goals

Vague Plans: Students with vague plans described their dream jobs with little specificity. Lennon envisioned, "Building [Legos], YouTubing, gaming, hanging out with friends, lazing around." Marcus described doing "stock work then an office job" when his physical stamina decreased. Jordan described his dream job as business management, stating "I don't really know" why that is appealing, but "I want to become my own boss," and that the steps towards this job would include "probably get all my materials, have my supporters to help me go through it." The

day-to-day would “probably [include] a lot of paperwork.” These students did not have concrete steps for the future; a career seemed a lifetime away, and jobs were described as task-based vocations or extensions of childhood.

Burgeoning Plans: Students with burgeoning plans contemplated fit between potential interests, careers, and in rare cases personal meaning. Numerous students in this category could identify that they would pursue something STEM-related. For example, Giovanni described “something that has to do with technology and making video games or contributing.” Janiyah described, “something in STEM, something in science, or in math, learning technology or probably artificial intelligence.” Halle described:

> I don’t know exactly what the business model [is] going to be and what I’m going to sell, but I know I want to start a business and have that business open up. Have that business hopefully one day get big enough to fund nonprofits because I really want to give back to my community.

Halle was motivated by a “give back” sensibility, thinking engineering might be part of the business venture, and the specifics would fall into place later. Understandably, students in specialized career-focused programs, such as Career and Technical Education (CTE) pathways or Project Lead the Way programs, generally described more detailed long-term plans. Shamya, in the Pharmacy CTE program, described how her adverse schooling experiences were leading to re-contemplation:

> My goal is to become a traveling nurse. I feel like my school is putting me in that path, but also COVID, we can't really do certain things in school anymore how we did in ninth grade. So I’m rethinking this. I’m not really sure what I'm going to do once I graduate yet.

While she scapegoats COVID, the disillusionment and eroded trust in school (previously described) underpin the uncertainty. The end goal and steps there remain fuzzy. Daniel also described missed opportunities:

> I wanted to get into the [summer] program that they was doing. I didn’t know about it until later on into the year. I would’ve did that program... Yeah, it was a robotics one and it was also a windmill one, because that would’ve been pretty fun to do. And I would say that one of the best things about it, I wanted to try out because I’ve never been on a plane or gone out anywhere before. So that would’ve been a pretty good experience for me too because I never went out somewhere for education... [or] out of Maryland. You know what I’m saying? That's something I’ve never done before... That would’ve been good for me.

Daniel acknowledged how participation in STEM extracurriculars would have not only opened up his imagined possibilities, but also broadened his world in more ways. The only real career he had seen up close was his uncle, “when he used to work on washing machines and stuff at other people’s houses as a side job... we was pulling apart everything and put[ting] them back together or get[ting] new parts.” He concluded, “it really was an eye opener for me just because I never

did anything like that before." While identity formation is fluid, particularly in this developmental stage, at times post-secondary plans remained ambiguous due to a sense of minimized possibility or not being sufficiently prepared.

Firm Plans: Students with firm plans could identify a future profession and the short-term actions to confirm that interest, flesh out skills, and overcome financial obstacles. For example, Maisie described with great detail:

> So, I was going to go through a two-year college and then find a job in a hospital where I can do ultrasound tech and then after working there for two to five years, I would go back to school and then get my master's and my bachelor's, earn more money, because they make six figures. So, if I do my associates and then I work and I go back to school, I feel like I would get a raise and then make six figures a year, and I wouldn't have to really worry about anything.

CTE programs provided a pathway towards employability, which most students in those programs felt was a feasible entryway into high wage jobs; notably, however, students in these CTE programs (Maisie, Sylvia, Shamya, and Avon) reported some of the worst experiences in math and science classes.

Outlier cases included students with crystal clear visions of their future roles. Gabriella, for instance, planned to be a teacher, first earning a degree in special education from an historically Black college or university. At 30-years-old, "I think I'll be a teacher and still working. I [will] probably switch grades because I plan to work with elementary, but I think I would push up to go to high school... just learn new skills and have fun." Her firm plans included doing the BOAST program and talking to her own teachers about their paths: "I talk to my math teachers and ask them what they like about their job, and what schools would they recommend for that type of major." Moreover, she took career surveys and discussed options at home. Avon was in the welding CTE pathway at his school and wanted to be a welder after college. These students could articulate the path they were on and what needed to be completed in the next few years.

Notably, students at School Zeta spoke differently about their future plans and dream jobs. Their responses revealed enhanced self-awareness and ability to see their own capacities, skills, and interests as related to desirable work environments. While they might not identify the exact role (computer engineer versus biomedical engineer), they maintained realistic, flexible ideas, reflecting on successful role models they aspired to be like. For example, Trinity from Zeta identified her own assets:

> Definitely working with, not myself, but with a group. Being able to work with others and help them or teach them. Not really teach, but lead... Because I've watched other people, who are like engineers or... I just want to be like them when I'm older. Just, yeah, they give me all the inspiration.

Trinity emphasized how engineers worked collaboratively and articulated the leadership skills she aspired to embody. Another student, Zara, also described her dream job by the diverse skills and scientific praxis she wanted to do in teams:

> I want a job that's more diverse. I don't want a one-race team stuff. I want to do team-building. I want to make hypotheses, I want to do the experiments, I want to do something engaging, hands-on work. I don't want to be sitting down doing... all day. I just want to do engaging stuff. That's what I like about doing stuff like physics or chemistry, bio-medic.

While Zara concludes "like the hands-on activities basically," her response (like Trinity's) summarizes various capacities, such as communication, collaboration, leadership, inquiry, and management skills. They have been accultured to think about twenty-first century skills [27], transferable traits of effective employees in many different work environments. This is a more nuanced, mature, and realistic view of working environments than some students held.

Moreover, in the short-term, students at Zeta indicated knowledge of extracurricular activities—such as summer programs, clubs, or internships—and many actually participated. Zara, for instance, did the school Robotics Club, Science Club, SAT prep, and Science Olympiad, in addition to the biomedical pathway at Zeta; Janiyah did SAT and ACT prep, along with other clubs; Flo participated in paid research internships at the university and STEM-related volunteering. Some students at school Beta also described STEM extracurriculars as important, but participation was not as high as students at Zeta. For example, Ailani hoped to work at the aquarium over the summer and Giovanni and Raphael participated in the school Robotics Club. While the BOAST program was one of *many* extracurricular activities for most students at Zeta, for most students at other schools, BOAST was the *only* extracurricular students participated in. The next section describes how these long and short-term goals are constructed, formed, and supported by socioenvironmental factors: peer support, family support, and school-based support (advising, mentoring, counseling). Specifically, the next section maps patterns across these tiers of the system.

RQ3 – Differences between high- versus low-persisting BOAST students

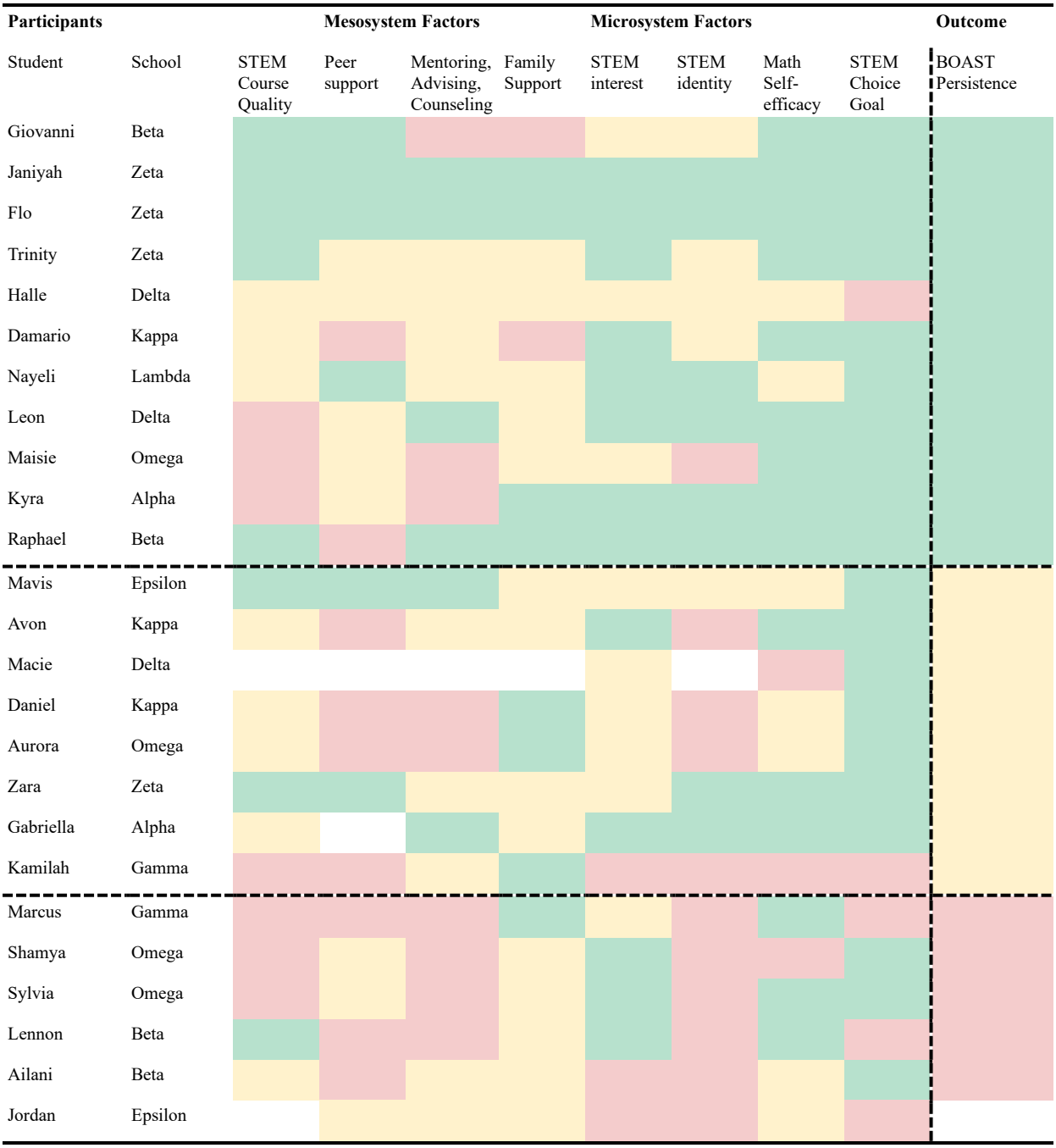
The third research question asked, "What are differences between high-persisting versus low-persisting BOAST students with regard to mesosystem factors (peer support, mentoring, family support) and microsystem factors (STEM interest, STEM identity, math self-efficacy, and STEM choice goals)?" This section clarifies two themes: Enabling Factors and Coordinated Planning Clusters by School.

RQ3 Theme 1: Enabling Factors

To visually illustrate relationships between these factors [19], data are presented as a color-coded chart in Table 3 below:

Table 3

Matrix of Student Participants, Ratings for Mesosystem and Microsystem Factors



Note. Each row represents a student participant in the study. School and student pseudonyms are used to preserve anonymity. Data is organized by self-reported persistence in the BOAST program (Green = high, Yellow = medium, Red = low). Empty cells indicate missing data, or non-STEM choice goals.

For low-persisting students in the BOAST program, students tended to have absent or negative peer groups supporting STEM participation or limited conversations with their friends at all about post-secondary futures. They minimally identified caring adults at school; however,

many reported strong emotional support at home. Despite strong math self-efficacy and STEM interest, weak school-based learning experiences coupled with weak mesosystem factors appear to contribute to a shaky STEM identity and low participation in the program.

In contrast, high-persisting students in the BOAST program tended to have peer groups with whom they discussed future plans and shared interests in STEM careers. Students tended to have teacher or counselor support, and at least emotional (if not pragmatic) support from family. Students had high STEM interest, high or medium STEM identity, and high math self-efficacy. Their STEM choice goals were either burgeoning or firm, and some displayed metacognitive traits undeveloped in the low-persisting group. These overall trends are summarized in Table 4.

Table 4

Comparison of Low and High Persisting Students in BOAST

Type of Factor	Low Persisting	High Persisting
Mesosystem	Absent peer community supporting participation	Emotional support from peers, community of friends in class
	Absent caring adult at school	Teacher or counselor support
	Limited emotional support from family member	Emotional and/or pragmatic support from family member
Microsystem	Variable STEM interest	High STEM interest
	Low STEM identity	High or Medium STEM Identity
	Variable math self-efficacy	High math self-efficacy
	STEM choice goal (vague) or non-STEM	STEM choice goal (burgeoning or firm)
	Procrastination, waning motivation	Metacognition

Outlier cases are noteworthy to this trend. For example, Damario showed high persistence in BOAST, yet identified weak mesosystem supports. In this case, his robust microsystem factors (STEM interest, math self-efficacy, STEM choice goal) seemed robust enough to maintain his motivation and continued engagement with the program; however, his STEM identity was shaky and his short- and long-term goals vague ("I want to play sports, if not sports a rocket engineer"). He may be vulnerable to attrition from STEM (i.e., beginning but not completing a STEM college degree) given weak school-based STEM class quality, limited advising, and overinflated math self-efficacy. Maisie had low to moderate mesosystem and microsystem factors, with the exception of high math self-efficacy, and self-reported high persistence in the BOAST program. Given the actual participation rates and work completion of students from Omega in BOAST in 2022-2023, it is likely that her persistence is over-estimated. This topic will be discussed further in the Limitations section of this chapter.

The trends outlined in this theme align with the PVEST conceptual model, purporting that in the presence of structurally responsive education (i.e., high-quality STEM courses, opportunities to apply theoretical concepts), students can develop supportive, protective factors leading to increased participation in STEM fields [16].

RQ3 Theme 2: Coordinated Planning Clusters by School

Within the same district, uneven access to school-based mentors, advisors, and teachers is evident. Students from Zeta described multiple adults shepherding them in their future planning process. For example, Flo said: "I spoke to my AP English teacher about my careers and she really supports me with it. She helped me do the best that I can do with what I have." Another student Janiyah described, "I've talked to my guidance counselor. I talk to her almost every day. Yeah, she asked me questions about what I want to do after high school and what colleges I'm planning to go to." School-based, coordinated planning opened doors to STEM extracurriculars such as internships. Advisors offered pragmatic advice and accountability.

Roughly half of the students from Alpha, Beta, Delta, Epsilon, and Lambda identified multiple school-based adults with whom they discussed secondary plans. Two students at school Beta recounted divergent experiences of support within the same school. Raphael described:

> I am consulting with our school college people. There's someone on the third floor who works up there and she works with students about college and I have gotten a paper from her and it has a list of things that I should do before I want to go to college to get ready. And earlier today, we had an assembly where a new staff member has been hired from the College Bound Association and I'm going to visit her too.

In contrast, Giovanni described only having beginning-stage conversations with counselors, but he was aware that school resources existed.

Students from Gamma, Kappa, and Omega uniformly cited an absence of mentors, advisors, and teachers at school. Shamya and Maisie described mistrust of all adults at school: "I don't like none of the adults here." Six students simply responded "no" to having had *any* conversations with *any* adult in the school about plans for after high school. Shamya starkly interrogated the system failure: "y'all, how did we all just pass this [math class] with no teacher?"

For multiple eleventh grade students at Kappa, the BOAST trip to the sponsoring university was their first time on a college campus. One student who loved math and wanted to take harder classes, Damario, relayed circumspect advice from his automotive CTE pathway teacher:

> He told me that automotive isn't really about book smart, but it's hands-on learning. So if I want to work at a shop, they're not going to really look at credentials. They're going to look at what you can do, hands-on.

For a student contemplating college, this advice could be misinterpreted as devaluing academic performance, contributing to a muddled feedback loop between academic performance and math self-efficacy (as suggested by SCCT). Overall, students' access to trusted adults and post-secondary advice varied greatly by the school attended.

Significance of Study

Public education holds promise as an equalizer of uneven luck and circumstance in society. This study shows that the current school system does not yet fulfill that promise: variable Teacher Quality (RQ1 Theme 2), Uneven Access and Learning Loss (RQ1 Theme 3), and Coordinated Planning Clusters by School (RQ3 Theme 2) demonstrate these structural inequalities. Practical implications are discussed next.

Practically, this study points to modifiable socio-environmental factors relevant to program developers, school administrators, and policy makers interested in supporting flourishing urban STEM ecosystems. This study concludes that while peer, family, and mentoring/advising support persistence in STEM, not all three types of supports need be present. Those without family or peer support are not necessarily doomed to veer off STEM pathways. However, as supported by prior research [28], this study found that those with precariously integrated STEM identities across home, school, and peer contexts were vulnerable to veering off STEM pathways. An asset-based framework shows that students can receive positive influence from many sources, but high-quality STEM courses—opportunities to develop content knowledge along with metacognitive knowledge—catalyze clearer STEM choice goals and higher persistence.

The factors that are modifiable by schools or out-of-school programming—counseling, advising, and mentoring—ought to be addressed further in this context. Representing the Center for Educational Outreach at Johns Hopkins Whiting School of Engineering, positioned to serve students and the school district in multiple ways, below are some ideas for intervention based on this research:

- Expose and inform school teachers and counselors about the STEM ecosystem and opportunities for high school students to support coordinated post-secondary planning
- Assist with professional learning of math educators to incorporate project-based learning, competency, and skill development
- Develop and deploy role model videos highlighting URM professional pathways
- Grow internship opportunities for experiential learning in research settings
- Support provisioning of mentors to all students interested in STEM pathways
- Share research on student voice and experience with district leaders
- Develop resources for parents (primarily mothers) to augment their pragmatic support
- Shift school accountability away from letter grades and towards competency-based learning
- Promote metacognitive and cognitive monitoring skills

These actions may encourage long-term STEM education and workforce persistence of URM youth from this context.

Lastly, these qualitative findings help illuminate surprising quantitative findings from the same project: comparing treatment and control groups, the algebra-for-engineering program had no significant effects on math self-efficacy, STEM interest, or STEM outcome expectations, as measured by validated surveys [3]. However, students in the treatment group had significantly

higher levels of STEM choice goals. This in-depth qualitative investigation reveals how students overall have elevated mathematics self-efficacy, despite weak learning experiences, performance, and persistence; while these theoretical implications are beyond the scope of this paper, they may indicate that SCCT does not fit this population.

Limitations of the Research Design

While this qualitative research addressed important gaps in the literature, the research design bears limitations. According to developmental perspectives, as well as participants during member-checking, STEM identity and career goals evolve; a longitudinal design would have more thoroughly captured these constructs. Moreover, a singular measure of persistence is a limited outcome variable. Persistence was estimated by self-report, but interviews occurred at the beginning, middle, and end of the school year (i.e., they were not a true measure of program completion). Future research should employ a longitudinal design.

Multiple types of data were collected as part of the BOAST project. However, due to data safety procedures in line with IRB approval, de-identified interviews could not be matched with identifiers from quantitative data (i.e., validated pre-post surveys, attendance data, Algebra 1 grades). Thus, additional correlations and relationships could not be analyzed. While dozens of students participated in BOAST, only 25 were interviewed. Moreover, slight modifications to the protocol over time yielded inconsistent data collection. For example, students in 2021-2022 were not asked to rate their self-efficacy on a scale of one to ten. Future research should align quantitative and qualitative methodologies.

Conclusion

This study sought to understand the larger problem of URM underrepresentation in STEM education and the workforce, specifically studying contributing factors to the low persistence of URM youth in an algebra-for-engineering afterschool program. The study utilized PVEST and SCCT to understand how STEM career goals form in high school-age students in a large urban district in the United States. The study contributes to a gap in the literature on pre-college populations [29], specifically focusing on empirical data to extrapolate relationships between mesosystem and microsystem factors and emphasizing marginalized students' lived experiences through phenomenological approaches [9].

Regarding students' experiences in school-based STEM coursework (RQ1), three themes emerged: Achievement First, Interest Second; Teacher Quality; and Uneven Access and Learning Loss. As for students' plans for postsecondary pathways (RQ2), two themes emerged: College Aspirations? Get Good Grades; and Vague, Burgeoning, and Firm. With respect to differences between high- and low-persisting BOAST students (RQ3), two themes emerged: Enabling Factors and Coordinated Planning Clusters by School. While the school district ought to strive for equitable access, school systems are limited in resources, including staff, STEM expertise, and agility. Through an asset-based approach, these findings reveal not deficits but opportunities for universities, community organizations, and industry partners to supplement STEM-focused support systems for URM students.

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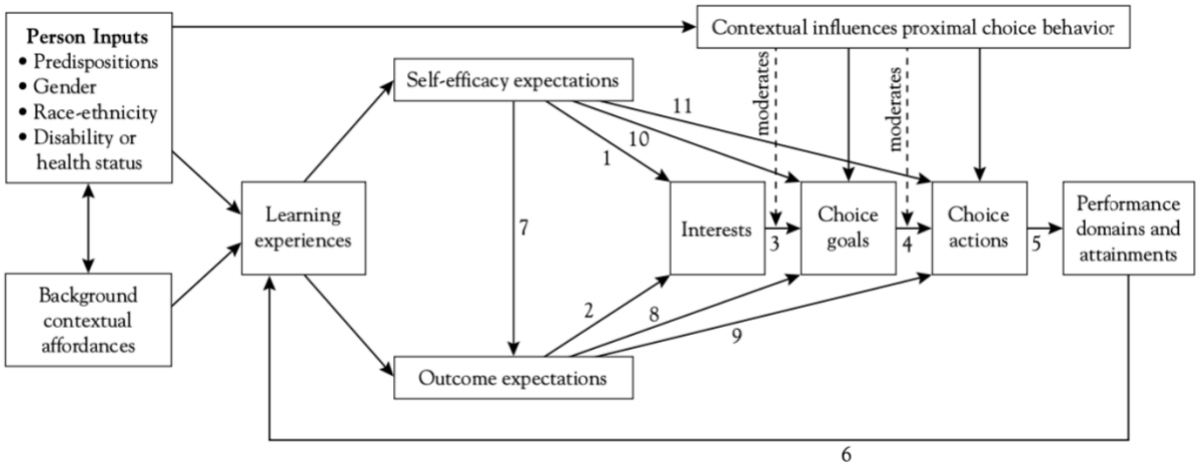
Figures

Figure 1

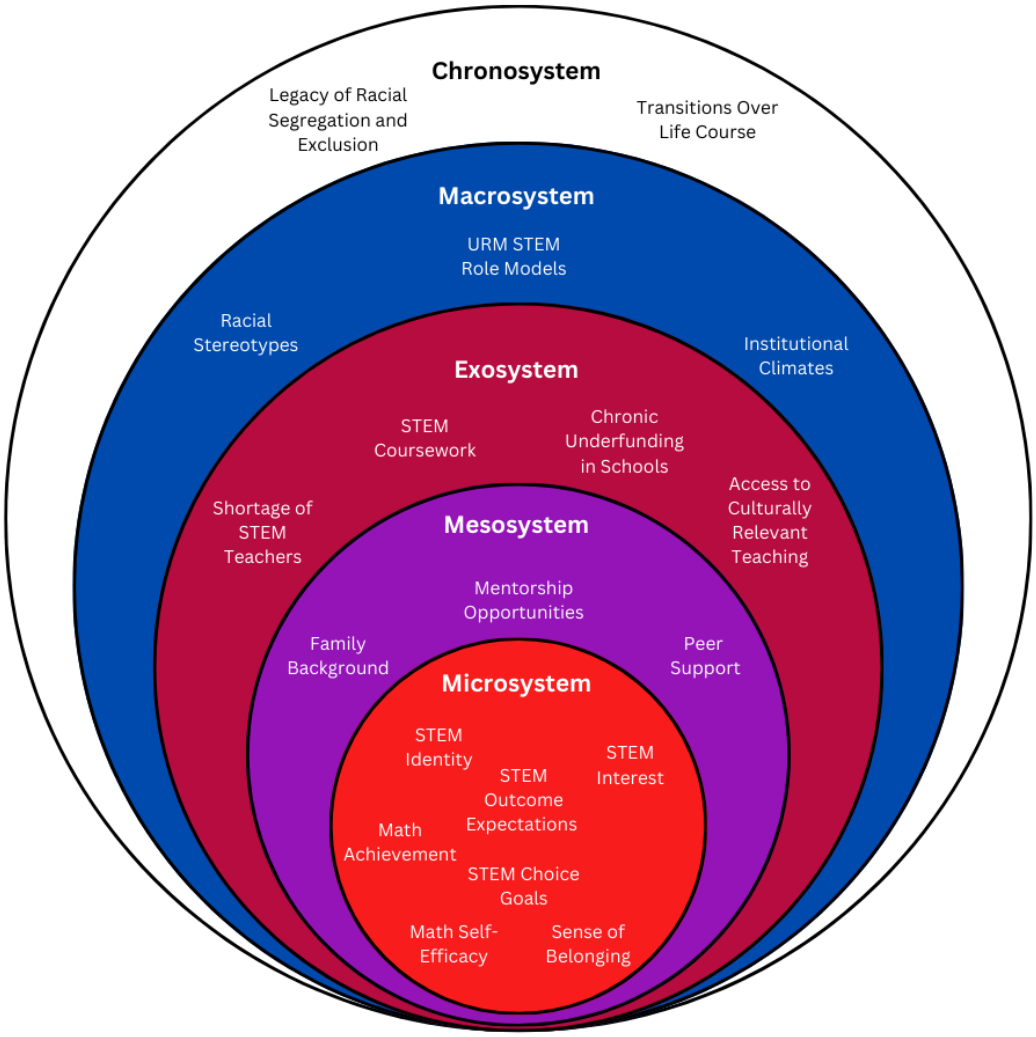
SCCT Model of Person, Contextual, and Career-Related Choice



Note. SCCT model includes person, contextual, and experiential factors influencing career choice. Solid lines indicate direct relationship between variables. Dashed lines indicate moderator effects [11]. Copyright 1993 by R.W. Lent, S.D. Brown, and G. Hackett.

Figure 2

SCCT and PVEST: Factors Contributing to the Low Participation of URM Youth in STEM



Note. The factors outlined in a doctoral dissertation literature review are organized according to levels from the PVEST model [17].

Appendix A

Student Interview Protocol

Intro: *[Confirm assent to record.]* I want to thank you for taking time to meet with me. If any point during our interview you'd like me to repeat or clarify a question, just stop me and let me know.

First I want to ask you a few questions about the BOAST program.

1. Can you tell me what got you interested in joining BOAST? [Prompts: Did someone encourage you to apply, and if so, who? Why do you think they encouraged you to do BOAST?]

2. Have there been times when you weren't able to complete the modules or projects in BOAST?

    1. [*If yes*] What was happening that kept you from them? (Prompts: access to a computer/internet, work obligations, something else more fun, other responsibilities, stress, projects too difficult)

    2. [*Follow-up]* What would need to be different about the program to make you more likely to complete the projects?

3. Have you had the opportunity to watch any of the role model videos?

    1. [*If yes*] What did you think about them?

    2. [*If no*] Why haven't you been able to watch them?

4. [*If applicable*] Have you attended any field trips?

    1. [If yes] Did that experience affect how you think about your plans after high school? If so, what did it make you think about?

[School experiences]

Next, I'd like to ask you a few questions about school.

5. Can you tell me about your experience in school with math classes? (*Prompts*: What do you find enjoyable? What do you like least about math classes?)

    1. When you're doing math work, how confident do you feel on a scale of 1 to 10?

    2. Do you think BOAST is helping you feel more confident? (*Prompts*: If so, how / if not, why not?)

6. What has been your experience in school with science classes? (*Prompts*: What do you find enjoyable? What do you like least about science or engineering classes?)

[Post-high school plans]

Now, I want to ask you a little more about yourself and your plans for the future.

7. High school students have some ideas about what they might do right after high school. For example, some students want to go to college, start working, or join the military. Do you have some ideas of what you'd like to do after graduation?

[If they say college is part of their plans]

1. What do you think your major will be? (If student doesn't know what a major is, elaborate as: the subject area that you will focus on in college)

2. What type of classes do you think you will be taking when you get to college?

3. How would the number of math courses you'd need to take affect your decision on a college major?

4. Tell me a little about what you're doing now to get ready to go to college. [*Prompt:* what are the next steps as you see them?]

8. Is there anything that you worry might make it harder for you to reach your goals after high school? (Prompts: What and why?)

9. If you imagine your career when you're 30 years old, what type of job would you most want to doing?

[If they name a job]

1. Why does [job] appeal to you?

2. What do you believe you will need to do to become a [job role]?

[*If they do not specify a job]*

1. It's fine if you don't know right now, but could you maybe describe the sort of activities you'd like to be doing every day?

2. Why do [activities] appeal to you?

[*If no job specified or their desired job is not in STEM*]

1. You've maybe heard people refer to science, technology, engineering and math as just 'STEM.' Besides in the BOAST program, have you explored or thought about any STEM careers?

    1. [*If yes*] Which STEM areas have you explored?

    2. [*If no]* Would you be interested in learning about jobs in these fields?

        1. [*If yes*] What makes you feel interested in STEM careers?

        2. [*If no*] Why would you say you're not interested in STEM careers?

[Social support and relational influences]

10. Have you had any conversations with your family and friends about your future education or career plans?

    1. [*If yes]* Who have you talked with? What would they like to see you do after high school/why?

    2. [*If no*] When do you think you'll start making plans for after high school? What do you think might be helpful for figuring this out?

11. Have you had conversations with any adults in your school about career options?

    1. [*If yes*] Who have you talked with (e.g., teachers, counselors, coach, mentor)? How does [person role] help you think about a career?

    2. [*If no*] Is there an adult outside school you'd want to talk with? How could that person be helpful?

[Closing]

Those are all my questions. Thank you so much for talking to me today! This has been really helpful and I'm grateful I got to meet you.