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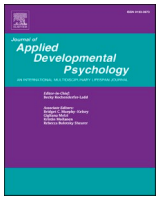

The development of science identity through near peer mentoring and research experiences

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ABSTRACT

Research experience programs (REPs) provide young people with real-world science engagement, including participating in lab work, often alongside mentors. However, there is little research on REPs targeting diverse secondary-level students. This study begins to fill that gap using a longitudinal comparative case study design to demonstrate (a) the importance of an intersectionality lens on science identity, (b) the potential of near-peer mentoring in science, (c) the potential of brief lab-based REPs—even as short as three days—for developing or sustaining science identity, and (d) the diversity of routes that science identity and pathway development unfold for diverse students. This qualitative study focuses on five high school students, each paired with an undergraduate near peer mentor—all from underrepresented groups. Female-identifying participants emphasized how their mentors' modeling and messaging shaped their motivation in, identification with, and aspirations to pursue science. The younger male participants experienced different challenges that related less to their gender and racial identities. Findings can help shape the design of school- and community-based mentorship programs and classroom instruction for science.

Introduction

As the demographic composition of the United States continues to become more multicultural, society benefits from having researchers and scientists who reflect that diversity. Research shows racial, ethnic, and gender diversity can enhance science team performance and productivity (Freeman & Huang, 2014; Herring, 2009) and intellectual problem-solving, and creativity (Page, 2007; Reagans & Zuckerman, 2001). Additionally, diverse teams benefit from expanded social networks, which allow for broader sources of knowledge and larger audiences for dissemination (Burt, 2004). The field of STEM post-secondary pathway development has increased the focus on experiences and factors that shape this pathway development for diverse high school students.

However, despite decades of federally funded and industry-sponsored efforts to increase diversity in the sciences, challenges persist (Atwater, 2000; Fry et al., 2021; Grumbach & Chen, 2006; National Center for Science and Engineering Statistics (NCSES), 2021). For example, math courses taken in secondary school are key predictors of success in post-secondary STEM pathways (Chen, 2013; Hazari et al., 2007). Underrepresented minorities participate at lower rates in academia, especially in STEM fields (Li & Koedel, 2017). However, interest in science appears to be equal and even greater for some students of color compared to their white peers (Hurtado et al., 2007), suggesting the lower representation of some diverse groups in STEM pathways is not due to lower interest. For instance, a recent national survey of high school students illustrated that Latinx students demonstrated similar STEM career aspirations as peers from overrepresented groups, specifically White and Asian students (Hispanic Heritage Foundation et al., 2020).

Near-peer mentoring presents one potential solution to address this issue. This study aims to demonstrate the potential of near-peer mentoring, even in brief, three-day science research experiences, to develop or sustain science identity for racially diverse students, using an

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intersectional lens on science identity and pathway development.

Developing science identity

Carlone and Johnson developed a definitive model of science identity, consisting of three distinct yet interrelated dimensions—competence (knowledge and understanding of scientific content), performance (demonstrating this knowledge to others), and recognition (being recognized as a scientist)—which shape how individuals incorporate science into their sense of self (Carlone & Johnson, 2007). The model was originally developed to understand the experiences of women of color in science but has since been applied to understanding science identity development more broadly. Science identity development correlates to students' decision to pursue a STEM pathway, a career in science, computer science, engineering, or math. Kim and Sinatra (2018) identified the need to understand science identity through approaches that recognize the intersectional nature of the varied identities that individuals carry. They critiqued Carlone and Johnson's model for not sufficiently accounting for the impact of *socializing agents*, such as near-peer mentors, and the *environment* on the development of science identity. Although the recognition dimension involves how individuals perceive or seek out recognition from others, the other two dimensions of performance and competence center the individual. This individualistic focus contrasts with the importance of a communal orientation in science career pathway development that often matters more for racial minority students than individualistic motives and goals (Author, 2021; Author, 2025; Bonilla et al., 2023).

Strong STEM identity functions to create resilience that buffers students against discrimination and other barriers and oppressions. In a similar way, research from an identity-based motivation (IBM) perspective shows that merely having information about science careers is not enough to develop an identity in science that will lead to pursuing a science pathway (Oyserman & Destin, 2010). Rather, students will act on information only if they believe the pathway described fits with other current identities (Stephens et al., 2015). When identities feel congruent within a context, according to IBM theory, students who experience challenges are more likely to interpret those difficulties as evidence that what they are doing is important and worthy of effort (Oyserman & Lewis Jr, 2017).

Within the context of identity formation in science or some other academic domain, race, ethnicity, and culture also matters, and students need to know how other students who share similar personal histories and face the same environmental stressors, such as discrimination and bias, have experienced success (e.g., Phinney & Ong, 2007). By assisting students in seeing that these possible futures are extensions of who they are now and feasible for people like them, mentoring from other young people on that pathway can go beyond providing students with information and show how those pathways are possible and relevant.

Near-peer mentoring in research experiences toward science identity development

Research has demonstrated that mentoring can be particularly beneficial for youth from backgrounds of environmental risk and disadvantage (DuBois et al., 2002). However, far less is known about how to effectively design and scale naturalistic, relationship-based interventions to specifically promote science outcomes for high school students from underserved backgrounds. The near peer model is distinct from other relationship models such as mentoring, role modeling, and coaching, in which content knowledge is transmitted from expert to novice using a top-down model. A *near peer* mentor is conceptualized as someone who recently passed through experiences or stages that the mentee is presently facing (Michielsen, 2015). Near peer mentoring is also known by other terms, such as peer instruction, peer teaching, and peer tutoring, but all revolve around the common feature that a near peer is an individual who is *just beyond* the students they are instructing (e.g., Lockspeiser et al., 2008). Research shows that students tutored by near peers perform as well, if not better, than students tutored by faculty members (ten Cate et al., 2012).

Two primary advantages make near peer mentoring ideal in the context of science identity and pathway development. First, the model capitalizes on the unique developmental period of adolescence, which is marked by profound shifts, notably the transition to greater autonomy and search for social acceptance. Adolescence marks an increased interest in and need for a sense of identity, purpose, and affiliation among their similarly-aged peers (McLean, 2005). The hierarchical distance between a near peer mentor and mentee is smaller than for an adult mentor or teacher and a student, so more *social congruence* allows for greater trust and informality (e.g., Lockspeiser et al., 2008; Schmidt & Moust, 1995). This social congruence, and greater "street cred" allow these individuals to exert greater influence than mentors or coaches who are older and who may not share the same contemporary language and perspectives as younger mentees.

Second, near peers also possess greater knowledge in the learning spectrum. While this knowledge can be content-specific, it can also refer to institutional knowledge regarding unspoken norms and expectations. The concept of *cognitive congruence* refers to the closeness in maturity and age between near peer and mentee that allows the near peer to use language and examples readily understood (Lockspeiser et al., 2008). It is this congruence that creates greater accessibility between near peer mentor and mentee, as the near peer is perceived as being "just like them," providing a foundation of shared experiences upon which to build a meaningful relationship. It is in this sharing of social-cultural aspects of learning that can make the near peer relationship model so powerful. These concepts of cognitive congruence and social congruence overlap with one of the defining features of identity-based motivation theory, which posits that individuals interpret situations in ways that are congruent with their currently active identities (Oyserman, 2015). Extending this theory to our proposed project, a mentee who connects with a near peer mentor in a science context may experience a high degree of cognitive congruence that in turn will influence how the adolescent's identity and pathways in science takes shape or not.

Near peer mentoring within brief science research experiences

Engaging with near peers as they conduct real-world scientific research, complete with its occasional mundaneness, frustrations, setbacks, and breakthroughs, may help students learn to interpret their own failures and hardships as part of their personal journey in a science career pathway. Research experience programs (REPs) in science for high school students can take on a variety of formats, from mentoring and internships to formal enrichment programs (Kabacoff et al., 2013). The value of these experiences is in both the research activities and the informal discussions, career advice, and connections that occur (Kirwan & Streckman, 2009). High school students with research experiences alongside an integrated approach to science across the curriculum had a greater likelihood of completing a STEM major than peers (Gamoran et al., 2011). In another example, Kabacoff et al. (2013) designed a summer REP for students from underrepresented groups to provide experiences in a professional lab firsthand. They also structured time for relationship-building between the high school students and the faculty and post-secondary students to talk openly about tips, challenges, and curiosities. Though shorter than other REPs, the program at the center of this current study provided an intensive mentoring experience doing research with these same ingredients.

High school may be an ideal time to reach students with this kind of experience because students begin to form and solidify beliefs about their abilities and future prospects during secondary schooling. Beliefs like "I am not good at math," or "Science isn't for me" take shape and can deter students from further exploration (Sax et al., 2015). High school students are developmentally prepared to engage in deeper exploration of science (Guillen et al., 2011). REPs introduce them to scientific

methods, which can cultivate critical thinking and problem solving skills (Feldman et al., 2009; Leedy & Ormrod, 2005). Although REPs are effective, they can be difficult to scale. Costs and time commitments associated with facilitating rich and immersive experiences can be prohibitive, and the numbers of students able to personally participate is typically small (Ahmad et al., 2021).

Given the cost and intensity of most REPs, it is valuable to learn about the potential of near-peer mentored REPs of brief duration. Research supports the potential efficacy of short-term interventions if structured dialogue and reflection targets students' subjective thoughts, feelings, and beliefs (see Yeager & Walton, 2011, for a review). Moreover, these brief interventions can have strong academic and psychological benefits, particularly for students of color (e.g., Cohen et al., 2006). A more recent review of brief, low-cost psychological interventions to improve gender and racial equality in STEM found support for the application of communal goal interventions, values-affirmation interventions, belonging interventions with role models, and growth mindset interventions—all of which are relatively short in duration and intensity (Casad et al., 2018).

Intersectionality of gender and race in science

The importance of social and cognitive congruence in role models and mentors in science is even further emphasized when considering near-peer mentoring of female students of color, who likely experience discrimination and bias based on multiple and intersectional identities. Crenshaw (1989) introduced the term *intersectionality* as an analytic framework to understand the multiplicity of oppression experienced by Black women given the unique intersection of their race and gender. As Jagers and colleagues (2019) emphasize, healthy social-emotional integration of identities in adolescence requires recognizing that students "belong to multiple social categories that occur in historical and sociopolitical contexts that may subject them to multiple oppressions simultaneously" (p. 171). Students must develop the agency and skills to negotiate their intersectional gender-racial-cultural identities and belongingness—traditionally dismissed and excluded within the science community—while also seeking belonging and identity within a field currently governed by White dominant norms and perspectives. Near-peer mentors matched with mentees on key intersectional identities, such as being a female student of color, can provide important knowledge, role-modeling, shared experiences, and skills to prepare for and navigate the complexity of this context. For this reason, we focus first on the two female students of color in our comparative case study approach and research questions outlined in the following sections.

Study context and aims

The purpose of the present study is to examine high school students' reflections and perspectives on their experience participating in a short-term intensive REP, called My STEM Story, with a near-peer mentor, to demonstrate the role near-peer mentoring can play in a REP to develop science identity. The study incorporates students' immediate reflections after the REP and reflections two and a half years after the program. We explored what aspects of the experience were salient for them, what may have changed about their ideas about their future in science, and what aspects of their experience, if any, were influential in their academic and career trajectories in the subsequent two and a half years. The purpose of the study is not to evaluate the impact of the mentoring program. Rather, we sought to understand how students reflected on their own past experiences and what similarities or differences existed between students carrying different intersectional identities. Results from the study can provide insights into how brief lab-based REPs, even those that only last three days, can be enhanced by near-peer mentoring in a way that reflects and responds to an intersectional lens to science identity and pathway development. Applying a longitudinal comparative case study design with five student cases, we explored three sequential research questions that follow from this overarching inquiry: *What does case-study evidence of intensive brief near-peer mentoring reveal about future use of this kind of programming?*

1) How did the first two student cases, both female students of color, think about their science identity in relation to other identities at the end of the REP, and what role did they feel the brief near-peer mentoring and lab experience would have on their science identity and pathway development?
2) Two and a half years after the program, how had the pathway and identity development in science unfolded for the first two cases, and what role, if any, did they feel the REP and near-peer mentoring had played in their decisions and self-beliefs?
3) How did the pathway trajectories and perspectives of three additional cases, all younger male students of color, compare and contrast with the primary and secondary cases related to science identity and pathway development and the role of near-peer mentoring and the REP?

Methods

Participants

For this study and program, students were recruited from approximately $N = 50$ students attending summer enrichment programs hosted by the university that served as the site for the near-peer mentoring REP. The two primary selection criteria were that participants needed to be students of color who also had an interest in learning more about scientific research on a university campus. Program coordinators provided informational material to all high school-age students in their program and encouraged them to bring the material home to their parents to discuss. These students had demonstrated enough personal interest and motivation in STEM for this extracurricular engagement. From that pool, $N = 6$ high school students were able to meet all of the expectations of the program. The project team sought to get an even representation of three male and three female students from across different racial, ethnic, and cultural backgrounds underrepresented in science. Among the $N = 10$ students' who returned applications and were able to meet the expectations of the program, the project team selected three male-identifying and three female-identifying students. Theses final six students ranged from Grades 9–12, with all male students in Grades 9 and 10 and the female students in Grades 11 and 12.

In this way, this study relied on convenience sampling, based on who applied for and was accepted into the program. For instance, we did not purposively select younger male students and older female students. However, the sampling was also purposive in that this research, funded by the National Science Foundation, aimed to learn specifically from students of color how this kind of REP might play a role in their science identity and pathway development. Student participants identified as African-American, Latinx, Native, Vietnamese, and biracial among other identities, and mentor pairings were based on shared interests and gender. Table 1 provides additional demographic information about the students. Of the original six REP summer experience participants, the data of one participant was not included in this study because researchers were unable to reach the students' parent or guardian to

Table 1
Case study participant characteristics.

Participant[1]	Gender Identification	Racial or Ethnic Identification	Grade Level at Start
Tyler	Male	Pacific Islander	9
David	Male	Latino	10
Mark	Male	Latino	9
Katie	Female	Asian American	12
Nova	Female	African American	12

[1] Pseudonyms have been used to protect the identity of the participants.

schedule the follow-up interview with the student. This Latinx female student, a high school sophomore, was younger than the two female cases included in this study.

Program description

This research paired high school science-curious mentees with near-peer college-level mentors—all students from underserved populations—for a three-day intensive summer REP during the summer of 2019. The immersive experience took place on a university campus in the Pacific Northwest region of the United States and provided mentees extensive opportunities to bond through shared lab, dining, and after work experiences over this brief three-day period. These high school students were trained to do video-based blogging every day as a way to reflect on their thinking and feeling throughout the program. These students also played an active role in interviewing their mentors toward the project-level goal of editing a series of videos to share the experience and perspectives with other high school students—this was another phase of the larger project, called My STEM Story.[1] The personal video blogging data of some students were incorporated in the final edited videos for the program. They were not primarily collected for research purposes. Moreover, the research team found the use of video blogging to be inconsistent across students, so those data were not included in this study. However, the experience of video documentation and reflection should be considered an essential part of their experience.

High school mentees engaged in both lab and field data collection and experiments across three days in marine biology, biology, and chemistry labs. Mentors introduced their mentees to their lab, showing them how to use the equipment, reviewing the studies they were involved in, and actually preparing for or engaging in a variety of experiments. Skilled undergraduate videographers were trained and employed by the research teams to document the mentor-mentee interactions, which were later condensed into edited highlights. Prior to Day 1, mentees received basic training to use handheld video recorders to record their thoughts throughout the experience in mini-video blogs that served as structured and open-ended reflection opportunities. They also developed interview questions for their mentee and conducted short video-recorded interviews. Each experience was meant to provide formal and informal opportunities for personal reflection and dialogue between the mentee and mentor. REP organizers held daily debriefing group reflection sessions as well. The mentors and mentees also gathered together each day to share lunch, get to know each other, and play games.

Procedures

The research team conducted multiple interviews with each student following a semi-structured interview protocol on the final day of the REP (see Appendix) to capture the immediate reflections from students and again two and a half years after the program to learn how the students' pathway developed and what stood out most memorably for the student, retrospectively. Both protocols asked students if and how they identified as a scientist and what, if anything, they envisioned for their future self in science. Additionally, both protocols asked students to reflect on the interactions, discussions, and experiences with their mentors that stood out most prominently. The study was approved by the Institutional Review Board at the university where the study took place, and informed consent and child assent were obtained from students and their parents prior to our interactions.

[1] We direct readers to the following website to learn more about the My STEM Story program: www.mystemstory.net.

Analytic approach

We employed a longitudinal comparative case study design to explore and compare the perspectives and experiences of five student case studies, each with different intersectional identities. The aim was to gain an in-depth understanding of the pathway development of high school students of color and what aspects of the mentoring and REP may have played a role, if any, on how their pathway unfolded and what they envisioned for their future. The case study approach was chosen because it allows for a comprehensive analysis of individual cases, while also facilitating cross-case comparisons on key characteristics and perspectives of the cases (Yin, 2014). Whereas the individual case study analysis prioritized the individual's experience of the phenomenon across multiple years, the cross-case comparison centered on the phenomenon of interest—science identity and pathway development—rather than on the individual, as Bartlett and Vavrus (2017) encourage in their comparative case study approach.

The data analysis process followed a systematic approach, guided by the principles of thematic analysis within each case. Initially, two members of the research team read through all interview transcripts to gain a holistic understanding of the data. Next, the research team developed an a priori coding framework used first by a single researcher (the second author) to identify and label significant concepts, themes, and patterns that emerged from the data. These codes were then organized into higher-order themes and sub-themes in the data analysis software, Dedoose (2021). That first researcher sought to draw out a narrative for each case based on the themes. Next, the first author completed a review of the coded data and found a discrepancy of less than 10 % of coding disagreement, all of which were excerpts that were missed by the first researcher in their coding process. These discrepancies were resolved through discussion and consensus resulting in additional excerpts within the transcripts to be included in the narrative development for each case.

After individual narratives were composed, we followed Yin's (2014) approach to comparative case study analysis by treating one of the female students of color, Nova, as our primary case. We chose this approach over other approaches, such as that proposed by Bartlett and Vavrus (2017), because our cases were bound clearly at the micro-level of the individual student. Given the intersectional framing of this study, we prioritized revealing the uniqueness of the lived experience of the phenomena of interest first at the individual level prior to cross-case comparison and integration of narratives. We felt that Yin's (2014) structure provided the best analytic tool for this purpose, and a focus on the micro-level of the individual was the first priority. However, we also sought to maintain a processual openness to emergent themes and insights about the phenomena of interest (Bartlett & Vavrus, 2017), such as at the macro-level of society and meso-level of schooling and employment, that the case comparisons would reveal.

We chose Nova as our primary case following prior work on intersectionality since Crenshaw's original proposal of the framework (Crenshaw, 1989) highlights the substantial ways that Black women face greater oppression than both men and women of other racial and ethnic backgrounds inside and outside STEM pathways. Choosing Nova as a primary case and replicating analyses with multiple other cases follows replication logic that is analogous to multiple experiments (see Hersen & Barlow, 1976). In this approach replications can try to duplicate key characteristics of the case or conditions of the setting, and other replications can alter key aspects (Yin, 2014). We chose this approach over a thematic analysis narrative that integrated perspectives and experiences from all five cases simultaneously because we privileged the voice of Nova as a Black female individual first and the voice of Katie, another female student of color, next, prior to the integration of the voices of their male peers. In this study, we duplicated and altered two key characteristics of the cases—gender and age. However, all cases shared the characteristic of being a student of color from groups underrepresented in science.

After coding, analyzing, and writing up Nova's study, we compared that experience and perspective to the most closely duplicated case in our sample—Katie—whose perspective and experience served as the *literal* replication (i.e., she identified as a female student of color with an ethnic background (Vietnamese-American underrepresented in science pathways, both in her perceptions and experiences and in data from the field). After enriching the analysis and understanding with the addition and comparison of Katie's narrative, we applied this understanding to the perspective and experience of the younger adolescent male students of color as *theoretical* replications. These were theoretical replications based on our intersectional framing because we expected differences would emerge based on identifying as male students of color and being in Grades 9 and 10. We chose to only analyze and report on the 2-year follow-up for these three cases to focus on what, if any, role the REP and near-peer mentoring played in their science identity and pathway development. In this way, we developed an understanding first from the perspective of older students at the intersection of minoritized race and gender, then compared that perspective to the experience the three male students from groups historically underrepresented and marginalized in science. When appropriate, we drew implications and insights at the meso- and macro-levels based on cross-case comparative analysis.

Researcher reflexivity

The first author is an educational scientist and designer, identifies as White and male, and has extensive training on culturally responsive and sustaining practices in education and intersectional analysis in research. The second author is an educational scientist, identifies as White and female, has a specialization on the representation and engagement in science of female students, and is a former middle school/high school science teacher. Both were involved in interviewing students, analyzing data, and drafting and refining case study analyses and narratives. Both have extensive research experience in educational interventions, adolescence, motivation, and identity development. Each of the authors completing coding and analyses reflected on their experiences and identities and how they might influence the research process. In particular, both researchers incorporated complete excerpts as often as possible to privilege participants' voices and intersectional perspectives over the authors' interpretations.

Results

We present in-depth analyses from one primary case and a secondary case in line with our research questions. Then, we provide a shorter analyses of the replication cases afterward. Table 2 summarizes information regarding the descriptions of each student's science pathway and identity development. All students are identified with a pseudonym to protect participant privacy.

Primary Case 1: Nova

General description and reflections after the summer research experience

At the time of the REP in 2019, Nova was a rising junior in high school. She self-identified as an African-American female. She did not identify as a scientist then but held a strong interest in and background with STEM. As she noted, "Like STEM isn't just science. It's not just math. It's not just engineering. It's also everything that you do." She described herself as motivated to overcome any social pressures in high school that might hinder her academic career, stating "…I often tell my friends, I'm like well if you want me to like hang out with you guys, I have to keep my grades up." She described her motivation as partially coming from her family, noting that she is interested in working to help both she and her brother go to college and allowing her mother to step back from working so hard to take care of their family.

Table 2
Pathway development and science identity descriptions of each student case.

Mentee Cases	Science Pathway Development	Science Identity
Nova (Primary case)	• Graduated high school and working as pharmacy technician • Saving money to pay for community college • Plans to enroll in 4-year university for medicine or pharmacy	"In some ways, probably not, like, you know, like a full blown scientist. But I do believe that my curiosity is that of a scientist…I've definitely become one of those people that's like, oh, I wonder how this turned out. And then I kind of look into it. And then I kind of ask a couple more questions…I look a little bit more into what it is that is causing the things…my curiosity is definitely something of a scientist now."
Katie (Literal replication)	• Graduated high school and was in third year of college • Planned to gain patient care hours for a physician's assistant program and tutor • REP program influenced her dream to run a lab	"I do not feel like a scientist as of right now, because I feel like, if you're really a scientist, you would be in some on the research, or some level of education, which I have not reached yet. I feel like I would be…I'm on the path right now. I hope to be called a scientist one day…Have I made some, like new discoveries? No. Am I in like a lab? No…I hope to reach that level. But as of now, I don't think I am."
David (theoretical replication 1)	• Graduated high school & plans to attend university to study psychology and some day become a psychiatrist • His interests shifted from meteorology to psychology due to the stress of the pandemic on mental health in his community	"I felt like [the University] is the place where I belong. And also like the little things, the projects we did here and there…" As far as identifying as a scientist, David, shared "…as of now, I'm just another student trying to get there. But one day, I hope to be considered [a scientist].
Markus (theoretical replication 2)	• Was still a senior in high school and did not have specific post-secondary plans yet • REP program influenced his completion of his science course requirements by end of sophomore year • REP experience encouraged him to attend college and study engineering	"I like to think of myself as a scientist, because…I like to approach things with a lot of trial and error and just trying the same thing over and over again, with slight differences to see what has changed…I think the program did influence that approach a little."
Tyler (theoretical replication 3)	• Graduated high school and planned to attend college • REP experience in lab with zebrafish influenced his exploration of science courses, including marine biology • REP experience helped him see beyond traditional roles in science and embrace his heritage and beliefs	"I don't know. I mean, I do like [science] things…I just never really thought about it until now. Because I find myself really intrigued when it comes to anything science here, mathematics, and stuff. So for me, science is kind of what I look at a lot of the time now. I just kind of want to learn more about it."

Future aspirations. Nova noted an interest in attending a Historically Black College (HBC): "And I kind of just want to go to like an HBC just like see if I find some type of comfort or like home or like roots or just like some form of like settling there." Her future career aspirations in STEM included a range of interests in science, technology, and engineering. When asked to describe the characteristics that make a good scientist, she shared: "Someone that doesn't just tell you how things work … they want you to keep asking questions as opposed to just telling you like well it's this way…" She believed scientists have to be

passionate and enthusiastic and noted her near-peer mentor modeled how this was such an important characteristic.

Barriers she expects to confront. When asked to describe possible barriers she might encounter in pursuing a career in STEM, she specifically noted both gender and race barriers. She described her high school as "predominantly African-American" and "fairly diverse", which she believed was a supportive factor in her academic career. In response to being asked if there was anything that makes her nervous about taking science classes in the future, she responded "…being confused. I know I'm going to hit a point where I'm like I don't know what else to do, like how to help myself, it will definitely be hard…My drive to keep going I think will push me through." Nova saw social media as a challenge. "It is a huge distraction…impacts everything that I do…I'll start to procrastinate because I'm like oh I'll just set a timer on my phone and then get distracted and never go back to it."

The role of mentors in science. When asked if she currently had science mentors in her life, she stated, "Not a lot of them. I wish I had more. I just finished AP chemistry and I definitely wish I had like maybe two or three tutors. Like just constantly either checking up with me or just like checking in with me." Nova also noted that in general her teachers were supportive, but they do not have time to help students individually. Nova described her experience with her summer program mentor positively. She felt they connected because of some similar experiences and personal characteristics.

> Well, she was a first generation college student. So like everything she was saying I can relate to. So like she had a lot of perseverance and she was like even if someone tells you no like the like the worst thing you can hear is 'no'…Like it doesn't mean stop. It just means like find another way to try something new or like go after something else.

She enjoyed the summer lab experience with her mentor, where she examined worms in petri dishes, preparing them for analysis. Her affect toward the experience shifted from it being "kind of gross" to feeling "really fascinated…I wanted to keep looking and wanted to find the differences [between the worms morphology]." She further described the lab space as being slightly different than what she expected in a way that made her feel more like she belonged: "…you know everything's, like, organized and clean but…it was like a real environment…being in there made me feel like ready to be a scientist and try new things."

Themes from summer research and mentoring experiences

Nova noted that she did wish she had more time in the lab itself, as she really enjoyed the experience, and that she would probably have asked her mentor even more questions if she had time to get to know her. Nova stated she felt she would continue to take more science-related classes in her senior year after attending the summer program. For Nova, the primary themes from her reflections on the summer research and mentoring experiences were (a) developing an identity and sense of belonging in science connected to the values of her family, (b) holding aspirations for a career in science, (c) recognizing the importance of feeling passionate and curious to be a good scientist, and (d) understanding the role that a variety of potential distractions and barriers may play.

Literal replication Case 2: Katie

General description and reflections after the summer research experience

At the time of the REP summer program in 2019, Katie was a rising junior in high school. She self-identified as a Vietnamese-American female. Katie emphasized the importance of giving back to the community and shared that her family had instilled a strong work ethic in her and a commitment to giving back to the community. Katie was involved in community service, establishing an Asian Student Union at her high school. Katie discussed that in her view, scientists aim to give back to society by applying their knowledge to help others and contributing to community good. Based on her experience in the summer program, she believed having passion, love for the field, and knowledge were crucial to being a good scientist. She also had come to see the importance of enjoying the journey and working toward a specific end goal. She shared, "I use this word a lot…passion. You have to love it…If it's not enjoyable, your end result won't matter to you. And I think what you want in the end…is not the most important thing, it's the path that you take to it."

Future aspirations. Katie reported that she planned to attend college to work toward a pharmacy degree or Chiropractic work as a backup plan. She discussed three things she felt she would need as support in working toward that goal, including financial support, moral support from family and friends, and more hands-on experience to explore all of her options.

> I don't have as much time to think about the future as I wish I could…And I think just being able to have hands-on experience that really is like driving me forward toward what I want to do. And, of course, I can't say that I even want to become a pharmacist because there are so many variables that would change my path…

Barriers expected. Katie expected that a focus on making money, the intensity of family expectations, and perhaps dissatisfaction with different types of science learning experiences were all present barriers.

> Maybe I'm greedy with money and maybe it's like, oh if I had, what if I have like a good stable job before I become a pharmacist…I don't want that type of money…that greed to come over me…I believe that my goal in life is to help others…also if my family, since they would push me, they could also drag me down. Because [they are] Vietnamese, they have very high expectations of me and for my sister. I know that they have good intentions, they want me to become better. But of course, they never had the best of education. So, for them to push me forward, I understand why they were doing that, but it also, it gets hard.

Katie experienced mixed levels of encouragement at her school for young women in STEM, where some teachers made substantial effort to support women in STEM and others exhibited a more male-dominant mindset. She shared, "I believe that we need a new rotation of teachers who treat students with more equality," and she felt older teachers hold more bias against women in science. For herself, she believed that both her gender and her race could be challenges to her goals of pursuing a pathway in STEM, noting "For me personally, yes it's my race. And it's also my gender because I'm very much the minority. A female Vietnamese woman trying to pursue something that is also a very competitive field." For now, she plans on trying to ignore this barrier, but hopes that teachers can treat her like an equal.

Role of mentors. Katie reported she felt a strong connection with her mentor from their extended conversations. Katie shared her mentor was willing to involve Katie in lab activities and helped her feel at ease and engaged. Katie and her mentor discovered common interests and a shared love for science. They both appreciated the unique aspects of various scientific fields and had a similar mindset of wanting to give back to their communities. She was impressed by how her mentor aspired to educate through TED talks and nutrition-related initiatives. The mentor's advice about stepping outside one's comfort zone, even in non-diverse environments, resonated with Katie. This lesson inspired her to consider taking on leadership roles and embrace new experiences despite the discomfort she expected in future situations.

> I think because I've always been the minority for my whole entire life. And it gets to me sometimes, saying like, Oh why do I not see

other people like me. But I think her [mentor's] idea of…stepping outside your comfort zone. It gets to me because I myself get uncomfortable in many situations but I realize when I'm uncomfortable I should live up to it and just go forward no matter how awkward I get…And so I think for me, I want to be a leader…when I created Asian Student Union I'm trying to lead people to feel like, hey this is your home. If you ever feel uncomfortable we're here for you.

When asked about other science mentors she might have outside of the summer REP, Katie felt her science teachers lacked passion due to years of teaching. She felt mentors closer to her age could be more relatable to discuss both science and personal matters. "I think having someone as close of age because you're able to connect more on a social level as well…But if there's someone who is older I understand, I would look up to them but it's harder for me to connect with them."

Effect of being in a professional lab. Katie reported that just being in the lab, working with her mentor and other lab students, was when she most felt like a scientist. She described the difference between being in a professional environment versus a high school classroom and being motivated by her mentor's passion and the team's determination. She noted.

Like the energy in the room… Everyone was so determined for their end goal which is to get their embryos and dye it…to cure cancer eventually…the second I walked into the room having that environment…rather than the high school classroom…I think that was the second I felt like, this is real. This is phenomenal.

Themes from summer research and mentoring experiences

Katie reported that she was eager to explore higher-level science courses and dive deeper into subjects beyond the surface level. She felt there weren't classes at her high school that allowed that level of rigor, so she was more excited about future college-level courses. She also expressed nervousness about the future, specifically about the competitiveness of science. Overall, many of the same themes and development from Nova's case study analysis were replicated, such as an emphasis on family, aspirations and expectations for barriers in science pathway, and close connection to mentor. Katie added greater emphasis on feeling discomfort and heightened awareness about the lack of diversity, generally, in science and the effect of some teachers' male-dominated approach. She also recognized the importance of facing the discomfort with courage and maintaining one's passion in what they study—both characteristics modeled by her mentor.

Two-year follow-up reflections on the program and personal development

Case 1: Nova

Two years after the summer REP, Nova was not currently enrolled in post-secondary school, but she had been working to save money for future education. She took a pharmacy technician job and was about to take the official test at the time of the interview, which would allow her to transfer to a healthcare facility if she chose. She planned to begin her studies at a community college for basic credits, then transfer to a 4-year university to pursue a degree in medicine or pharmacy. Since participating in the summer REP, Nova felt more comfortable pursuing her interests, stepping out of her comfort zone, and interacting with new people. She felt her REP participation and mentorship contributed to greater comfort and confidence to pursue science or a health-related field and to take math classes.

I do feel like having the opportunity to meet new people and interact with the things that I do enjoy and like to do has been kind of helpful since the program, now that I kind of reflect on it…I like to step out of my comfort zone and approach people and tell them what I'm interested in.

She reported her participation enhanced what felt possible for the future by allowing her to become more open to trying new things. In particular, she remembered the sense of community among the staff and fellow participants, especially interactions outside of the lab experiences.

Nova noted she became more engaged in science-related topics after the REP, particularly during the pandemic, by researching and staying informed about scientific developments. She stated that the REP provided valuable support and encouragement to explore new fields. While she hadn't actively sought out mentors yet, she believed the program's experience would help her find them in the future.

I definitely wouldn't have pursued the pharmacy technician spot [without the experience in REP]…and after leaving the program, and knowing that there are people who can answer those questions or be supportive…I did feel kind of some form of a reassuring boost into pursuing it.

Nova felt she didn't yet fully identify as a scientist but recognized her curiosity aligned with scientific thinking. She described her science identity as.

…probably not, like…a full blown scientist. But I do believe that my curiosity is that of a scientist…I've definitely become one of those people that's like, oh, I wonder how this turned out. And then I kind of look into it. And then I kind of ask a couple more questions…my curiosity…is definitely something of a scientist now.

Nova felt the biases she confronts about her age, race, and position as a manager in a pharmacy, especially during interactions with customers, to present the biggest barrier. Nova reported that even in the face of these challenges, she handled situations with confidence, asserting her knowledge and skills in her role with support from other women of color her in the pharmacy. She emphasized her commitment to providing helpful services despite potential biases.

It's kind of hard to hold my authority, because a lot of people are like, you know, we'll want to talk to the manager…How can I help you? And they're like, "no, there's no way" and I'm like, "yeah, I am a 20-year old African American woman that is a manager"…And it is sometimes a power struggle…whether it is something that, you know, they don't fully understand they tend to aggress the person that is trying to help them because there's a sense of pushback…it is a topic that is always going to be there…considering, you know, the person that I am, and what I look like and what I stand for… for some people that is a little bit harder to accept because of my age and my color. But it is something that I feel more confident to step into…I am going to be that woman that you dealt with at the pharmacy that was extremely nice and of color, and knew what she was talking about and helped you along the way…this is not what you were expecting, but this is what is happening.

In this way, Nova found that confronting people's biases about her intersectionality of race, gender, and age gave her courage. After providing people responsive customer service, she found people would share "…'oh, you know, you're a lot more…approachable or conversational or helpful than I anticipated'… I'm like, Yeah, I'm not some bully, I'm not someone that just is out to be mean, or that stereotype, I am genuinely here to help." Nova believes she carries confidence developed in the summer REP in these challenging moments, feeling buoyed by the supportive mentors and peers—all people of color—who talked about taking people's biases and stereotypes in stride. "It's nice to note there are other people of color and…ethnicities that are willing to take that opportunity to [model]…or be that person who took that step…guiding others to pursue the opportunity…".

Case 2: Katie

At Katie's 2-year follow up interview, she was in her third year of college with a focus on human physiology and biochemistry. She

planned to gain patient care hours for a physician's assistant program application and was involved in various activities, including tutoring and leadership in a student association. Katie selected her university based on scholarship opportunities and the good location of the university. Upon reflection—in contrast to Nova's experience—Katie reported that the REP summer experience did not seem to affect her sense of identity as a scientist or directly align with her ultimate career goals. However, she did feel that it ignited a stronger interest in STEM fields, particularly health and research. Katie shared,

> I do not feel like a scientist as of right now, because I feel like, if you're really a scientist, you would be in some…research, or some level of education, which I have not reached yet. I feel like…I'm on the path right now. I hope to be called a scientist one day…Have I made some, like new discoveries? No. Am I in like a lab? No…I hope to reach that level. But as of now, I don't think I am.

Katie noted that the REP experience expanded her perception of what is possible for her future. She specifically reported that she is now more open to trying out different opportunities, including graduate research and lab work. She has a "bucket list" dream of leading her own lab, due, in part, to the summer REP and mentoring.

Katie found the REP experience valuable in sustaining her interest due, in large part, to her interactions with enthusiastic and passionate mentors. The most memorable moments included the engagement and genuine interest of all participants and the lab activity involving worms and microscopes. Katie reported that she still felt a sense of camaraderie years later. Katie noted that since the REP, she had found new mentors, particularly among her graduate instructor peers at her university, who offered insights and guidance related to her academic journey. The experience didn't necessarily lead to increased reading or research in STEM but did encourage visits to various facilities related to her interests to learn more about her options.

Comparing cases

There was considerable overlap in the themes Nova and Katie emphasized about their science identity and pathway development and the role of the REP. The modeling of their mentors appeared to play the biggest role. Both shared how their mentors followed their passions and their values to be resilient in the face of biases, stereotypes, or other external challenges, such as limited financial means for college. Those characteristics were important to both Nova and Katie as women of color in a field where they were likely going to feel discomfort and less acceptance. In the two and a half years following the program, both shared experiences that demonstrated the poignancy of that role-modeling and messaging in facing strong biases from others as they began to grow in their science pathway. Another influential aspect of the REP was feeling a sense of belonging and inclusion in the professional labs they worked in. These cases also differed in some important ways. At the time of the follow-up, Katie was in college and Nova was in the workforce. Nova seemed to have experienced more bias and stereotyping through her engagement with the public she served in her pharmacy job compared to Katie in the college setting. Additionally, whereas Nova emphasized how the REP played a direct role in her identifying more as a scientist and in her plans to pursue science, Katie felt the REP was less impactful in that way.

Three theoretical replication case studies

The final analysis in our case study design sought to generalize and contrast the themes from the primary case, Nova, and the literal replication, Katie, to the two-year follow-up reflections of three younger male students. The driving question in this analysis was how the program appeared to influence these three younger male students in similar or different ways than their older female counterparts and how to understand similarities and differences in their pathway development through an intersectionality lens.

Theoretical comparison Case 1: David

In the follow up interview, David had very recently graduated from high school and planned to attend university to study psychology, transitioning from a previous interest in meteorology. He reported that his interest in psychology stemmed from his understanding of the importance of mental health awareness and support. David explained he became interested in psychology due to the significant emphasis on mental health issues he experienced both personally and with family and friends during the two years of the COVID-19 pandemic after attending the REP summer program, prompting a desire to prioritize and contribute to the mental health care system of support. His ultimate goal was to be a psychiatrist.

David reflected that the summer REP further solidified his previous desire to attend a local university (where the REP summer program was held), emphasizing the importance of the sense of belonging and community inclusion he felt. David noted the experience boosted his self-confidence and encouraged him to pursue personal growth and new connections with like-minded individuals—both aspects he related to a developing identity in science. He opined that the summer REP instilled the belief to strive for his aspirations, even if not achieving perfection, and highlighted the importance of pushing back on societally constructed boundaries—a theme present across the first two cases. David attributed the decision to take some science courses to his REP participation. He shared that external factors, like injuries and family loss, limited his choices, prompting a desire to maximize other future opportunities. David felt inspired after the REP to seek guidance and advice from those with similar career paths and planned to find mentors at his university, indicating a proactive approach to research and help-seeking support.

David currently identified as a student rather than as a scientist but hoped to eventually identify as a scientist once he achieved his goals. He saw psychology and psychiatry as sciences due to the study of the brain, patterns in behavior, and the quest to understand mental health. Identifying as a scientist, for David, meant continuous exploration, growth, and innovation to achieve higher levels of understanding and contribute to meaningful discoveries in the field.

Theoretical comparison Case 2: Markus

Markus was a senior in high school during the follow-up interview. School felt challenging, and he did not know what he planned to do after high school. He reported the summer REP helped maintain interest in science and led to completing science courses early in high school: "I ended up finishing all these science courses in high school my sophomore year…[the REP] definitely helped me keep interest and I still feel interested to this day." Memorable moments from the summer REP included the campus tours with the mentors and learning about aluminum minerals and their applications while working in the lab with his mentor. Markus felt the program had broadened his interest and outlook on potential career paths in science, motivated him to take more science courses in high school, including advanced physics, and was looking for internships. However, the REP did not initiate extracurricular research into science topics. As Table 2 shows, Markus saw himself as a scientist, and attributed some of that identity to the REP's emphasis on being experimental. Markus saw being a scientist as a combination of pursuing knowledge and contributing to societal progress: "I think it means that you are on the constant pursuit of knowledge and accelerating society toward benefits." Mark felt the REP encouraged the possibility of attending college and pursuing engineering.

Theoretical comparison Case 3: Tyler

By the 2-year follow-up interview, Tyler had graduated from high school and planned to attend college the following year. Since attending the summer REP, he had faced some challenges with school, particularly

with time management. Getting a job helped him get back on track. Regarding the summer REP, Tyler particularly remembered his experiences working with and interviewing his mentor, the time he spent in the lab with the zebrafish, and the relationships he formed with the other summer program participants. Tyler felt the REP had influenced his choice to explore more courses related to science, including marine biology, noting "I definitely got a little bit more into the science field. I ended up taking marine biology at one point…the teacher was amazing." In addition, the experience helped him embrace his heritage and beliefs, leading to a deeper understanding of his identity:

> I knew who I was already, but it kind of helped me to understand who I was on a deeper level than just a basic 'Oh, I'm this, I'm that'. It helped me understand more of who I really am…Back then I probably wouldn't have answered your email…But after going [to the REP], I just, it taught me how to embrace what I am. So, from my Hawaiian heritage, my Japanese heritage, all that. But also to embrace my beliefs.

Tyler explained the summer REP expanded his sense of possibilities for his future by highlighting the various pathways that can emerge in science, such as starting a business. The experience with his mentor broadened his overall view of careers in science. He showed him that science pathways encompass more than just traditional roles like doctors and psychologists. He did additional research as a result of the program into different fields of science, even writing a paper for school on the topic. Though finding additional mentors was challenging, Tyler discovered new mentors through attending another summer university-based program. As Table 2 shows, Tyler did not explicitly identify as a scientist, but characterized his relationship to science as a strong interest. Tyler felt identifying as a scientist involves belief in one's research and the opportunity to embrace and explore different scientific fields, even if they are related to personal beliefs, such as religion.

Integrating theoretical comparisons

Some of the experiences and perspectives of Nova and Katie mapped onto the experiences of these three younger male students, while other aspects differed considerably. First, there was a common sense that the program made a long-term impression on some of the students. That impression led to taking more science classes in high school, pursuing science pathways after high school, maintaining an interest in science, developing more confidence in themselves, and feeling a willingness to try new things. Whereas the two older female students shared how they began to identify as a scientist, such as through their developing curiosity, they did not feel they would be seen as a scientist by others yet. In contrast, the male students all considered they may identify as a scientist in the future.

A noteworthy contrast between the three theoretical replication cases and the first two cases was the lack of emphasis on experiences of bias or other external pressures, such as family expectations. The barriers that these three cases discussed were primarily internal (e.g., time management or motivation) or societal (e.g., the disruption of the pandemic). It is possible that this contrast is a mixture of the two defining factors of these two comparative groups—gender and age. Developmentally, the REP was proximal to the transition from high school for Nova and Katie, so they both inevitably confronted the reality of being a woman of color in a STEM context—college or career—exposed to all of the macro-level pressures of biases. In this way, the stories and experiences shared by their mentors may have carried more weight. The younger male students' trajectories were interrupted by the COVID-19 pandemic, which may have limited their attention to other factors. It was also clear that identifying intersectionally as both a woman and minoritized race/ethnicity called forth different types of pressures and barriers for the first two cases. These important themes and contrasts are discussed further in the discussion section.

Discussion

In the discussion below, we integrate the findings into the existing literature and theory on the role of near peer mentoring in REPs for the development of identity and pathways for students from underrepresented identities and backgrounds. We organize this discussion in four sections: (a) the aspects of the experience that were most influential across time, (b) how students' identities and pathways unfolded differently across two and a half years reflecting different *funds of science identity*, especially regarding gender, (c) intersectionality in students' science identity development and experiences after high school, and (d) REPs as *counterspaces* in STEM that emphasize communal goals for students. We discuss the implications for practice and research throughout.

Most influential aspects of summer REP

Across cases, participants found the informal conversations and social time they had with both their program peers to be memorable and important in their sense of belonging. Most cases also found the work in the lab with their near peer mentors to be memorable and influential in their pathway development. For instance, Nova reflected that being in an actual lab, for even just a couple sessions, made her *feel* like a scientist. Across cases, the experience resulted in aspects found in other REPs (Kabacoff et al., 2013; Kirwan & Streckman, 2009), including (a) developing an identity and sense of belonging in science connected to the values of students' families, (b) holding aspirations for a career in science with communal purpose, (c) recognizing the importance of feeling passionate and curious to be a good scientist, and (d) understanding how different distractions and barriers may make a science pathway challenging. Additionally, the program may have broadened students' ideas about what a science pathway can look like beyond the traditional ideas of becoming a lab scientist or doctor, reflected by David in how he viewed psychology as a science focused on mental health. Katie shared the hands-on experience was important to pull her attention from many other things to think about her future.

Both female students of color described the REP similarly to how Ong et al. (2018) encourage cultivating counterspaces in STEM for women of color. These safe spaces should provide underrepresented students the opportunities to (a) feel that their experiences and perspectives are important and validated, (b) vent frustrations through storytelling of microagressions, isolation, and other forms of discrimination, and challenge deficit narratives with a positive racial climate (Ong et al., 2018; Solorzano et al., 2000). Only one male comparative case, Tyler, shared that the experience made him embrace his cultural identity at a deeper level, but he did not attribute that to specific stories or experiences with his mentor. In contrast, the two female cases shared both stories of discrimination and isolation they experienced since the program and reflected on explicit conversations they had with their female mentors of color. The only Black female student, Nova, shared a particularly difficult story of discrimination from a customer, and drew direct links to her resilience in the face of that challenge to the counterspace she experienced in the REP. These findings suggest that REPs may benefit by drawing from the counterspace concept to consider how to design and structure the experiences specifically for women of color, with care to their individual racial, ethnic, and cultural experiences.

One shared motivational and behavioral outcome shared across all cases was the intention and follow-through on taking more science classes between interviews, including advanced courses. All cases felt their interest in and pursuit of a science pathway developed more resilience as a result of the program—their course-taking, extracurricular, and disposition toward science since leaving the program demonstrated that resilience. Finally, all cases also felt more prepared and motivated to connect with mentors in the future. The value of social and cognitive congruence (Lockspeiser et al., 2008) was a common experience across cases.

Congruence and integration of identities toward science pathways

The two primary female case study students and one male student indicated identity congruence between they and their mentors in different ways, and that congruence appeared to support greater integration of a growing science identity with other identities. Tyler expressed the importance of his Hawaiian cultural identity, Katie embraced her identities as a Vietnamese-American woman, and Nova felt validated as an African-American woman. For instance, the REP made Nova curious about attending an HBC to feel a similar intimacy and belonging. She felt identity congruence with her mentor in another important way—being a first generation college-bound student. Those aspirations had been stalled by financial and familial reasons, but she was solidly on a career path in science that she found rewarding. She attributed her continued interest, her confidence, and her tolerance for discomfort and risks to the congruence she shared in experiences and interests with her mentor. The benefits of this *cultural* congruence with science near-peer mentors expressed by three of the students of color reflects the perspective of science identity as social identity suggested by Kim et al. (2018). These students' social identity in science was augmented by feeling like they were a member of the group through their experiences in the lab, informal social time with their near-peer mentors and each other, and the connections they felt on the racial-ethnic-cultural-gender intersectional levels. Future work in research and practice of science near peer mentorship should explore these additional dimensions of congruence (Lockspeiser et al., 2008; ten Cate et al., 2012).

Findings across the five cases can also be contextualized within the *funds of science identity* framework to understand the value of identity-affirming contexts, importance of family, and structures of power, privilege, and oppression within STEM disciplines (Wofford & Gutzwa, 2022). For instance, as she reflected on her REP experience, Katie knew her identity as a Vietnamese-American woman would be perceived negatively by others in her STEM educational and career pathway, and she expected her family support, encouragement, and culture of high standards would be a vital resource to counter the deficit narratives and discrimination and bias of others. Similarly, Tyler shared explicitly that the program helped him embrace his Hawaiian heritage and beliefs, which deepened the meaning and purpose behind his goals in science and life. For both Nova and Katie, the advice and modeling they received to step outside their comfort zones, including into non-diverse settings where they would likely be *otherized* and excluded, had been and would continue to be very important to them in their pathway. This integration and congruence of identities reflects the tenets from IBM (Oyserman & Destin, 2010) that identity is constructed in context, such as in a science lab in a REP, and needs to feel congruent with other identities to lead to motivated proactive action toward goals, such as a science pathway. The lived experience of these case study students emphasizes the importance of valuing these *funds of science identity*, provided by peer connections and family values and support. Future work can consider ways to integrate the IBM and funds of science identity perspectives to enhance theory and practice.

Intersectionality in science identity

Sparks (2017) emphasized that an intersectionality lens requires care to not flatten the dynamic and diverse identities students may carry with blanket assumptions based on broader generalizations by group, such as race, ethnicity, culture, and gender. In this way, women of color will experience different types of discrimination and biases, as our two female cases demonstrated. Avraamidou (2020) suggested that an intersectionality lens can place the development and sustainability of science identity within the specific context of privilege and oppression each student experiences. For instance, Katie identified as a Vietnamese-American student, who shared unique experiences that may not fit societal perceptions about students from an Asian background in STEM. Avraamidou points out there has been little work to acknowledge intersectionality in science identity development in the education context and a limited view on what science identity can and should mean for students. Avraamidou argues intersectionality in science identity means there is "a landscape of…infinite ways of becoming a science person." (p. 325). Relatedly, Katie shared she felt some of her high school teachers, especially those who were older with more traditional views, held and perpetuated biases about women in science—apparently, they could not see and validate this diverse landscape of possible science identities. Avraamidou suggested this process of becoming should focus on emotions and recognition—two aspects reinforced by the student case studies. All cases recalled how thrilling and fun the lab experience was two and a half years later and several remarked on the importance of being trusted by their near peer mentor to work with their lab equipment and recognized for their skill and perseverance.

Communal goal orientations to science identities and pathways

Another key dimension of identity and pathway development elucidated in this study is the communal nature of students' motives to pursue science, especially for the two female students of color—a finding supported by goal congruity theory (Bonilla et al., 2023; Diekman et al., 2010). Nova sought to help put herself and her brother through college, and Katie wanted to make her family proud and give back to the community, which she had already begun through leadership in Asian student associations. Indeed, Katie found she shared interests with her mentor to give back to their communities and educate and inspire others through efforts, such as a TED talk. Only one male student shared, David, connected his shift in interests from meteorology to psychology with an explicit link to wanting to help others and contribute to the system of support for mental health care. As goal congruity theorists and others have urged (Author, 2025; Bonilla et al., 2023), it may be essential that near mentoring and REPs in science emphasize the communal affordances of science pathways to offset the cultural myths and biases that emphasize individualistic pursuit and recognition. Future work can develop this understanding further.

Limitations and constraints on generality

The generalizability of this comparative case study is limited to the evidence that short-term, lab-based near-peer mentoring can make a difference, even across the variations of the small sample of cases in this study. We caution readers to not generalize about how or why near-peer mentoring works for specific groups beyond this general evidence. Beyond the identity markers of our cases, such as race/ethnicity and gender, other contextual characteristics, such as geographic location and family background, will likely play important roles that researchers should anticipate. It is very possible that the age and maturity of the male and female students shaped some of the differences in perceptions and experiences, as well. We did not have socioeconomic information about students' families and sought to allow them to share that information and related experiences if they felt it mattered in the context of their engagement and development in STEM.

Given the impact of the COVID-19 disruption, the pathway development of students in this sample may have taken very unexpected turns that may not map well onto the pathway development of students during other periods of time. This point underscores the need to stay attuned to the broader sociohistorical and macro-level context in which science learning and identity development unfolds, especially during school and life transitions. We designed interview protocol that balanced specificity with open-endedness to not be overly leading in a way that would encourage students to respond in ways that might please the interviewer rather than with honesty about their thoughts and feelings. As our results noted, several students responded that they did not feel the program played a role in their independent reading and research or in

expanding their interests in science. These moments provide some evidence that students may not have felt much, if any, pressure to respond due to social desirability to please the interviewer. Additionally, during the program we conducted multiple interviews, establishing a strong rapport with participants demonstrating that we valued their honesty and directness. Still, there is a chance students framed their thoughts and feelings to please the researchers.

Conclusions

This study used a longitudinal comparative case study approach to learn about the potential of a lab-based summer REP with near-peer mentors of color to support the intersectional pathway and identity development of high school students of color. Our results contribute new support and dimensions to an intersectionality lens on science identity, the potential of near-peer mentoring in science, the potential of brief lab-based REPs—even as short as three days—for developing or sustaining science identity, and the diversity of routes that science identity and pathway development unfold for diverse students.

CRediT authorship contribution statement

Ross C. Anderson: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Tracy Bousselot:** Writing – original draft, Methodology, Formal analysis. **Ed Madison:** Writing – original draft, Project administration, Funding acquisition, Conceptualization. **Matthew H. Kim:** Writing – review & editing, Writing – original draft, Conceptualization. **Jenefer Husman:** Conceptualization.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appdev.2025.101765.

Data availability

Data will be made available on request.

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