Career Development Impacts of a Research Program on Graduate Student and Postdoc Mentors

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Abstract—This evidence-based practice paper explores how graduate students and postdocs benefit from serving as mentors to undergraduate research interns. Utilizing three years of qualitative data from 38 mentors, our findings indicate that mentors feel better prepared for future faculty careers as they gain skills in project management, supervision, and communication. This paper reviews common themes across mentor evaluation data and discusses how these factors are contributing to the development of future faculty members prepared to work with diverse student populations. Our preferred method for delivery is a short traditional lecture followed by facilitated discussion of best practices among session attendees.

Introduction

The positive effects of receiving mentoring have been well researched and documented. Mentoring has been linked to the academic success [1], research accomplishments [2], and matriculation to graduate school [3] of undergraduate students. Furthermore, mentoring has been found to be especially important for students from underrepresented backgrounds. For example, mentoring relationships empower underrepresented students and enhance their science identities [4].

The positive effects of being mentored by a faculty member are well documented [1], [2], [3], [4]. However, undergraduate students also benefit from mentoring relationships with graduate students and postdoctoral researchers [5], [6]. For many undergraduate students, working with a graduate student or postdoc mentor can be less intimidating and provide a "safer environment" to ask questions and engage with new material [5, pp. 488]. Similarly, graduate students and postdocs are less removed from the undergraduate experience, having earned their Bachelor's degree more recently than their faculty supervisors. Therefore, graduate students may be more personable, understanding, and better able to empathize with undergraduate mentees [7]. Finally, depending on their own background and training, graduate students may also have cultural competency skills well suited to mentor students from diverse backgrounds [8]. As such, undergraduate students have been found to highly value, and sometimes prefer, being mentored by graduate students and postdocs [6].

Existing research has primarily focused on how mentees benefit from mentoring relationships. In recent years, scholars have begun to also study how graduate students and postdoc mentors are affected. In 2009, Dolan and Johnson found that mentors experienced "cognitive and socioemotional growth, improved teaching and communication skills, and greater enjoyment of their own apprenticeship experience" [5, pp. 487]. The mentors felt more connected to their identities as scientists and more qualified for their careers. Similarly, Reddick et al. [9] found the benefits of mentoring to be threefold for graduate students at UT Austin. By mentoring students in a pre-graduate internship program, mentors: (1) developed a better understanding of themselves and their field of study, (2) gained skills in mentoring and advising pre-graduate students, and (3) were able to contribute to their field by mentoring students from historically underrepresented backgrounds. Ultimately, these graduate students valued the reciprocal nature of the mentoring relationship.

Building on the existing literature, this study intends to further explore how serving as a mentor in a summer research program affects graduate students and postdocs. Through analysis of

evaluation data from mentors in the Transfer-to-Excellence Research Experiences for Undergraduates program, we hope to understand how the mentoring relationship prepares graduate students and postdocs for faculty careers at diversifying university campuses.

Transfer-to-Excellence Program Overview
The Transfer-to-Excellence Research Experiences for Undergraduates (TTE REU) program was founded in 2012 at the University of California, Berkeley. Each summer, the program hosts California community college students in the laboratories of UC Berkeley faculty. The program is intended to inspire California community college students to transfer to a four-year university and pursue a degree in science or engineering. Additionally, the program seeks to encourage interns to pursue further research opportunities and consider graduate studies.

The TTE REU program targets community college students for several reasons. First, community colleges offer a very important service to their communities: broad and low-cost access to lower-division instruction. However, this focus on teaching means they offer little infrastructure for faculty or students to conduct scientific research. As such, community college students have limited access to hands-on learning and understanding of the scientific research process. For most interns, the TTE REU program is their very first research experience. Second, community colleges enroll more students from underrepresented groups than their four-year counterparts, including ethnic minorities, financial aid recipients, students with disabilities, and re-entry students [10]. To date, 89% of TTE REU interns have been from backgrounds underrepresented in STEM fields. Successfully involving these community college students in scientific research is important for building diversity within the engineering fields.

Community college students who participate as interns of the TTE REU program benefit in a variety of ways. Analysis of mixed methods evaluation data shows that interns are better able to find scholarly resources, design ethical scientific experiments, conduct independent research, and analyze data after participating in the program [11]. Additionally, the program developed interns' science identities and their confidence to pursue further education and careers in science and engineering fields [11], [12]. Finally, 94% of interns have successfully transferred to a four-year university to complete a Bachelor's degree in a science or engineering field [11], as compared to the national transfer rate of 31.5% [13].

Transfer-to-Excellence Program Mentors
Before their arrival on campus, each TTE REU intern is matched with a doctoral level graduate student or postdoctoral researcher within their field of study. These advanced students are responsible for collaborating with their faculty supervisor (PI) to create an independent research project for their intern. The projects must be accessible for community college students with no research experience, include weekly deliverables, and be achievable within eight weeks. The graduate student or postdoc mentors are also responsible for the day-to-day training and supervision of their intern. Towards the conclusion of the summer, mentors provide guidance and feedback as the interns prepare (1) a research paper, (2) a fifteen-minute research presentation, and (3) a research poster.

Prior to the interns' arrival, the mentors each participate in a half-day orientation that briefly covers the following topics: creating a project, project management, mentoring, providing

constructive feedback, and cross-cultural communication. In exchange for their mentorship, the graduate students and postdoc mentors each receive a $1,000 research stipend.

Methods
Data collection
An online survey was administered to all TTE REU mentors during the final week of the mentoring experience. The questions were open-ended prompts, designed to allow mentors to share their experiences from their own perspective rather than responding to pre-developed statements in scaled items. The mentors were asked to reflect on how serving as a mentor encouraged their professional development in a variety of areas including how it impacted their communication skills, project management skills, and supervisory skills. An item also asked how the experience serving as a mentor impacted their career goals. Mentors were given one week to respond to the survey and were encouraged to be candid in their answers. The collected data was used to help the TTE REU program staff develop and improve future summer opportunities.

This study considers data from the 2017, 2018, and 2019 mentor cohorts. There were 38 total participants.

Year	Graduate Student Mentors	Postdoc Mentors
2017	8	7
2018	9	4
2019	6	4
Total	23	15

Data analysis
The research team began the analysis process by reviewing the qualitative evaluation data a number of times, paying attention to recurring topics discussed by multiple mentors. The research team selected one data set for initial coding, assigning descriptive words and phrases to the 2019 mentor's responses. Smith and Osborn [14, pp. 68] detail this process, noting "the skill at this stage is finding expressions which are high level enough to allow theoretical connections within and across cases but which are still grounded in the particularity of the specific thing said". After coding the interview, the research team grouped similar and redundant codes into larger themes. The coding and grouping process was then repeated for the 2018 and 2017 data sets, adding codes to the existing themes when appropriate and creating new themes when necessary. This process led to a master document of compiled themes and some outliers. The research team continued consolidating the themes until they were able to achieve maximum "mutual exclusivity and exhaustiveness" [15, pp. 2]. These themes are explored in the following section.

Results
Analysis of evaluation data shows that serving as a mentor for the TTE REU program benefits graduate student and postdoc mentors in four core ways. Mentors recognize that their improved project management, supervisory, and communication skills will prepare them well for future careers as faculty members.

<u>Project management skills</u>
The mentors shared that participating in the TTE REU program improved their project management and goal setting skills. This was coded into three themes: project design, goal setting, and time management.

Many of the mentors were involved in the creation of their intern's research project. They shared that being involved in designing their interns' project improved their ability to develop a "realistic clear experimental plan." Because of the rigid and time-bound structure of the program, the mentors had to ensure the plan was achievable within eight-weeks and that the intern would have data to present at the conclusion of their summer internship. Additionally, the interns' limited background knowledge and lack of research experience required that mentors create projects that specifically fit their abilities. This is supported by the following evaluation data:

> It has strengthened my ability in terms of developing a research project that is tractable for a fresh person to come in and contribute towards. It has also enabled me to manage the tasks for the project in a manner that makes it suitable to integrate the contributions from this project towards the overall research agenda that I am pursuing. Finally, I get the opportunity to plan out the entire spectrum of tasks and activities—starting from project design and setting research goals, to generating and evaluating research output. This is a substantial boost for my project planning and time management skills.

> After serving as a mentor several times, I am now improved at establishing the initial project such that the mentee can complete the work in the allotted time.

The mentors found that goal setting was important to the project design and management processes. The mentors provided their interns with weekly milestones that they were expected to achieve and adjusted them through the summer as necessary:

> This experience helps me to understand the importance of break[ing] down large projects into smaller, readily-achievable sub-projects.

> This mentoring experience has shown me the value of time-management and crafting many incremental goals ahead of time. This let [the intern] understand the broader research direction, and stay busy at all times as she's still a bit new to our work to be entirely self-directed.

Gains in goal-setting skills were accompanied by enhanced time management skills. Mentors were no longer responsible for just their own work, but had to ensure they were able to balance the needs of an inexperienced intern, including providing time for training and questions. Mentors learned to work with their intern to ensure that they were completing the research project at a reasonable pace and shared the following comments:

> This project caused me to think more about the timeline of a project, especially for someone who wasn't familiar with the research initially so the time required to get up to speed had to be accounted for as well.

> In this project, I had to make sure we were a few steps ahead of the project, so that [Intern] would not be stuck without a key reagent, plasmid, or yeast strain.

Balancing several different projects at the same time significantly helped my time management skills. In addition, I learned to separate a large project into smaller, more manageable chunks, and reserved one section of the project for my intern to work on. This certainly helped me understand better how to divide work more efficiently for multiple people to work on simultaneously.

Despite the prevalence of this theme, two of the research mentors did not feel that the mentoring relationship changed their project management skills.

Supervisory skills

Serving as a mentor gave graduate students and postdocs an opportunity to develop their supervisory skills. This was seen through the following themes: balance, adaptability, and logistics. This theme was especially important for less-experienced graduate students who were accustomed to serving in individual contributor or mentee roles.

Many of the mentors wrote that their supervisory skills were enhanced by learning how to delegate tasks. They were able to practice finding the delicate balance of providing interns with enough attention without micromanaging their work, as seen in the following comments:

It has helped me find a balance between being too hands on or too hands off that allowed him to complete the tasks but without too much micromanaging.

[Intern] was quite independent once she understood what she was doing, so I learned to judge when my supervision was necessary and when she could get things done on her own.

This was my first mentoring experience, so I learned a lot about how to help a student succeed without taking over their project too much.

When done correctly, delegation of work was found to facilitate collaboration and allowed the mentors to focus on the greater direction of the project and/or their own research tasks:

I spent more time thinking about the research direction and making plans instead of doing experiments by myself.

Given the diversity of the intern cohorts, the mentors had to adjust their supervisory style. In addition to recognizing that the interns had different academic backgrounds and limited science and engineering coursework, the mentors were able to discern different learning styles. For successful mentors, this resulted in a new level of adaptability. Approximately half of the mentors discussed being better able to meet the needs of the person they were mentoring. Below is just a subset of their responses when asked how the experience impacted their supervisory skills:

Major impact. I have learned more about my own style of mentoring, what works for various students, what doesn't work for various students, and what students need from me as a mentor so that I can better provide support for them.

This experience has shown me how to be a good mentor and what it takes on both sides to have a positive experience. I've learned some different mentoring methods and supervising skills that work for different people.

Continued experience in managing people with different personalities and learning styles.

It has taught me how to work with students that face challenges in following directions.

Mentoring a TTE REU student always gives a strong exposure to supervising students who are new to the research process, who have not worked on research extensively before. The ability to supervise these students working on complex research projects has been a significant boost towards developing my supervisory skills.

Mentors were also required to assess their organizational skills and create administrative structures to ensure their intern was adequately supported and their own research goals were met. Two mentors noted that they benefited from establishing concrete meeting times to connect with their mentees:

As I had two interns, I had organized our time and set some meetings with both and individually to follow the project. These made communication with them more dynamic.

It also required me to set up meeting time, review the deliverables and provide constructive feedback to others. During this process, I have become a more effective teacher and communicator.

One mentor wrote briefly about developing trust that their intern would do what was expected of them. Others wrote of their enhanced ability to be encouraging in difficult times and keep their interns motivated. This required reminding interns of the importance of their contributions and the projects' greater impact.

Communication skills
Being able to explain one's research to others is a critical component of the research process. Furthermore, it is a vital skill for any faculty member. The mentors unanimously agreed that serving as a mentor in the TTE REU program greatly improved their communication skills. This led to enhanced understanding of their own research, and better ability to explain scientific concepts to those outside their field.

The process of explaining a research project to an intern and then training them on the necessary methods provided an opportunity for mentors to further explore their own work. The mentors reported enhanced understanding of their own research as a result of participation in the program:

I have bettered my own understanding of my research material, as I needed to break everything down to a basic level at first to aid my intern's understanding, and then implement more of the advanced theories and techniques as we progressed.

It was a challenge for me to explain my work and its relevance to someone with little to no experience, but I think that working with my intern has helped me formulate my own research goals in a more coherent way.

Additionally, almost all the mentors referenced the relative inexperience of the TTE REU interns. They shared that training these students felt different from training experienced researchers. The mentors celebrated the opportunity to practice explaining their research to "fresh" students. As a result, they became more effective communicators:

> This has helped me find effective ways of communicating with my mentee and to explain different concepts to those unfamiliar with the field. It has also helped me learn how to communicate about project milestones and progress with others on the team.

> My communication skills were highly impacted during this summer.

> I greatly benefited from having a mentee, since this allowed me to work on better explaining and communicating the goals, results, and impact of my project. This helped my communication skills as well and helped me think through things more clearly and convincingly.

Mentors' reflections included realizations about their communication style and that of their intern(s). For example, they had to actively encourage confused interns to ask questions. Similarly, the mentors learned that the interns were not always willing to admit when they did not understand new material.

> I learned that I should encourage students I am working with to ask more questions earlier on and that I should be more active in confirming that my explanations are adequate. I can do this by asking the student to write in words what I have asked them to do or to show me after they do the first step.

> I learned that even when a student says they understand and gives a one sentence summary it does not necessarily mean that they understand.

> I have learned to think from the student side and make sure he really understands the concepts and details. Also I realized how important it is to encourage the student to ask questions and think creatively when encountering difficulties in research.

Mentors also shared that the experience improved their communication skills by requiring them to have difficult conversations with their interns, including discussion of performance management.

Faculty track preparation
Participation in the TTE REU program helped graduate students and postdocs prepare for future faculty careers by developing their teaching skills. Working with students from varying backgrounds and levels of understanding required the mentors to explore new ways to teach advanced concepts to a diverse audience. As such, this theme was very common among the evaluation data. Teaching skills are, of course, necessary if one is to be an impactful faculty member.

> This experience helped me to improve my teaching skills by explaining the knowledge clearly to students who are new to the field.

This has certainly been helpful in teaching me how to communicate with someone who has a different learning style than myself. Overall a very positive experience.

This mentoring experience has made me be more careful about how I present information and taught me that I really need to pay attention to the background of the person I am sharing information with.

The experience also provided the mentors with an opportunity to reflect on and refine their existing teaching skills

I have realized that sometimes I can be a little fast in explaining concepts/ideas, so I am trying to develop that skill to slowly explain concepts/ideas to people.

I tend to explain in too much detail, so I learned to hold back and let the student explain to me instead.

Ultimately, the graduate student and postdoc mentors were able to foresee the ways that their mentoring relationship will benefit their future careers as faculty members.

It provided training on teaching, communication and project management skills that will be beneficial to future career development.

This opportunity has enriched my mentoring experience and will be helpful for my future job interview for a faculty position.

Since I want to be a professor in the near future, all of the skills I learned this summer were very important for my future career and ensuring my future students' success.

Other benefits
Finally, the mentors shared that they found the mentoring relationship to be enjoyable and inspiring experience:

I'm so glad to be a part of the program and see the growth of the interns. My intern has inspired me to be a better mentor and leader and I'm grateful for the opportunity. I hope to continue mentoring students in my career.

This is my third time mentoring for this program, and it is always a fun part of my summer research plans. It has provided me with the chance to work with young students who are highly motivated and talented, and hail from diverse backgrounds.

The mentors report experiencing a lot of benefits from their participation in the TTE REU program. The mentoring relationship has developed their project management, supervision, and communication skills. Furthermore, they recognized the experience as an important professional development opportunity to prepare them for future careers as faculty members.

Conclusions
Evaluation data from the Transfer-to-Excellence Research Experiences for Undergraduates (TTE REU) program affirms that graduate students and postdoctoral researchers benefit from mentoring undergraduate students. As previously outlined, mentors reported that the program has enhanced their project design and management skills, supervisory skills, and communication

skills. Additionally, the study supports existing literature: the mentoring relationship enhances graduate students' understanding of their own research [9], their mentoring and teaching skills [5], [9], and can be an enjoyable experience [5].

The graduate student and postdoc participants of this study recognized that the TTE REU mentoring experience has prepared them for future careers in academia and research. Furthermore, the skills developed through the mentoring experience are important for the development of well-rounded engineering professors. The impacts explored in this study are especially important, as the mentoring experience helped mentors develop "soft" skills that are not easily taught in a classroom setting [16].

For example, the ability to design and manage a project will prove beneficial as the mentors move into faculty positions. As faculty, they will be expected to scope and scale projects appropriately as they run their own research labs and apply for grant funding. Additionally, the future faculty members will be required to communicate their knowledge to a wide variety of people with different backgrounds and levels of preparation. This includes the ability to explain their own research to those with limited background in the field, especially undergraduate students and funders. Supervisory and mentoring skills will be essential as the faculty members hire undergraduate, graduate, and postdoc researchers, as well as classroom teaching assistants. Finally, time management skills will be necessary to balance the competing pressures to teach, conduct research and complete department service expectations [17]. This will be especially important to new faculty members, hoping to obtain tenure.

The ability to collaborate and work well with a broad group of people has been found to be vital for the success of engineering faculty members [17]. This will prove to be more important than ever as universities work to diversify our engineering programs. Because the TTE REU interns attended community colleges, the mentors expanded their teaching skills, communicating information to students with limited background knowledge. They also gained experience training and coaching first-time researchers. Furthermore, the graduate student and postdoc mentors gained critical experience working with students from backgrounds underrepresented in their field. Developing cultural competencies, cross cultural communication skills, and an understanding of the experiences of scientists different than themselves will prove more important than ever if we are to be successful in broadening student participation in engineering.

In conclusion, the Transfer-to-Excellence program is not just developing undergraduate student researchers. By integrating graduate students and postdocs as mentors, the program is preparing tomorrow's engineering professors to teach and mentor future generations of diverse student researchers.

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