STEM Identity Development for Under-represented Students in a Research Experience for Undergraduates

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Introduction

In addition to advancing scientific knowledge, National Science Foundation (NSF) Engineering Research Centers (ERC) have a primary focus on Engineering Workforce Development. Indeed, the number of STEM jobs is growing faster than non-STEM jobs with projected shortages of up to 3.5 million STEM workers in the United States by 2025 [1]. Additionally, it is important to note the lack of diversity within the engineering profession; female students and students of color remain underrepresented in STEM majors and STEM careers [2]. The population of students who major in the STEM fields and who enter STEM careers do not reflect current demographics of the United States population. Despite progress in gender and racial equity in STEM careers, STEM fields have historically been and continue to be dominated by white men, particularly in engineering, computer sciences, and physics [2]. For example, although women and men receive undergraduate degrees at about the same rate, women account for only 30% of all STEM degree holders and have particularly low representation in engineering [3], holding just 12 percent of engineering jobs [4]. Similarly, people of color represent 27 percent of the adult population but only 11 percent of STEM professionals [5]. Thus, our goal as an ERC is to promote STEM pathways that both increase and diversify the pool of students seeking STEM careers.

National studies indicate that Black and Latinx students declare STEM majors at the same rate as their White peers [6], yet STEM degree completion rates for these students falls far below those of their white peers [7], [8]. Research identifies participation in undergraduate research programs as a positive driver for STEM degree completion [9], [10], particularly intensive apprentice-style research experiences which have been shown to positively impact academic performance and persistence in STEM [11], [12]. However, a growing body of research has shown that STEM interest, attitude, and identity serve as predictors of sustained pursuit in the STEM disciplines rather than academic performance [13], [14]. Furthermore, identity research has shown that students who show interest and enjoyment in STEM do not necessarily see themselves pursuing a STEM future career; this is especially true for students from historically underrepresented minorities within STEM [15], [16]. However, identity research is more prevalent at the K-12 level [17] – [20], while the literature related to undergraduate research experiences has focused on STEM persistence and careers [11], [12]. Thus, this study addresses a gap within the literature by addressing the limited research base related to science identity and undergraduate research experiences [21].

Additionally, the pandemic forced many REU programs to either be suspended or to be offered remotely. Several studies explored the rapid pivot to remote REUs with a focus on affordances and constraints of the environment [22]. However, given the importance of identity in persistence in STEM, it is critical that the impact of remote REUs on the development of science identity is investigated.
Research Questions

Thus, this study was guided by the following research questions:

1. In what ways does participation in regular research group meetings impact science identity development?
2. How does science identity develop throughout participation in an REU program?
3. How does REU program delivery (in-person vs. remote) impact science identity development?

Theoretical Framework

The work broadly within our ERC and specifically within this study is grounded in identity as a theoretical framework. This stance draws on the understanding that learning occurs through engagement in the social and cultural practices of a community of practice [22], [23]. Within a REU program, undergraduate students engage in legitimate peripheral participation through which they gain the knowledge, skills, and practices of the scientific and engineering research community. Overtime, with the guidance of more experienced members of the community, the REU students take on greater responsibility and hopefully gain a deeper understanding of the culture and practices of the scientific and engineering enterprise. From the perspective of identity, it is important that we understand how REU students, as newcomers to the community of scientific and engineering research, negotiate the norms and practices of the community which can lead to positive identification as a member of the community, as well as possibly negative identification, or alienation. In other words, identity provides a lens into understanding the socialization of REU students in the culture and norms of scientific and engineering research [25], [26].

STEM identity is conceptualized as the ability to see oneself in one of the STEM fields and to identify with the identity roles involved in the position [18] - [20], [27]. This is critical given the stated goal of the REU program to promote further advancement in the STEM fields, such as attending graduate school. Identity as a framework allows us to understand how students’ emerging identities impact “changes in their more enduring sense of who they are and who they want to become” [28]. Unfortunately, given the institutionalized nature of science with ingrained normative assumptions and expectations about what it means to do science or be a scientist, students under-represented in STEM often struggle to exercise agency and to construct productive STEM identities [29], [30]. For example, in their study of female undergraduate students of color Carlone and Johnson [26] described how these students had to “negotiate a culture characterized by white, masculine values and behavioral norms, hidden within an ideology of meritocracy” (p. 1187).

Specifically, we drew on Carlone and Johnson’s model of science identity (see Figure 1) which includes three interrelated dimensions: competence, performance, and recognition [26]. They describe competence as an individual’s ability to understand scientific content, performance as an individual’s understanding and application of scientific practices, and recognition as both students’ (and the ability of others) to see themselves as participants in and producers of scientific knowledge. As summarized by Carlone and Johnson [26], “one cannot pull off being a particular kind of person (enacting a particular identity) unless one makes visible to (performs
for) others one’s *competence* in relevant practices, and, in response, others *recognize* one’s performance as credible” (p.1190). They further note the interactions between science identity and other identities such as gender and race, indeed their study shows the recognition component was a particularly important aspect of science identity formation for women of color (Carlone & Johnson, 2007).

Figure 1. Carlone and Johnson [26] Model of Science Identity

Research also points to a relationship between science identity and self-efficacy [21], [31], [32], [41]. Self-efficacy is defined as “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” [33]. As such, science self-efficacy beliefs impact students’ how students engage with a specific task, such as an REU, and ultimately their perseverance both in terms of the task at hand and future careers [31], [34] - [36].

Methods

This study reports on an exploration of STEM identity development with an ERC REU (Research Experiences for Undergraduates) program. As an exploratory study intended to understand the nature of identity development as case study design [37] was utilized. The case was bounded by the timeframe of the ten-week REU and units of analysis were the REU participants.
Context

The hybrid REU program was a ten-week summer experience with REUs placed at two geographically distant ERC sites. Due to the pandemic, one site was prohibited from offering in-person summer research experiences, however prior to the start of the REU this policy changed and two of these six remote REUs were able to switch to in-person participation. Weekly seminars and professional development workshops were conducted online to allow participation of all REUs.

Participants

Ten participants were recruited, all of whom were from groups under-represented in STEM and for whom this was their first research experience. REU participants included: seven Female, three Black or African American, one Native American or American Indian, two Hispanic/Latinx, and three first-generation undergraduate students (see Table 1). One of the students, Steven, only completed one of the weekly pulse surveys and none of the weekly journals and was thus excluded from the analysis.

Table 1. REU Participants Demographics

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Ethnicity</th>
<th>REU Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christine</td>
<td>Female</td>
<td>Asian, White</td>
<td>In-person</td>
</tr>
<tr>
<td>Devin</td>
<td>Male</td>
<td>American Indian, Black</td>
<td>Remote</td>
</tr>
<tr>
<td>Gwen</td>
<td>Female</td>
<td>White</td>
<td>In-person</td>
</tr>
<tr>
<td>Khadra</td>
<td>Female</td>
<td>Black, Muslim</td>
<td>In-person</td>
</tr>
<tr>
<td>Kiara</td>
<td>Female</td>
<td>Black</td>
<td>Remote</td>
</tr>
<tr>
<td>Saanvi</td>
<td>Female</td>
<td>Asian</td>
<td>Remote</td>
</tr>
<tr>
<td>Selina</td>
<td>Female</td>
<td>White</td>
<td>Remote*</td>
</tr>
<tr>
<td>Steven**</td>
<td>Male</td>
<td>Black</td>
<td>In-person</td>
</tr>
<tr>
<td>Tiana</td>
<td>Female</td>
<td>White, Hispanic</td>
<td>In-person</td>
</tr>
<tr>
<td>Vicente</td>
<td>Male</td>
<td>White, Hispanic</td>
<td>In-person</td>
</tr>
</tbody>
</table>

*Spent one week in-person

**Not included in the analysis because of incomplete data
**Data Collection**

Given that our goal was to understand identity development, we collected data throughout the REU program. Our primary data sources were weekly pulse surveys, weekly journal reflections, and bi-weekly check-in interviews.

The weekly pulse survey was administered each week on a Friday. The survey included five Likert-scale questions (strongly agree, agree, neither agree or disagree, disagree, strongly disagree) with each question providing an open-ended space to provide details and explanation (see Table 2). Questions on the survey specifically focused on participation in laboratory research group meetings (Table 2). Research group meetings are intended to facilitate research progress and provide opportunities for professional growth [38] by “creating an environment that nurtures group members as they learn the scientific process” [39]. Research group meetings provide opportunities for identity development as students are expected to present and defend their research progress and results (performance) [40], using specific scientific knowledge and language (competence) [39]. This regular critiquing of research provides opportunities for recognition and affirmation or refutation of science identity.

The accompanying weekly journal provided an open space for the REU students to reflect on their work and think ahead for their plans for the following week (see Table 2). Students also met bi-weekly with a member of the research team to discuss this progress and any concerns about their REU participation.

Table 2. Weekly Pulse Survey and Reflective Journal Questions

<table>
<thead>
<tr>
<th>Weekly Pulse Survey Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was prepared to discuss the topics for the webinars and the workshops this week.</td>
</tr>
<tr>
<td>I made valuable contributions to discussions and activities for the webinars and the workshops</td>
</tr>
<tr>
<td>I was prepared to discuss the topics for the lab meetings this week</td>
</tr>
<tr>
<td>I made valuable contributions to discussions and activities for the lab meetings</td>
</tr>
<tr>
<td>Others in my lab listened to my views.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflective Journal Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>How successful were you in accomplishing your goals for this week?</td>
</tr>
<tr>
<td>In your response, please describe the work you did this week.</td>
</tr>
<tr>
<td>What did you learn this week?</td>
</tr>
<tr>
<td>What are your goals for next week?</td>
</tr>
</tbody>
</table>

**Data Analysis**

Using the STEM identity framework, we looked for patterns in the data (both by individual REUs and across all REUs). First, the pulse surveys were coded for instances of competence, performance, and recognition experienced within research group meetings. In addition, the research team looked for patterns in changes in competence, performance, and recognition over
time. Second, the weekly reflections were coded for instances of competence, performance, and recognition experienced more broadly by the REU students. In addition, we allowed for the inductive development of additional coding categories that were pertinent to identity development, including self-efficacy, social issues, and program mode (in-person vs. remote).

Findings

The findings are presented by research question, first addressing the specific role of research group meetings on science identity development, second exploring science identity development more broadly throughout the REU experience, and finally addresses the ways in which program delivery mode (in-person vs. remote) influenced science identity development.

In what ways does participation in regular research group meetings impact science identity development?

The weekly pulse survey focused on the REU students’ perceptions of identity related to their participation in research group meetings. While regular research group meetings were a regular feature of all the REU host laboratories, two remote REU students (Kiara and Saanvi) did not participate in these research meetings. Kiara was a unique case as she participated remotely from Korea and the time difference precluded her participation. In both cases, the REU students met weekly with their PI and mentor rather than engaging with the full research group. Table 3 shares the results of the weekly pulse survey for the seven REU students who attended research group meetings.

The first research group meeting was primarily a space for the REUs to orient themselves to the work of the lab and to understand expectations. As Selina stated, “I think the first week was a little bit challenging in terms of just getting my feet under me and understand what the requirements are.” Students also expressed that they were just starting to learn about the specific research, they were realistic in expecting not to understand everything the first week. For example, Christine stated, “The projects that people presented in the lab meeting I attended were very specific so sometimes it was hard to follow along with postdocs who have spent years specializing in their respective fields, but this will all come with time and I am excited to learn more.” Devin was an exception during week 1, his comments illustrated his feelings as somewhat of an outsider when he stated, “Given that we talked about what my topic may have been I felt I could have provided more insight or ideas to what it was, but felt my opinion did not matter since they were the lab that was accepting me.”


Table 3. Results of the Weekly Pulse Survey

<table>
<thead>
<tr>
<th>Name</th>
<th>Q</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
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<tbody>
<tr>
<td>Christine</td>
<td>1</td>
<td>Somewhat Agree</td>
<td>No group meeting</td>
<td>Strongly Agree</td>
<td>No group meeting</td>
<td>Strongly Agree</td>
<td>No group meeting</td>
<td>Somewhat Disagree</td>
<td>No group meeting</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Somewhat Agree</td>
<td>No group meeting</td>
<td>Strongly Agree</td>
<td>No group meeting</td>
<td>Somewhat Agree</td>
<td>No group meeting</td>
<td>Somewhat Disagree</td>
<td>No group meeting</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Neither agree nor disagree</td>
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<td>Strongly Agree</td>
<td>Somewhat Agree</td>
</tr>
<tr>
<td>Devin</td>
<td>1</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Strongly Agree</td>
<td>Somewhat Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Somewhat Agree</td>
<td>Strongly Agree</td>
<td>Somewhat Agree</td>
<td>Strongly Agree</td>
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<td></td>
<td>3</td>
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<td>Strongly Agree</td>
<td>Somewhat Disagree</td>
<td>Strongly Disagree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Somewhat Agree</td>
</tr>
<tr>
<td>Gwen</td>
<td>1</td>
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<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
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<td></td>
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<td>Somewhat Agree</td>
<td>Strongly Agree</td>
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<td>Strongly Agree</td>
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<tr>
<td>Khadra</td>
<td>1</td>
<td>Neither agree nor disagree</td>
<td>Somewhat Agree</td>
<td>Strongly Agree</td>
<td>No group meeting</td>
<td>Neither agree nor disagree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Neither agree nor disagree</td>
<td>Somewhat Agree</td>
<td>Neither agree nor disagree</td>
<td>No group meeting</td>
<td>Neither agree nor disagree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
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<td>Strongly Agree</td>
<td>Neither agree nor disagree</td>
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<td>Somewhat Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
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<tr>
<td>Selina</td>
<td>1</td>
<td>Somewhat Agree</td>
<td>Strongly Agree</td>
<td>Somewhat Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
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<td></td>
<td>2</td>
<td>Somewhat Agree</td>
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<td>3</td>
<td>Strongly Agree</td>
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<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>Tiana</td>
<td>1</td>
<td>Neither agree nor disagree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
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<td>Strongly Agree</td>
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<td>Strongly Agree</td>
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<td>Strongly Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>Vicente</td>
<td>1</td>
<td>Somewhat Agree</td>
<td>Somewhat Agree</td>
<td>Somewhat Agree</td>
<td>Somewhat Agree</td>
<td>Somewhat Agree</td>
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<td>Strongly Agree</td>
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</tr>
</tbody>
</table>

1. I was prepared to discuss the topics for the lab meetings this week
2. I made valuable contributions to discussions and activities for the lab meetings
3. Others in my lab listened to my views.

* Remote REU participant

All of the REU students expressed how welcoming their group were, for example during week 2 Khadra stated, “Even if my questions might have seemed a little off, the people in my lab were able to understand what I was confused about and listened to my views about the topic at hand.” Similarly, during week 6, Christine stated, “All of my lab team members have been super supportive of my experiments and also our differences in skill level. I don't think I've ever been ashamed or afraid to ask questions.” While Christine was positive about her experience, her remote participation meant that she didn’t fully feel part of the team. For example, in week 3 she stated, “I do not feel that the weekly lab meetings necessarily apply to me because they are mainly about clean up in the lab and I am virtual” and in week 5 she stated,

I always feel welcome to share my views and my work in my lab meetings, but I think my work is a little bit different than most because I really only interact with my two advisors, but they always want to listen to what I have to say.

Similarly, the other remote REU student, Devin, expressed some struggle to receive full recognition from the research group. In addition to noting during week 1 that he was not sure if his opinion mattered, he stated, “Everyone was very welcoming and I really appreciate the patience they have had with my needing to be totally virtually for this summer research.” Over the next few weeks, he expressed frustration about interactions during the research group meetings. For example, he stated,

As I mentioned above, my views of the paper were overshadowed by my graduate mentor at times because they had a slightly larger base of knowledge than me. And I was unsure on how to handle with them not believing that I read the paper thoroughly and did not find a thermal protocol for a specific paper.

He went on to state, “I was struggling to get my point across as sometimes they did not hear my summary of the paper but only what they had read.” It was not until week 6 when he started to feel that his contributions were recognized by the research team. As he noted, “They viewed my comprehension and understanding of organ cryopreservation as more valuable than when I first started the REU program.”

Performance during research group meetings was viewed in different ways by the REU students. A focus for the REUs was presenting their project to the research team and during the first few weeks students were unsure of their role when not presenting. For example, during week 2 Khadra stated, “the lab meeting did not require me to talk” and Tiana stated, “I did not discuss
much as I had not gone into lab yet, but I was able to listen to the projects others were doing.”

REU students put in significant effort into preparing for research group presentations. For example, during week 3, Christine stated, “I had to present my project this Thursday, and put a great deal of effort into making sure I knew everything I was doing and how to answer predicted questions.” Indeed, as stated by Gwen during week 7, being asked to present in the same way as the graduate students and postdocs in the lab was an important recognition, “My views are valued in my lab, and this is shown through giving me tasks and allowing me to present my findings just as everyone else in the lab group.”

Competence was evident in research group meetings as REU students worked toward contributing to lab discussions on topics not specific to their research project. Feelings of competence shifted over the course of the REU, with students initially feeling a lack of competence. For example, during week 3, Tiana commented, “I did not give much opinion in the general lab meeting as I was not sure what they were speaking of.” Similarly, during week 5 Christine wrote,

I don't quite fully understand what is going on with other people's projects and how to advise them, so for most of the lab meeting I'm usually just observing, but it's still a great experience to see how everyone else interacts.

Over time, most of the REU students became more comfortable offering feedback to others. REU students used their growing competence in their specific project as an entry into the broader research group discussion. For example, during week 4, Gwen stated, “I presented my information and gave feedback on things that impacted my research.” By week 5, Tiana illustrated her growing competence when she stated, “I was able to give suggestions due to my knowledge through papers on what they might be able to do to improve their experiment.”

How does science identity develop throughout participation in an REU program?

Given the focus on research, performance was central to the REUs’ identity development. Students had to learn a lot of new laboratory skills and as scaffolding from mentors was removed, they had to develop confidence in performing procedures independently. Indeed, the most important criteria of success for the REU students was their confidence and ability to complete tasks independently. For example, at the end of week 4, Christine commented, “I rely on [my mentor] for a lot more than I should, and I need to start being more independent.” She continued to comment on her progress toward independence the following week, “This was done mostly on my own with occasional help from [my mentor]. I can be quite successful when I am independent; I just need to take the time to properly prepare and understand what I am doing” and proudly stated during week 6, “I can now successfully perform a collagen assay on my own.” Similarly, Khadra set her goal for week 3 to “be more confident in trying to accomplish running new chips by myself while still being supervised by my lab mentors” and by week 5 she stated, I feel like all the hard work has paid off, now I am completely confident in doing it all by myself without any supervision from my mentors and coworkers.”

Integral to the desire to be able to complete tasks independently, was acceptance that it was okay to make mistakes. During week 3, Christine expressed doubts in her ability to complete certain
lab task, she commented, “I get very stressed when I have to do new things on my own, but its ok to fail the first time, as long as I try.” Persistence in overcoming these struggles was important to science identity development. For example, during week 5 after struggling with a specific aspect of her coding for a couple of weeks, Selina stated, “I feel like a professional coder because I was able to make different files for each individual function!” Selina also understood the importance for her achievement for the research group, she went on to explain, “this will be important because we need to learn how fast the particle can be cooled down, as well as how cold the particle can get before ice forms.” The switch to using “we” instead of “I” demonstrated her identity as an important part of the research group. Similarly, despite her nervousness about successfully completing lab tasks, Christine expressed her identity as part of the research group that week stating, “We made a lot of progress … and have learned some beneficial lessons from our experiments performed so far.”

Developing positive self-efficacy with their ability to complete research tasks, especially completing them independently, took time. Reflecting back on the REU experience, Christine summarized her journey toward affirming her science identity,

I have realized that I am much more comfortable in the lab and feel way more independent now than I did in the first few weeks. Coming into this program, I had a lot of doubt about how I would handle different aspects of this field such as the workload, time commitment, and general organization of my experiments. I now know what I can handle, and what I can’t, and have left this program feeling confident that this is what I would like to pursue in the future.

Critical to the self-realization of science identity was the support and beliefs of other members of the research team, particularly the lab PI and mentor. Knowing that they could ask questions without fear of judgment was critical. Tiana commented, “everyone in lab was really respectful and always answered my questions.” Similarly, Christine commented, “asking questions never hurts, even if internally I think they may be stupid or I should know the answer myself.” Selina connected the ability to ask questions to her development of science identity when she stated, “I never felt left out of the lab group, and I always got my question answered.”

Most REU students expressed competence throughout their REU, and they were excited to share new knowledge during their weekly reflections and bi-weekly check-in meetings. For example, on her first weekly reflection, Christine shared, “rat hearts can beat ex vivo in a glass chamber (via perfusion, of course). Mind = blown.” However, in the absence of recognizing their own competence, self-doubt persisted and damaged science identity development. Even though Khadra expressed a moment of confidence in week 5 having successfully completed a lab protocol by herself, her self-efficacy remained low. During week 7, she still commented that she “was nervous about messing up the procedure” and that she was “surprised I didn’t mess anything up.” She was only just starting to feel comfortable asking questions, she shared, “I have been opening up to all my co-interns and mentors rather than keeping everything inside. I am able to communicate well with them and ask different questions even if it doesn't make any sense.” At the end of Khadra’s REU experience, competence remained a barrier to developing a science identity, as she shared, “to be honest, I do not see myself as a scientist. I don’t think I could handle all of the chem equations and trying to find different effects for all the causes.” She went on to say,
The most challenging part about the REU program was not having a background knowledge on the field of science. I had to learn everything from scratch and it took time to get on the same page as the others in the lab.

In contrast, Devin stated, “With this experience, I could find myself doing this work since I did not have a difficulty during the program when trying to understand the material.”

Interestingly, Khadra was one of only two REU students to comment on the impact of non-science identities on her experience. She commented, “as the only black female and Muslim STEM student; I found it difficult to fit in. When introducing myself to others and my STEM major; most people would be shocked.” This feeling of being out of place was something she experienced throughout all her STEM courses throughout her education. Whereas, Christine shared,

I am a mix of Asian and Caucasian, and feel that especially in the [site] 2nd floor lab space, there was a mix of different races and ethnicities in the lab. It was definitely comforting to have that much diversity in the workplace at my first real research experience. Similarly, as a woman in STEM, it was particularly reassuring to see so many higher female figures in post-doctoral and principal investigator positions.

Another theme related to science identity development was the need for a communal environment. The need for social interaction was felt similarly across both in-person and remote REU students. Even though she commented on her remote REU experience being somewhat detached, Kiara still identified with a future scientific career, stating,

Although only looking at numbers feels pretty detached from the actual field, reading the papers, and talking about what is generating this data brings it to life. I can see myself working in more of a hands-on version of this exact same field.

In contrast, even though Tiana stated a positive science identity, stating, “I consider myself a scientist in the ways that I am able to be working with a lab to gather data and do experiments in hopes of one day being able to share it with many other people,” she went on to say, “I do not think I would be able to do research full-time as I want a more person to person interaction.” Similarly, even though Saanvi stated, “I see myself as a scientist in that I am constantly seeking to learn more, I am actively participating in research, and I always try to answer questions I may have with evidence,” she did not “envision myself working in this field full-time. This is because I want to have actual patient interactions and thus plan on attending medical school to become a doctor.” Even embedded within a large research group, Khadra described science as a lonely and individual activity rather than a communal activity,

To be honest, I do not actually see myself working full-time within this environment because I am not the type of person who can handle being sat in a single corner having to read articles and finding different ways certain experiments could be handled. I prefer to be more hands-on and communicate with individuals rather than being alone.
How does REU program delivery (in-person vs. remote) impact science identity development?

REU students participating remotely were tasked with projects that involved either computational work or extensive literature reviews. Students doing computational work spent the first two to four weeks learning to code using specific software, working their way through a variety of tutorial exercises. While in-person REUs also had to spend time learning specific laboratory techniques, the remote students felt more removed from the research of the lab during this learning period. For example, during week 3, Kiara commented, “I hope to begin working with actual data so that I have valuable contributions for lab meetings.” Similarly, Devin expressed a disconnect between his assigned work and that of the research lab, in reflecting on his experience he stated, “most challenging was staying motivated virtually and feeling as though my research was having an impact on the research lab in the future.” The interactions of the remote REUs were often limited to periodic meetings with the lab PI and their assigned mentor, unlike the in-person REUs who were able to broaden their professional and personal networks. For example, Vicente commented,

I am socializing with my co-workers outside of work hours. We have gone to a Red Sox’s game together and have all had dinner together. Me and the other people in my lab try to eat lunch with each other as often as possible.

Indeed, Selina noted that being remote was “the most challenging part for me. I love being able to talk to people and shake hands, and also to be able to ask questions and get a response right away.” Selina had a unique opportunity to visit her REU site in-person for a week toward the end of the summer. Following that week, she commented, “It was also great being able to visit in person, where I actually was able to ask others for help besides [my mentor] and [lab PI].” While Selina had expressed her beliefs in her ability to overcome difficulties with learning to code, the in-person experience was identity affirming that her struggles were not unique and that “[all scientists] get stuck or confused at times.” The in-person experience humanized the others in the lab and helped Selina to identify her performance with theirs,

It helped that I was able to be [here] in person. I learned not to be intimidated by others who are doing difficult research, because they are all in the same difficult process of trial and error that I am.

Work-life balance was a challenge for most of the REU students. In-person REUs struggled with the reality of assays that took ten or more hours. For example, during week 7, Christine reflected how “it was hard to keep up with the things that I love doing outside of the program in the beginning” and that she had to learn how to “have more control over my schedule and my own experiments, I’ve tried to make time to do one thing I enjoy almost every day to combat the strenuous 9-5 work schedule.” Remote REU students were able to adjust their schedules to still enjoy personal pursuits. For example, Saanvi commented that she had “created a time management/work schedule for myself so that I can balance having fun during the summer while still completing my responsibilities for the research program.” While remote REUs were able to carve out more personal time, they also described having to develop strategies not to be distracted by working at home. For example, Devin explained that he had to “restrict access to
my phone by having my girlfriend keep it out of reach so that I could focus on my virtual research.”

**Discussion**

All aspects of science identity [26] – competence, performance, and recognition – were evident throughout the REU experience. Competence was seen to develop over time as students became more experienced and knowledgeable in their specific area of research. Students expected a steep learning curve and committed themselves to learning through in-depth reading of research articles and engaging in discussion during research group meetings and one-on-one meetings with their lab PI and assigned mentor. With one exception, the REU students held strong self-efficacy that with persistence they would be able to understand the new content (develop competence) and be successful. Parallel to other research, the role of self-efficacy was found to be important in promoting the development of a science identity [21], [31], [32], [41].

Students’ descriptions of performance were aligned with notions of situated learning [22], [23], as with the support of their mentor they moved from the periphery to the center of practice as contributing members of the research group [32]. Students’ primary description of this identity work revolved around notions of independence. While acknowledging the need for support from their mentors, they resolved to be able to complete their assigned research tasks independently. As the students recognized gains in both their competence and performance, they started to see themselves as contributing members of the research group, seeing how their project impacted the broader goals of the research group and their increased willingness and ability to contribute suggestions during research group meetings. With one exception, all REU students identified their competence and performance in the form of identification of themselves as a scientist. This parallels research that, while not framed through identity, shows that students experience gains in feeling like a scientist through their participation in undergraduate research experiences (e.g., Hunter et al., 2006).

Central to the development of science identity was recognition, particularly the recognition of experts within the community. The nature of this recognition needed to change over time, initially as supportive and understanding that the REU student needed to build their competence in terms of both content and laboratory skills and later in recognizing the REU student as an active and contributing member of the research team. Frustration when the mentor is less than supportive in the early stages of an REU can halt science identity development, Devin experienced two weeks of uncertainty, however his self-efficacy allowed him to rebound. However, even in the presence of positive support, Khadra’s low self-efficacy prevented her from developing a science identity. In addition, Khadra’s identity as a black, Muslim female had to be negotiated within the research community of practice which was predominantly White. As described by other researchers [21], in the absence of scientists of similar identities, she also had to negotiate her identity with the normality of whiteness within scientific research spaces.

Like other researchers [15], [16], our findings show that the development of science identity did not necessarily lead to the REU students seeing themselves pursuing a research career. Central to
this decision was the perception of the REU students that scientific research was an individual endeavor not aligned with their desire for personal interactions in their future careers.

This study supports further consideration of remote REUs, especially given the high cost of in-person REUs and geographic, family, and other constraints experienced by some students that might preclude their participation in an in-person REU [42]. Similarly, a handful of studies conducted during the pandemic [22], [42], [43], we found that students were still able to develop relevant knowledge, skills, or abilities through engagement in meaningful scientific performance. Critical to successful development of science identity within a remote REU was the quality of mentorship and establishing expectations and routines for remote work. Most difficult for remote REU students was developing a sense of identity as a member of the research team. In-person REU students were immersed in the work of the research lab and able to informally ask questions and learn about related research projects. For remote students, attending research group meetings was the only mechanism for learning about the broader work in the research group, making it more difficult to develop a sense of identity with the research group. Without this sense of community identified as important by other researchers [22], many students had a harder time identifying with a research career as they valued work with a communal environment.

**Implications**

Providing an appropriate project and support for REU students is critical. With in-person REUs, it was easier to select a project that was connected to the work of the research group and provide support in learning specific laboratory techniques. However, it is still important to understand the content background of the REU student, as when students struggle with competence, as was the case with Khadra, this struggle can prevent science identity development. Unfortunately, remote REUs have a narrower set of project options, relying on analysis of existing data or computational research.

As with other REU studies [16], [22], the role of the mentor is critical. The mentor helps to develop work routines and facilitates learning through activities such as modeling laboratory techniques and discussing research papers. Mentoring is also relational; this is particularly important when this is the first research experience for an REU student. Frustration when tasks are not completed “correctly” can impact science identity. For all our REU students, trust to let them work independently was critical. Like Thiry [16], we recognize the value of the mentor training provided for REU mentors to help them navigate what is often a new role.

Research group meetings are a critical space for science identity development. This is a “public space “where REU students engage in performance, putting their competence on display. While this was nerve-wracking for many REU students, it represented an important opportunity for recognition and being afforded the same trust and chance to share their work as other research group members. REU students' growing science identity was often marked by their developing interactions during research meetings. Thus, it is important that the lab PI include the REU student in regular research group meetings and scaffold the expectations.
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