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RESEARCH ARTICLE

Meta Mentoring: Mentors' Reflections on Mentoring

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Abstract
Science, technology, engineering, and mathematics (STEM) fields are incredibly valuable to the world as innovations can help improve infrastructure and save lives. The United States has called for improvements in mentoring to help build a larger STEM workforce. Many studies and reports have focused on the experience of mentees within communities of practice (COP) to determine mentoring best practices. But few studies have investigated how mentors define their role within the COP. In this study, we provide data from interviews with mentors in a Research Experience for Undergraduate program and a Research Experience for Teachers program. We compare the views of mentors who work with undergraduates to those who work with teachers to highlight the differing views of these two groups and how this affects the type of mentoring provided. Our findings show that mentors struggle to see their role in the RET program since there is not a direct link between mentoring teachers and building the STEM workforce. This is problematic as teachers could be crucial allies in this endeavor.

Keywords Mentoring · Research experiences · Undergraduates · Teachers

Introduction

The National Science Foundation (NSF) is the federal funding agency for the United States' foundational scientific research. As such, the NSF not only drives the research agenda of American STEM researchers but also plays a crucial role

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in STEM-related policy and program decisions. In the last 25 years alone, NSF has invested over $1 billion into research in the US (NSF, 2018). Part of this includes supporting initiatives that build the STEM workforce. The NSF typically refers to these workforce initiatives as part of their broadening participation efforts, which are a required part of proposals.

The STEM workforce is touted as a lucrative career because these fields are some of the fastest growing occupations in the US and abroad (Kennedy et al., 2021), and typical median salaries for these jobs are higher than the average median salary for all workers in the US by nearly $35,000 (Kennedy et al., 2021; NSF, 2018). However, representation in various STEM disciplines and pay is not equitable by race, ethnicity, and gender. People of color and women are considerably underrepresented in STEM disciplines (Kennedy et al., 2021), and for those women and underrepresented minorities who persist into the STEM workforce, the pay disparities are alarming, ranging from an average salary of $103,300 for Asian men to $57,000 for Black and Hispanic women (Kennedy et al., 2021).

Because of these discrepancies in representation, the NSF has focused on increasing the representation of women and underrepresented minorities in STEM fields (e.g., NSF INCLUDES, APS Bridge). However, research highlights that the underrepresentation of women, African Americans, and persons of Hispanic/Latin heritage begins much earlier in their life span due to cultural and social stereotypes that often dictate who belongs and can succeed in STEM—that is, white middle or upper-middle class men (Bremer & Hughes, 2017; Traweek, 1988). This stereotype makes it difficult for people who do not fit the stereotype to see themselves or their children succeeding in STEM fields (Prescod-Weinstein, 2021). Studies have shown that exposing all students—particularly those currently underrepresented—to STEM experiences like research opportunities can improve their sense of belonging and persistence in STEM (National Academies of Sciences, Engineering, and Medicine [NASEM], 2019). Moreover, to be successful at building the STEM workforce, mentoring within research experiences must address issues affecting students' sense of belonging (NASEM, 2019).

The NSF has supported mentoring opportunities through their Research Experiences for Undergraduate (REU) program established in 1987 (Bennett, 2015). In REU programs, undergraduates engage in NSF-funded research projects typically for an extended period (~8–10 weeks) with the goal of allowing students to experience research firsthand in order to make informed decisions about their future STEM career plans. Soon after REU programs were established, the NSF began to support Research Experiences for Teachers (RET) programs that also included prolonged engagement on a research project with an NSF-funded scientist. The purpose of RET programs is slightly different in that the teachers are not expected to continue into a STEM career but to translate the science and research they learn to their students, thereby increasing the STEM workforce by encouraging their students to pursue STEM careers (Davidson & Hughes, 2018). Additionally, RET programs are ideally a "reciprocal exchange of expertise between the K-14 STEM educators and the research faculty" (NSF, 2021, Synopsis section, para. 1) wherein both educators and researchers may learn from one another. Our literature review section outlines the research on the influences of REU and RET programs to highlight the benefits of these programs. However, very few studies focus on the mentors' perspectives. If mentoring is a crucial part of the research experience (NASEM, 2019) and key to building the STEM workforce; then, it is critical to understand how mentors view their roles and their mentees to determine if the goals of these programs are being reached.

Conceptual Framework

Our guiding framework for this study is Wenger's (1998) concept of Community of Practice (COP). Building on the social theory of learning, Wenger posits that learning occurs through active participation in the practices of social communities. Wenger sees true learning as a transformative process that occurs because of one's membership in a COP. Learning within a COP has four parts:

1. Meaning = learning through experience
2. Practice = learning through doing
3. Community = learning through belonging
4. Identity = learning as becoming

Wenger's concept of COP comes from apprenticeship models, wherein apprentices start as legitimate peripheral participants in a COP: peripheral because they are new to the COP, but legitimate because they are accepted within the community as a contributing member. As they continue learning within the COP, their level of participation and contribution changes and their identity are transformed (Lave & Wenger, 1991). Wenger (1998) views the COP as a dynamic space wherein new individuals learn through participation; simultaneously, the community also refines and alters its practice to maintain its existence, thereby refining the learning and membership process. Yet, STEM fields are struggling with equity in their membership process as evidenced by the continued marginalization of people of color and women (Bremer & Hughes, 2017; Prescod-Weinstein, 2021; Traweek, 1988).

Carlone and Johnson (2007) pointed this out in their seminal work on science identity development as it applied to women of color. In their concept of science identity, individuals must develop competence in their given science discipline and then have opportunities to perform and be recognized for these competences. This concept of science identity highlights how the meaning of the COP must be mutually negotiated in the mentoring relationship (Wenger, 1998). For mentees to become legitimate members of the COP, they must feel like they belong in the COP (i.e., identify with) through opportunities to participate in mutual engagement with other members, negotiate the joint enterprise, and learn the shared repertoire of resources. Learning and identity are intimately tied together. Identity is a trajectory because it is a "constant becoming," a process and not an end result (Wenger, 1998, p. 155). To support strong identity trajectory, then, novices within a COP must learn "to contribute to, take responsibility for, and shape the meanings that matter" (Wenger, 1998, p. 197), thereby coming to be—and to identify as—fully legitimate participants. With this in mind, mentorship within COP is a critical aspect of supporting and strengthening the recursive relationship between identity development and learning for novice members. To this end, the next section highlights relevant research on REU and RET programs as contexts for mentorship and enculturation into aspects of the COP of science and STEM.

Literature Review

Research Experience for Undergraduates Programs

REU programs are apprenticeship-style, NSF-funded programs intended to situate undergraduates as legitimate participants within the COP by engaging them in STEM-related research endeavors through immersive and collaborative work with scientists over multiple consecutive weeks (NASEM, 2017). REUs are often housed within national laboratories and research universities and—while the academic environments, institutional cultures, research infrastructures, and foci of the disciplinary work may vary across REU programs—share three primary goals that align with the COP concept: (a) increasing retention and persistence of students in STEM, (b) promoting STEM disciplinary knowledge and practice through increased ownership of the project, and (c) integrating students into STEM culture (NASEM, 2017). While participants typically work with a primary mentor, they likely encounter others during an REU program—such as fellow scientists, graduate students, postdocs, and support staff—who may also support REU students' integration into the broader COP (Crisp & Cruz, 2009; Foertsch, 2019; NASEM, 2017).

Benefits of REUs

Due to their experiential, immersive, and student-centered nature, REUs have been identified as a high impact practice with significant educational benefits to undergraduate participants (NASEM, 2017). Such benefits include increases in: mentee's STEM skills which leads to increased self-confidence and self-efficacy, mentee's understanding of how research is done, mentee's sense of belonging in STEM as they gain ownership of research tasks, and mentee's persistence in STEM (Fischer et al., 2021; Gardner et al., 2015; Kuh & Schneider, 2008; NASEM; 2017; Russell et al., 2007; University of Wisconsin Eau Claire, 2020). Within REUs, students develop research and critical thinking skills through the guidance of a mentor (Foertsch, 2019; Kuh et al., 2017). Mentors provide advice, answers to complex questions, and support as students work to integrate themselves into the COP (NASEM, 2017). As students integrate into the community, they often transition from peripheral roles and gain autonomy to perform more complex tasks (Gardner et al., 2015; Johri & Olds, 2011; Seymour et al., 2004; Thiry & Laursen, 2011). As a result of these improved skills, they also develop an increase in self-confidence, independence, and sense of belonging (NASEM, 2017; Zydney et al., 2002).

The Role of the Mentor

Mentors play a key role in the structure and shaping of students' experience within the STEM COP during REUs by setting goals for the experience, designing experiments, and developing schedules (NASEM, 2017). Thiry and Laursen (2011) interviewed 73 undergraduate research students and identified three effective practices that research mentors employed to integrate students into the COP: professional socialization, intellectual support, and personal/emotional support. For professional socialization, students identified ways that mentors helped them become and/or feel like a scientist. These included setting expectations for research projects, explaining important conceptual or theoretical ideas related to the discipline or underlying the project, and guiding scientific behavior and norms (Thiry & Laursen, 2011). Through these mentoring practices, students were intellectually supported to take on more significant roles in the COP. Mentors provided novices with a basic understanding of projects and procedures, and more experienced students developed problem-solving skills and the ability to plan next steps (Thiry & Laursen, 2011). Mentors also provided personal and emotional support by facilitating productive relationships through practices like being receptive and open to students' ideas (Thiry & Laursen, 2011).

While the importance of the role of mentors in REUs cannot be overstated, most studies focus on the perspectives and growth of mentees with only peripheral nods to the mentor (Shortlidge et al., 2016; Zydney et al., 2002). For example, Gardner et al. (2015) conducted a study of an REU program for college freshmen to explore the program effectiveness in integrating students into the COP and supporting the development of their research identities (Gardner et al., 2015). Using both qualitative and quantitative research methods, the authors found that students relied heavily on the social support networks that mentors helped them create to negotiate the COP and "looked to mentors to renegotiate and define [students'] identity trajectories" within STEM (Gardner et al., 2015, p. 63).

Additionally, Corwin and colleagues (2015) note that when students are engaged in research activities that personally interest them, it not only helps to integrate them into the STEM culture but also improves their independence and confidence as they take ownership of the work. This approach can increase student motivation, further develop their sense of scientific self-efficacy, and provide clarification of intended career paths (Auchincloss et al., 2014; Corwin et al, 2015; NASEM, 2017). Few studies have asked mentors whether they seek out students' interest or how they align students' interest with a chosen research project. Given the power that mentors hold toward supporting and shaping student STEM identity in REU programs, it is necessary to better understand the perceptions that scientists hold about their mentoring role, their motivations for mentoring, and the enactment of mentoring students into the STEM COP.

Mentor Motivation

Research studies that have made mentors the focal point have typically focused on mentors' motivation to participate in REU programs. Because faculty must manage a multiplicity of competing priorities and requests for their time, it is important to understand how and why those that choose to serve as REU mentors do so (Linn et al., 2015; Zydney et al., 2002). Several compelling reasons have been documented by Zydney and colleagues (2002), including faculty desire to influence undergraduate career pathways, provide graduate students with an opportunity to mentor, and improve their own research productivity. Other studies have found that faculty participate as REU mentors to connect authentic research to what students learn in their classes (Anderson et al., 2011; Brownell & Tanner, 2012; Gibbs & Coffer, 2004; Hativa, 1995; Weiss et al., 2004). However, such motivation often requires students and mentors to center research work around the interests, expectations, and the potential for rewarding outcomes—such as publications—of the faculty member rather than the student (Blackburn & Lawrence, 1995; NASEM, 2017).

Research has hinted that the time commitment and uncertainty of how an undergraduate will integrate into the research are two issues that prevent mentors from participating in REU programs (Shortlidge et al., 2016). In addition, many mentors are not aware of best practices in mentoring and could be turning students away simply by not utilizing these practices (NASEM, 2017). With the national call to build the STEM workforce and the evidence pointing to REUs as a highly effective way to do this, it is critical to understand more about the motivations of REU mentors and the extent of their understanding toward best practices.

Research Experience for Teachers Programs

RET programs are another part of the NSF portfolio for broadening participation in STEM. RET programs are apprenticeship-style professional development experiences intended to situate K-12 teachers as legitimate participants within the COP by engaging teachers in STEM-related research endeavors through immersive and collaborative work with scientists over multiple consecutive weeks (Dixon & Wilke, 2007; NSF 2013; SRI International, 2007). RET programs were developed in response to the concern that K-12 STEM teachers often have very few experiences to engage in STEM-related research in ways that are analogous to or situated within the STEM COP (Sadler et al., 2010; SRI International, 2007), yet they are the representatives of these communities in their classrooms and assume the complex responsibility of teaching students the content, practices, dispositions, and norms of STEM without often having direct experience with the COP.

Like REU programs, RET programs occur within national laboratories and universities and may vary in terms of disciplinary focus, duration, and degree to which teachers have choice over their research project and interests (Krim et al., 2019; NSF, 2013; Sadler et al., 2010). Even with these variations, the universal aim of all RET programs is to support K-12 teachers' development of more robust understandings of STEM and the STEM COP so that these understandings will inform their pedagogical practice and translate to productive ends for student science learning (Krim et al., 2019; NSF 2013; SRI International, 2007).

Benefits of RETs

One intuitively reasonable outcome of RET participation is the potential for an increase in teachers' scientific content knowledge (Buck, 2003; Dresner & Worley, 2006). However, many other benefits have been documented by the field. Teachers have reported an increase in their abilities to engage in scientific discourse and to skillfully engage in the practices of science—such as analyzing data, engaging in argumentation, and developing claims from evidence—in the context of their research experience (Faber et al., 2014; McLaughlin & MacFadden, 2014). RET participants have also described increased confidence in their ability to teach science, as well as increased self-efficacy and outcome expectancy with respect to student learning (Dresner & Worley, 2006; Grove et al., 2009; Hughes et al., 2012; Miranda & Damico, 2015). There is also evidence to suggest that some RET participants feel more willingness to serve as STEM advocates and teacher leaders within their school contexts (Davidson & Hughes, 2018).

Much of the body of research around RET programs has focused on the degrees to which such experiences might promote shifts in teacher views about the nature of science and STEM. For instance, some studies have empirically documented—through interviews and validated survey instruments—changes in teachers' conceptions of science from naïve to degrees of increasing sophistication after participating in RET (Anderson & Moeed, 2017; Buxner, 2014; Dixon & Wilke, 2007; Schwartz et al., 2010; Varelas et al., 2005). Indeed, firsthand research experiences can serve as powerful "change events" for teachers regarding their disciplinary understandings of STEM. Davidson and colleagues (2022) documented productive shifts in one teacher's conceptions of science as a direct result of her participation in a six-week RET. From her collaborative participation in laboratory work with her mentor scientist, lab group members, other cohorts in the RET program, and extant members of the STEM COP, the teacher experienced productive shifts in her understanding of who scientists are and how science is done.

Research on RET programs has also documented the ways in which such immersive experiences position teachers as science learners by placing them as novices within STEM laboratories (Davidson & Hughes, 2018; Feldman et al., 2013). As "spectator novices" in the RET research context, teachers straddle the immersive nature of the research experience while also taking on the intellectually demanding task of connecting their experiences back to their classroom (Davidson & Hughes, 2018). That is, because teachers are likely not experts in their RET research work, they may encounter bouts of anxiety and frustration related to their epistemic work in the same way that their students might (Davidson et al., 2020). Yet, with support from mentors and others within the RET, teachers may also develop a stance of perseverance and experience feelings of joy as new ideas and research findings emerge (Davidson et al., 2020). To this end, teachers have reported increased feelings of empathy toward their K-12 students as science learners in their own classrooms after RET participation (Davidson & Hughes, 2018; Davidson et al., 2020), recognizing that their affective experiences and attempts to learn new content engage in new practices and embed themselves within a professional science community mirror and have transferability to the affective and epistemic experiences their students experience in science. However, few studies have made direct links between teachers' pedagogical changes due to their participation in RET programs and impacts on their students' science understanding (Krim et al., 2019; Sadler et al., 2010). In addition, few studies have focused on the role of the mentor in facilitating teachers' integration into the COP (Davidson & Hughes, 2018; Hughes et al., 2012; Krim et al., 2019; Southerland et al., 2016).

The Role of the Mentor

Like the REU, mentors play a significant role in teachers' experiences within the STEM COP (Blanchard et al., 2009; Capps et al., 2012; Hughes et al., 2012; Southerland et al., 2016). Some mentors may allow teachers to develop and pursue their own research questions and methods (Blanchard et al., 2009; Buck, 2003; Dresner & Worley, 2006), while others may engage teachers in ongoing research designated and controlled by the mentor (Davidson & Hughes, 2018; Enderle et al., 2014; Faber et al., 2014; Grove et al., 2009). Mentors also have sway over the nature of the social interactions that teachers have with scientists and others in the laboratory or field (Davidson & Hughes, 2018; Southerland et al., 2016). This social interaction is particularly important to teachers' improved orientations toward science (Southerland et al., 2016).

Furthermore, Hughes and colleagues (2012) highlight the notion that teachers who worked with supportive, hands-on, and present mentors during their RET participation were more likely to develop a better sense of the disciplinary norms, practices, and underpinnings of the STEM COP. Further illustrating this point, Davidson and colleagues (2021) found that mentors were critical resources for teachers who experienced scientific uncertainty during their RET research work. In that study, mentors were identified as key in helping teachers come to view uncertainty as part-and-parcel to the work of science by normalizing teachers' encounters with anomalous data and setbacks in the laboratory. Additionally, Wakefield's (2022) research asserts that engineering mentors played critical roles in supporting teachers' understanding of the engineering design process as well as the STEM-related content with which they were working during their RET participation.

Mentor Motivations

As important and agentive as mentors are to teachers' experiences and learning within the STEM COP, the motivations, philosophies, and practices of mentors who partner with RET teachers have not yet been adequately or sufficiently studied. Even though some research has addressed mentor motivations for REU programs, these may not necessarily shed light on the reasons mentor scientists choose to participate in RET programs nor the approaches they take toward fostering understandings about the STEM COP to teachers.

Given the differing goals of REU and RET programs—the former being aimed at directly building the STEM workforce by encouraging undergraduates to pursue STEM and the latter being focused on exposing teachers to STEM research with the aim of translating this understanding to their students—there may be key differences in the mentoring approaches and guiding philosophies among those who mentor in these types of apprenticeship programs. From this lens, what is missing from current research on REU and RET programs is the voice and perspective of mentors. An understanding of mentor perspectives can help programs improve their design to address the STEM workforce needs both in numbers of workers as well as diversity. Consequently, this study is aimed at addressing this gap through the following research questions:

1. What are the skills that mentors develop in their REU and/or RET participants?
2. How do mentors in REU and/or RET programs view their role and its value?

Methods

Location and Participants

This study occurred at a large NSF-funded facility—the Interdisciplinary Research Lab (IRL; pseudonym)—wherein scientists work in various STEM fields including physics, chemistry, engineering, geology, and some biomedical fields. The IRL has had an REU and an RET program since its creation in 1999. On average, each summer, 25 undergraduates participate in the REU program and 10 K-12 teachers participate in the RET program. Our study focuses on mentors and mentees from the 2014 and 2015 programs. During this time, the REU program ran for eight weeks and the RET program ran for six weeks. Participants (i.e., undergraduates and teachers) were given a pre- and post-survey that measured the impact of the program through use of both qualitative and quantitative metrics. The surveys measured changes in understanding of scientific research (e.g., understanding how research is conducted and/or applied, becoming familiar with analysis procedures) and levels of participation in various skills utilized in research (e.g., collecting data, analyzing data, and operating instruments). The surveys also included open-ended questions asking their goals for attending (pre-survey) and whether their goals were met and the impact of the program on their teaching or career plans (post-survey).

The focus of this study is on the mentors in the REU and RET programs in 2014 and 2015. These participants are listed in Table 1, and pseudonyms have replaced their actual names. Some of these faculty have mentored in the REU or RET program in the years previous to the 2014/2015 timeframe, and their holistic reflections were included as part of our data collection. The first author interviewed mentors from REU and RET programs during May of 2016 to determine their perspectives of the program, its influence, and their perception of their role as a mentor. Fifteen scientists agreed to participate in either an audio-recorded interview or email response interview. The second author has worked with the IRL RET program and is familiar with the structure and many of the mentors. The third author now runs the IRL REU program and is familiar with the structure and mentors.

Table 1 Interdisciplinary research lab REU and RET mentors

Mentor	Demographics	REU mentor	RET mentor*
Ellie	White, female, chemistry, non-tenure track, 6 years as faculty at time of interview	2015	
Tom	White, male, chemistry, non-tenure track, 14 years as a faculty at time of interview	2014, 2015	
Henry	White, male, engineering, non-tenure track, 14 years as a faculty at time of interview		2014, 2015
Sam	White, male, engineering, non-tenure track, 15 years as a faculty at time of interview	2014	
Tessa	White, female, physics, tenure track, 2 years as a faculty at the time of interview	2015	
Boris	White, male, physics, tenure track, 11 years as a faculty at time of interview	2014	*
Qianfan	Asian, male, physics, tenure track, 15 years as a faculty at time of interview	2014	*
Muchen	Asian, male, engineering, non-tenure track, 15 years as a faculty at time of interview	2014	
Gabriel	White, male, chemistry, tenure track, 15 years as a faculty at time of interview	2014	2015
Frank	White, male, chemistry, non-tenure track, 2 years as a faculty at time of interview	2014, 2015	
Murray	White, male, physics, non-tenure track, 3 years as a faculty at time of interview	2014, 2015	
Abe	White, male, chemistry, tenure track, 7 years as a faculty at time of interview	2015	
Bryan	White, male, physics, non-tenure track, 9 years as a faculty at time of interview	2014, 2015	
Erik	White, male, engineering, tenure track, 8 years as a faculty at time of interview	2014, 2015	*
Li	Asian, female, chemistry, tenure track, 15 years as a faculty at time of interview		2014, 2015

*Indicates faculty who have mentored RETs in the past but not during the timeframe of the study. These individuals reflected on their experience in both the RET and REU program. Consequently, they are included in the data for both programs

Table 2 Codebook

Code	Definition
Mutual engagement	Communities culture and practices as evidenced by patterns of interaction among members (group social norms, expectations, interactions, and sustained mutual relationships). How scientists do research
Joint enterprise	The common purpose that brings members together for a unifying goal and drives collective action. Why scientists do research
Shared repertoire	Shared set of community resources, accessible to all who are part of the community of practice. What tools and resources are used
Ownership	By taking part in the negotiation of meaning, individuals contribute, take responsibility for, and shape the meaning
Developing science identity	How the mentor develops the following in their REU/RET: sense of belonging, interest in STEM research; developing competence, being recognized for performance of competence, giving ownership (individuals contribute, take responsibility for, and shape the meaning)
Building the STEM workforce	Mentoring as a recruitment tool; motivation for mentoring
Spectator novice	Teachers get a brief experience with the COP with the expectation that they will take it back to their classrooms

Analysis

Because few studies have focused on mentors' views of mentoring, we saw this study as driven by emergent design (Creswell & Poth, 2017). The authors created a codebook based on the COP framework which initially included mutual engagement, joint enterprise, shared repertoire, and spectator novice. Each author reviewed three REU and three RET mentor interviews to determine what other codes were present in the data; we then convened and finalized the codes found in Table 2. Using the finalized codebook, the first and third authors coded the REU mentor interviews and the first and second author coded RET mentor interviews. Interview sets were first coded individually; then, each dyad met to discuss coding and reach consensus for each data set. From here, we combined both data sets and each author individually reviewed the data for themes across REU and RET mentors. We met again as a group to develop consensus around the identified themes (presented in the Results section).

To ensure that the REU and RET programs were successful in meeting their goals, we examined the pre- and post-survey responses that related to our COP framework from undergraduate and teacher participants collected during the 2014 and 2015 programs. The pre- and post-surveys for both programs included quantitative questions and qualitative questions related to our COP concepts (i.e., science identity, mutual engagement, joint enterprise, and shared repertoire). These findings are presented first in our Results section to show that the programs, and the mentors, were successful in their goals.

Results

Skills Developed Through the IRL REU and RET Programs

The goals of the REU program during the research study timeframe were to engage undergraduates in authentic scientific research (mutual engagement), to build their research skills (science identity), and to help them make informed decisions about their STEM pursuits (experiencing the culture of STEM and determining if they belong). All of this was dependent on their mentor. The RET program goals were to engage K-12 teachers in authentic STEM research (mutual engagement) and expose them to research skills so that they can translate this experience to their students (spectator novice), thereby improving their students' understanding of STEM research. As such, the survey metrics for the two programs are slightly different. Despite this difference, the data highlights the skills that the mentors in each program developed in their participants and demonstrates that both programs were successful in their goals.

REU 2014 and 2015

Over 50 students participated in the REU program during the research study.[1] At the end of both summers, the majority rated their mentor as above average or outstanding (2014 = 86%, 2015 = 89%). The post-survey asked students if they were still interested in pursuing scientific research as a career. All participants, in both years, maintained their moderate and/or very interested categories. In addition, the post-survey had a set of questions that asked about learning gains that included participants' sense that they (1) have the ability to be a competent researcher (science identity), (2) have the patience for research (science identity), (3) know that "real" research is much different from classroom experiences (mutual engagement), and (4) know how their work contributed to the "bigger picture of research" (joint enterprise). In both years,[2] a majority of students expressed evidence that their science identity and mutual engagement in the COP had improved due to the program.

Based on this data, we can see that the majority of REU students developed multiple skills through their participation in their respective programs. These included improved sense of abilities to design research projects, discuss research, present research, and understand the process of scientific research. In turn, the program also improved their sense of belonging within the COP as they indicated an increased

[1] In 2014, 29 students participated in the REU program, 38% identified as female and the majority (83%) were juniors or seniors in college and majoring in the physical sciences or engineering (83%). In 2015, 24 students participated in the REU program, 67% identified as female and the majority were juniors and seniors (86%).

[2] In 2014, the majority of students (89%) provided evidence of improved science identity and a smaller majority (68%) indicated that they improved their understanding of mutual engagement and joint enterprise. In 2015, most respondents provided evidence of improved science identity (~70%), and again a smaller majority indicated an improved understanding of mutual engagement (61%) and joint enterprise (65%).

outlook on their abilities as competent researchers (science identity), a stronger understanding of how "real" research is different from classroom experiences (mutual engagement), and an improved understanding of how their work contributed to the "bigger picture of research" (joint enterprise).

RET 2014 and 2015

Twenty[3] K-12 teachers participated in the RET program over the 2014 and 2015 research study. At the end of each summer, 100% of the teachers in both years indicated that they enjoyed their relationship with their mentor (rating it as either good or higher). The majority of teachers[4] indicated that they had made improvements in specific COP categories based on their participation in the RET program. The post-survey questions asked about relevant COP categories. One set of Likert questions asked them the extent to which they had (1) observed research activities (mutual engagement, culture, and spectator novice); (2) collaborated in ongoing research with lab staff (mutual engagement); (3) assisted in the process of developing, modifying, and/or documenting applications of science for their mentor (mutual engagement); (4) operated instruments, equipment, and other technologies (shared repertoire); (5) participated in conducting research or collecting data in the lab (mutual engagement). For both years, the post-survey responses indicated that all teachers had observed research activities. The final section of the survey asked teachers about the impact of the program on their teaching. In both years, 100% strongly agreed that the program had increased their confidence as a science teacher, an indication of increased identity as a science teacher. In both years, 100% strongly agreed that the program increased their interest in research and the ways that science can be applied to current science, another indication of an improved science identity.

Based on the results for both programs (i.e., REU and RET), we can see that the programs, through the work of the mentors, engaged participants in various aspects of the COP (e.g., mutual engagement, joint enterprise, and shared repertoire). However, with this data alone, we do not know what role the mentor had in this skill development. Hence, the second research question helps us to delve deeper into our understanding of mentors' perceptions of their roles.

Mentor Perceptions

Our second research question focused on how mentors viewed their role. Mentors in both programs took time to plan research projects for their mentees, demonstrating that they cared about the experience. The themes we observed based on our mentor participants' perceived roles were building the STEM workforce, improving their own research productivity, connecting what is taught in the

[3] 10 teachers each year for two years; 65% identifying as Hispanic or African American, 36% identified as female.

[4] In 2014, 90% of teachers expressed improvement. In 2015, 100% of respondents expressed improvement.

college classroom to its applications in the field, and building a STEM identity through social connection. We saw differences between the REU and RET mentors in terms of perceptions as we will highlight below. Most importantly, none of the RET mentors referenced improved research productivity, connecting college classroom teaching to research applications, or building a STEM identity.

Building the STEM Workforce REU

Mentors saw the REU program and their participation as scientists as foundational to building the STEM workforce. For the REU program, all but one mentor explicitly referenced this as a goal for their participation. These mentors seemed to understand the direct role they played in building the STEM workforce by mentoring undergraduates. Bryan expressed this best:

> I think it helps undergraduates get a taste of what doing full-time research is like. This helps tremendously with the decision on whether they want to work toward a post-graduate degree in science. It also gives them training in marketable skills like electronics, robotics, mechanical design, technical writing, coding, and cryogenics.

Here, we see Bryan referencing the development of competence—the first step in developing a stronger STEM identity—and participating in the mutual engagement of the COP. Abe agreed, "[The REU] gives them a taste of research at the graduate level, helps them make career decisions, focus their interests, makes them aware of research and shapes their careers."

Mentors also saw the REU as an opportunity to recruit graduate students for IRL as well as generating graduate students for other universities. Qianfan explained that:

> Being a mentor has been productive, [since] many REUs continue to Ph.D. physics programs. REU has helped me identify excellent future Ph.D. students for our research. I am one of the thesis committee members or advisors for some of the REU students who later enrolled in [the affiliated university to the lab] as Ph.D. students.

Other mentors referenced the role of the program in helping their REU students decide to apply to graduate schools that might not directly benefit the mentor but served to build the STEM workforce. Frank explained:

> The REU student presentations have led to new collaborations and expose the undergraduates to active faculty at graduate schools who are looking for well-qualified candidates to join their lab.

Mentors who participated in both programs, like Li, highlighted how participation in research builds interest in both REUs and RETs (STEM identity), "The program allows the REU/RETs to get valuable hand-on experience in research and fosters/enhances their interest in STEM."

Building the STEM Workforce RET

All the RET mentors interviewed saw their role as helping teachers to translate science to their classes. But none mentioned a direct link to building the STEM workforce. Henry expressed this best when he said:

> I know many teachers that feel somewhat removed from current scientific techniques and/or discoveries. I am interested in giving them a glimpse into some really exciting aspects of science so that they can take some of their excitement and experiences into the classroom.

Notice that Henry uses the term "glimpse" here, alluding to our concept of spectator novice and the odd structure of RET programs—the brief exposure teachers receive to the COP but with the expectation to translate the COP in its complexity to their students.

Other RET mentors referenced their participation as a way to broadly reach the public, again an indirect way of building support for STEM if not building the STEM workforce. Qianfan explained:

> As a faculty member, I am aware of the importance and urgency to promote science via educating the general public about the importance of basic research. Demonstrating the connection between basic physics research and technologies people embrace every day is an effective way of communicating the importance of physics. RET is a good channel to realize these goals.

Gabriel explained, perhaps more bluntly:

> RET is mostly helpful in giving me bragging rights in NSF Broader Impacts. Pardon me for being honest here, but the RETs rarely yield much by way of research that I could not have accomplished faster and cheaper with my team.

We can appreciate Gabriel's honesty as it also provides evidence of the intensive work required to mentor and the perception of many scientists on research productivity as a main goal—our second theme.

Improved Productivity of the Research Team REU

These latter two comments highlight the culture of STEM, particularly in an academic setting. Researchers are often applying for grants which require evidence of mentoring and broader impacts. To be promoted/tenured, faculty mentors need to establish strong publication records. As such, Boris, Abe, and Gabriel were not alone in referencing the role that REUs, in particular, played in improving their research/personal agendas (i.e., all but two of the REU mentors referenced this as a motivation for being part of the program). These mentors often referred to REU's as an "extra set of hands" that allowed them to address projects that might not be possible without an additional researcher.

Other mentors referenced the improved research productivity but also saw REUs as idea generators, not just mindless hands. Muchen explained, "Participating in the REU increases my research productivity. And [REUs] have helped to generate innovative ideas and technology for us." Similarly, Frank saw the REU program as mutually beneficial to his research team and the REU student:

> Our projects are huge, and we often generate more samples and information than one person can complete. Summer REU students allow us to gain extra science from our existing projects, as we can break large projects into smaller [ones]. This allows us to demonstrate to our funding agencies (namely, NSF), that we're completing our original projects AND doing additional science while training undergraduate students.

Here, Frank introduces the concept of funding agencies looking favorably on participation in REU programs. Frank was not alone in seeing the benefits mentoring can have on his own career. Boris explained,

> "[Being an REU mentor] was (and is) well regarded by supervisors and funding agencies. It can also help in having my outreach work appreciated by supervisors and funding agencies."

Abe also discussed this broader impact value as one of his motivations for participation: "[I] participate [so] that it can be listed in the broader impacts section of future NSF proposals."

We would like to highlight that many of these mentors saw improved research productivity not just for their sake but also the participating mentee through research publications. Murray explained that he saw REUs as co-authors:

> I think it's just an opportunity where you have some extra hands and you can explore some new directions and you can do it, pretty easily, because they have lots of energy and they'll try lots of different things. And a good example is that right now, one of the main papers that we're finishing was initiated as part of last year's REU program. I don't think that is unusual.

Improved Productivity of the Research Team RET

Murray was not the only mentor to have REUs on publications, but only one RET mentor discussed publishing with teachers. Gabriel helped three of his past RET mentees to submit and present their research at national meetings, but he did say that RETs did not help his research productivity; instead, the process took longer because of them.

Bridge Between Classroom and Authentic Research REU

All of the REU mentors referenced that the REU program could strengthen their interest and sense of belonging in STEM. Three of the REU mentors explicitly referenced how the REU program served as a bridge that connects students' learning in their classes to applications. Sam expressed this best:

> By working in the materials characterization lab, they get firsthand exposure to stuff that you only read about or see demos of. Here, a fundamental experiment is conducted for an applied engineering reason.

Some teaching faculty explicitly discussed the importance of connecting their classroom teaching with their mentoring. For example, Frank recruited students from his classes to apply for the REU program:

> I often used real-world examples in my lectures, including applications to Marine Geochemistry/Oceanography, and this piqued some interest in several excellent students. One student demonstrated genuine interest and ability, and sought an opportunity to intern with me… the REU program was a perfect fit.

The majority of the mentors discussed how important the research experience was to keeping students motivated to stay in STEM. Tom expressed this best:

> Working in lab is so different than taking classes and even doing class projects. We had one student who was almost ready to change to a non-STEM major, but she liked the lab environment much more than her classroom experience and she moved on eventually to a PhD program [at a prestigious university].

The REU mentors saw the REU program as directly responsible for motivating students to go to graduate school—become more central participants in the COP. The RET mentors did not mention this concept of the program being a bridge between the COP and teachers' experiences and classroom contexts.

Building a STEM Identity Through Mentoring REU

All of our REU mentors saw their role within the COP as developing novices' skills so that they can move from peripheral to more central participants. Some mentors were also able to see the role they played in building STEM identity in their mentee by explicitly referencing how they facilitated participants transition from complete novices to more central COP members. Abe described his goal of building STEM skills for his REUs (STEM identity) by "helping the student to feel ownership of their project. If possible, projects should lead to co-authorship on a peer reviewed publication." Here, we see the concept of "ownership" described and this sense of independence is key to the development of a stronger STEM identity (Wenger, 1998). Erik provided more detail on how he facilitates the transition from novice to more central COP member: "Initially, daily interactions are needed, but as REUs get familiarized with the work, the more independent they get." It is important to point out that Erik saw both undergraduates and teachers as being able to take on the role of more central COP participants.

Another way in which mentors helped to building participants' science identity was by connecting participants' interests to the research project. For example, Boris briefly referenced that he "discusses with the REU about their interests and tries to tap into them." But he explained that this primarily serves his goal of improved productivity on the research project as he went on to say, "An REU passionate about the project will work much more efficiently."

Building a STEM Identity Through Social Connection in Mentoring REU and RET

Only two mentors explicitly discussed getting to know their mentees and the value of that social connection—Ellie as an REU mentor and Henry as an RET mentor—which has been identified as key to building STEM identity and helping students persist into the STEM workforce (NASEM, 2017). As a result, we would like to provide more detail on these two mentors to highlight their perceptions of their role. Ellie explained her motivation for mentoring in the REU:

> I approach the project as an opportunity for the REU, not my own research goals, to provide them with an actual project design, experimental setup, hypothesis, data driven conclusions, rather than use the REU as busy work and labor. This gives me an opportunity to learn from the students and help teach on a different level. Take the time to craft a project that the students have input on, from start to finish, and don't stick them at a benchtop testing repeatedly over and over again. We want students to think that SCIENCE IS AWESOME AND FUN, and when students are disregarded to busy work, they lose interest and think science is boring and monotonous.

Here, she explicitly says that her choice to mentor is not to complete her own research goals or give REUs busy work. She explains that her role is to show them the entire process of research (mutual engagement) so that they feel valued. Not only does she get to know her mentees, but she also shares her science trajectory with them. She mentioned this in her advice to other mentors:

> This is an opportunity to truly make a difference in some student's life. You do not know what obstacles stand in their way. Tell them how you have struggled in the past or challenges that have occurred to your career. Think back to when you were in college and graduate school, and the person who changed your life and guided your career. Be that person to someone else.

Ellie was one of the only mentors to express the significance of the mentoring role as "making a difference in a student's life." As such, she explicitly got to know her students to inform her own mentoring choices not to simply be more productive. She expanded on the concept of building the STEM workforce through STEM identity development where she got to know her students and recognized their value not just as a productive set of hands but as human beings.

For the RET program, Henry served as an exemplar in his focus on social interaction and getting to know his mentees. He explicitly mentioned that he "loved to get teachers' views on teaching and communicating with students." None of the other RET mentors referenced asking teachers about their expertise. Rather, most of the mentors saw their role as simply transmitting their own expertise to the teachers without acknowledging that teachers bring an expertise to their lab. Henry saw his mentoring as important to helping teachers understand research, "The teacher gets a better idea of the operation of the lab and a confidence to be able to handle scientific projects." But he designed the project with the teacher in mind, "I set the goals from the very start so that they would have something to take back to their class and that they would have fun." Rather than focusing on his own research productivity, he made sure to consider how the research could be translated to the teachers and their K-12 students.

In addition, Henry recognized the teachers as contributing members of the COP rather than simply spectator novices. He explained that "The RET projects that have been developed adorn the walls of my lab and are on display for tours, like a mini-museum." He reiterated that "Teachers can often have valuable input." In both comments, he highlighted that he sees these teachers as valuable to his lab and research, not just as another set of mindless hands but as experts.

Discussion

By using the COP framework to guide our study, we were able to see how mentors view their role as guides for undergraduates and—to a lesser extent—teachers, who help to move them from novices to more central members of the COP. As Wenger (1998) explained, part of this trajectory from outside the COP to central membership is accompanied by the development of a stronger identification with the COP. Our survey data shows that our mentors and their respective programs engaged participants in the four key aspects of the COP: mutual engagement, shared repertoire, joint enterprise, and identity building. The interview data showed that mentors perceived their role more related to mutual engagement and developing science identity, particularly for the REU students (Carlone & Johnson, 2007; Wenger, 1998).

Our mentors all referenced the cost of participation in REU and RET programs—the time commitment—yet all also believed the benefits outweighed these costs. While some were motivated by personal gain in their research agenda or broader impact requirements, most were motivated to mentor because they saw value in building the STEM workforce (Shortlidge et al., 2016; Zydney et al., 2002). Particularly for the REU program, mentors referenced the value they saw in their role as building research skills and confidence that often led to mentees continuing in their STEM trajectories. Here, we see how mentors were building the STEM identity of their mentees through skill development (REU—Fischer et al., 2021; Kuh & Schneider, 2008; NASEM, 2017; Zydney et al., 2002; RET—Sadler et al., 2010).

Both REU and RET mentors discussed their goals of improving students and teachers understanding of how scientific research is done, which is a crucial part of the COP and a best practice of REU and RET programs (REU—NASEM, 2017; RET—Davidson & Hughes, 2018; Davidson et al., 2022; Southerland et al., 2016). This understanding of and participation in the COP can give participants a stronger sense of ownership, self-confidence, and a sense of belonging. These skills are crucial to STEM identity development and best practices for REU and RET programs (REU—Corwin et al., 2015; Fischer et al., 2021; NASEM, 2017; Thiry & Laursen, 2011; Zydney et al., 2002; RET- Davidson & Hughes, 2018; Davidson et al., 2022; Hughes et al., 2012; Wakefield, 2022). These aspects of STEM identity development also require mentors to engage with and get to know their mentees on a personal level (NASEM, 2017). This mentorship relationship can be strengthened when mentors see their mentees as having value and helping them recognize their value in STEM contexts, particularly for mentees who are underrepresented in STEM (NASEM, 2017).

Mentors Valuing Their Mentees As important as recognizing mentees' value is to the mentorship relationship, only two of our mentors mentioned this as a goal—Ellie and Henry. Before exploring this finding further, it is important to note that mentors in both programs successfully influenced participants' understanding of the COP and strengthened certain aspects of their STEM identity as evidenced by the post-survey responses. But we argue that the level of success could be improved if more mentors engaged with mentees in ways similar to Ellie and Henry. Most of our mentors saw themselves as experts and their mentees as novices, even those who worked with teachers who would have an expertise in pedagogy that mentors could learn from. This view of the mentoring role—wherein an expert dictates knowledge through hands-on activities to the novice—puts mentors in the role of gatekeeper. As gatekeepers, the mentors hold power over their mentee because they hold all the knowledge.

If this is the view that mentors have; then, how well can they be welcoming their mentees into the STEM workforce? Ellie and Henry served as bridges for their mentees by asking the mentees about their interests and their ideas about the research. In the gatekeeper metaphor, the mentor is spending more time explaining the research, which is only one part of developing a STEM identity (Carlone & Johnson, 2007). The other important part is a sense of belonging within the COP (NASEM, 2017; Wenger, 1998). If a mentor does not get to know their mentees on a personal level, their mentee might interpret that as the mentor not caring about them. If mentees see themselves as simply a means to an end or spectator novice not fully trusted to engage at a higher level, how strong will their sense of belonging be and how will this affect their motivation to persist? Research has shown that STEM fields can be particularly intimidating for individuals who do not fit the stereotype of who succeeds in STEM fields (Bremer & Hughes, 2017; Prescod-Weinstein, 2021).

By demonstrating the value that mentees have in STEM, mentors can improve mentees' STEM identity, which can in turn serve as a source of motivation leading to the persistence of many more novices in the field. Ellie and Henry serve as exemplary cases of two mentors who focused on their mentees by getting to know them on a personal level, but also by asking their input and sharing personal stories of their own STEM paths. Perhaps if more mentors combined all these skills, a stronger and more diverse workforce would result. It is important to note that both Ellie and Henry are non-tenure track faculty, which could broaden their views of mentoring (e.g., not just to create more academics but to prepare students for many types of positions) or lessen their pressure to publish which would change how they view mentorship. Future research should compare faculty mentors across tenure and non-tenure track and compare the longitudinal outcomes among mentees to see what mentoring practices are most influential to keeping students in STEM.

Mentors Overlooking RET Role Another important finding from our study was the lack of clarity that RET mentors (except for Henry) had in terms of the value that teachers can have as potential allies in building the STEM workforce. Only Henry referenced seeing value in teachers as experts which he valued in his lab, thereby improving their sense of ownership, self-confidence, and sense of belonging within STEM. All of these can occur in RET programs (Davidson & Hughes, 2018; Hughes et al., 2012), but other than Henry, none of our mentors saw teachers as contributing members of the STEM COP. This might be because mentors could not see a direct connection between their work with the teacher and building the STEM workforce. While this finding may be understandable given the differing goals of REU and RET programs, we contend that it is important for mentors to consider the ways in which RET participants may function as conduits in and of themselves because they teach thousands of students over their careers.

K-12 teachers are the bridge that could facilitate students' interest in STEM through their description of a relevant and inclusive COP. Yet, because of the mentors' roles as academics and central participants in the COP, it was often difficult for them to fully understand or appreciate their RETs' expertise and value in the lab. For example, Gabriel was proudest of the publications his RETs had taken part in, a success in academia for sure. Perhaps these publications boosted the confidence and self-esteem of the teachers, but these teachers brought multiple years of experience in communicating science and facilitating science learning, an expertise that all mentors could benefit from. In fact, the goal of the RET program as identified by NSF (2021) is for mentors and mentees to engage in mutually beneficial projects wherein both parties learn from each other. Only Henry saw the RET as a learning experience for him and not just the teachers.

We contend that much is lost in RET programs when mentors do not value the expertise of teachers. Mentors could learn techniques that could improve their publications, grant writing, and teaching, but more concerning is the potential for teachers to maintain stereotypes related to the STEM COP if they are not seen as valued members. When this is the case, teachers may translate these same stereotypes to their students, thereby perpetuating the continued marginalization of underrepresented minorities in the STEM workforce (Bremer & Hughes, 2017; Prescod-Weinstein, 2021). Future research should focus on mentor training for RET programs to support mentors to recognize the expertise of teachers and lead to stronger outcomes for these programs with regard to motivating and sustaining students' interest and persistence in STEM via teachers' first-hand experience with scientific research.

Limitations

There are two limitations to our study. First, this is a qualitative study and is therefore not generalizable to all mentors across all REU and RET programs. Rather, this study highlights a potential difference between RET and REU mentors that future studies should investigate. A second limitation is the lack of diversity among our mentors. Although we had some women mentors, none of these mentors were people of color. Research has demonstrated that students of color can improve their STEM identities when they see mentors who look like them and share similar experiences with various forms of oppression (NASEM, 2019). Future research should include diverse mentors to determine what effect each mentor's lived experience has on their views of mentoring.

Conclusion

The comparison both within and across the REU and RET program highlighted what is gained and what is lost by current conceptions of mentoring. Most of the mentors viewed their participation from an academic perspective: mentoring serves to create new scientists. While this is not a false narrative, the way in which mentors approach this work may be highly consequential to whether undergraduates—and teachers—understand what it means to be part of the STEM COP. We contend that to support the development of science identity and persistence within STEM, it is important for mentors to view REU and RET participants from a lens that goes beyond academic productivity toward one of inclusion—seeing the value in getting to know their mentee and thereby making the experience more impactful for all parties.

Our study highlights two important findings that can improve REU and RET mentoring. First, few mentors in either program discussed getting to know their mentees. We argue that to develop more resilient STEM identities that can withstand the setbacks and failures inherent to STEM research, this social aspect of mentoring should be equally prioritized. Second, from an RET mentoring perspective, it is clear that most mentors either implicitly or explicitly ignore the science teaching expertise that teachers can bring to their lab. Besides Henry, no other RET mentor referenced the science teaching expertise as a value that the RETs brought to the lab. There was no reciprocal relationship between mentors and teachers which could be interpreted by RETs as a message that their role as science teachers is less important than science doers. In addition, there is something lost in these programs if mentors are not valuing teachers as part of the group effort in building the STEM workforce. We propose that future research investigate this further.

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Data Availability The datasets generated during and/or analyzed during the current study are not publicly available because at the time of data collection which was approved by the lead author's human subjects board, participants were told that their interview responses would only be shared with the research team.

Declarations

Ethics Approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Florida State University Human Subjects Board (Nos. 2013.11528 and 2014.14275).

Informed Consent We would need to get participants' permission to share their deidentified interviews if requested.

Competing Interests The authors declare no competing interests.

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