Developing Postdoctoral Scholar and Graduate Student Mentorship Ability

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***Abstract*— This research full paper presents a mixed methods study in developing the professional skills of engineering postdoctoral scholars and graduate students. It has been well documented that mentorship ability is crucial for mentee-mentor pairs in educational settings. The ability to be a mentor is a valuable professional skill for postdoctoral scholars and graduate students regardless of the career path taken following their education. How postdoctoral scholars and graduate students themselves develop an ability to mentor has not been widely researched. National Science Foundation (NSF) Engineering Research Centers (ERC) provide summer mentoring opportunities, including Research Experiences for Undergraduate Students (REU), Research Experiences for Teachers (RET), and Young Scholars Program (YSP), for postdoctoral scholars and graduate students to learn and practice how to be a mentor. A major challenge associated with this opportunity is the belief that such activities are not a valuable time investment. This belief can come from both the postdoctoral scholar or graduate students and their advisors. This paper presented a mixed methods study to investigate how practicing mentorship impacts the development of various professional skills for those involved in ERC Summer Programs.**

Keywords—mentorship, postdoctoral scholars, graduate students, engineering research centers, summer programs

I. Introduction

The ability to be a mentor is a valuable professional skill for postdoctoral scholars and graduate students regardless of the career path taken following their education. In academia, mentoring leads to greater academic success, positive academic development, and retention [1-3]. In organizations, mentoring has been found to be related to salary level, promotion rate, and job satisfaction [4]. It is odd then to discover that postdoctoral scholars and graduate students rarely receive formal training in mentoring within traditional education settings [5]. This lack of formal training forces these new professionals to learn how to mentor through alternative means, including recall of their experiences with how their advisors have mentored them during their studies [6-9]. Scholars have recently proposed a variety of mentoring training opportunities for postdoctoral scholars and graduate students [6, 10-11], but investigations of these opportunities have focused on the mentee's progress gained from mentoring [13], while the benefit to the mentors has been overlooked [12].

This paper aims to address this research gap by taking a look at whether participation in mentoring opportunities helps postdoctoral scholars and graduate students develop their mentoring skills. The study was conducted on engineering postdoctoral scholars and graduate students associated with a National Science Foundation (NSF) Engineering Research Center (ERC) to investigate the impacts of a short-term, lab-based, summer mentoring experience.

II. Background & Purpose

The bulk of research investigating the potential gains of mentors from mentoring others has examined organizational settings. The most documented gain within these contexts was what mentors could learn from the experience [14-16]. This learning ranged from new perspectives on the organization [17, 16] to enhanced managerial skills [16]. Protégés or mentees were identified as valuable sources of information themselves that could help mentors learn updated information, knowledge, and technologies from other levels of the organization [18, 19]. Additional potential benefits of mentoring to the mentors included improved job performance [16, 20], personal growth and gratification [15, 16], development of new personal relationships [16], and recognition by others [20].

Similar examinations have rarely been seen within an engineering context. Most studies have looked at the skills that mentors need to be successful [21-24], rather than what is gained from the mentoring experience. One study by Dolan and Johnson [25] did study mentor gains for mentors involved in a long-term undergraduate research engineering mentoring program. Gains reported by mentors through interviews were categorized into five different groups: 1) instrumental gains (e.g., improved research ability and productivity), 2) socioemotional gains (e.g., enjoyment of life experiences), 3) interpersonal gains (e.g., improvement of mentoring, teaching and communication skills), 4) professional gains (e.g., understanding of faculty work and potential careers), and 5) cognitive gains (e.g., intellectual growth and a deeper understanding of engineering concepts). Benefits of long-term mentoring differ from those gained from a short-term experience [26]. No studies to date have looked at and compared the benefits of short-term mentoring experiences in

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engineering to those of a long-term experience. Our purpose is to examine the impact of a short-term, engineering mentoring experience.

III. Theoretical Framework

Mentoring is a prime example of social constructivism where human development is socially situated and knowledge is constructed through interactions with others [27-29]. Vygotsky [30] theorized that individual development is measured by the distance between what a learner could potentially do under proper guidance and what a learner can learn by themselves alone [30]. This Zone of Proximal Development (ZPD) indicates that the skills a person can develop with collaboration exceeds what they can obtain alone [31].

The notion of the ZPD has been advanced and adopted in teachers education [32-34]. Teachers' professional growth has been observed in two ways: 1) teachers teaching students [34] and 2) teachers mentoring each other [34, 35]. Mentoring and teaching are different activities, but share many common traits including imparting knowledge in a social situation. The ZPD focuses on the gains made by the learner, but disregards what, if anything, is gained by those who provide guidance. Carberry & Ohland [36] suggested that the teacher or mentor also benefits from this interaction and that the experience exceeds what they can learn by themselves alone. This notion speaks to the old adage that "to teach is to learn twice." This theoretical perspective suggests that mentors have the potential to gain along with mentees through their interactions.

IV. Context

A. *Models of Mentorship*

Many different mentorship models have been developed for a variety of mentoring experiences [12, 37-39]. The model adopted in this study was the "Short-term, Lab-based, Engineering Mentor Model" developed by Chandler and Larson [40]. It was specifically developed for ERC Summer Programs and used to guide both mentors and mentees throughout their experience. This model was drawn from the situational leadership model [41] and divides the mentoring experience into four phases over time: establishing, growth, performance, and finalizing. The amount of explicit instruction provided by mentors to mentees gradually decreases from phase to phase, while assistance and encouragement starts low, increases and peaks in the third phase, and then gradually decreases back down. The chosen mentorship model was selected and adopted by those organizing the Summer Programs and was not specifically identified to inform the development of the tools used in this study to assess participants.

B. *ERC Summer Mentoring Opportunities*

ERCs offer voluntary mentoring opportunities to their faculties, postdoctoral scholars, and graduate students through multiple Summer internship programs, including Research Experiences for Undergraduate Students (REU), Research Experiences for Teachers (RET), and Young Scholars Program (YSP). The REU program supports undergraduate participation in scientific research. The goal is to prepare these students for careers in science and engineering. The program usually last 8 – 10 weeks [42]. The Research Experiences for Teachers (RET) program supports the active involvement of K-12 teachers and community college faculties in engineering research in order to bring knowledge of engineering and technological innovation into their classrooms. Interns are also required to generate curricula and teaching plans based on their in-program research experience, which usually lasts for 6 – 8 weeks [43]. The Young Scholars Program (YSP) is designed to inform and excite high school students about science, engineering, mathematics, and technology and to encourage them to investigate and pursue careers in these fields. The experiences vary in length from 3 – 8 weeks [44].

Participating mentors within these programs are assigned as research/lab mentors. NSF encourages organizers to provide mentor training to mentors of these programs and to develop a plan to encourage continued interaction between mentors and mentees during and after the program. The mentorship program received by these mentors varies from little or no guidance to week long mentor training.

V. Research Design

A mixed methods approach was used to investigate the perceived development of skills for postdoctoral scholars and graduate students involved in an NSF ERC. Phase 1 included a quantitative assessment of mentorship, leadership, collaboration, and communication skills. Phase 2 involved interviews of a subset of the samples who participated in the ERC Summer Programs. The quantitative assessment was used to reveal existing differences between those who have and have not mentored as part of the ERC Summer Programs. The qualitative component was used as an in-depth follow-up assessment to explore the potential reasons for any significant quantitative findings.

A. *Phase 1: Quantitative Study*

Data collection: During the fall semester of each year, the ERC Evaluation team led an annual survey of postdoctoral scholars and graduate students involved in the ERC. The survey was developed as part of a yearly evaluation instrument for the ERC and has only been used within this center. The goal of the instrument is to evaluate the overall impact of the ERC on its postdoctoral scholars and graduate students. Items within the survey were designed to ask single, direct questions pertaining to a variety of skills that may have been impacted by involvement in the center. This study used a subset of the responses, specifically questions instructing respondents to self-evaluate their level of skill development toward mentorship, collaboration, communication, and leadership. Questions asked respondents to directly assess themselves on their level of skill development on a 5-point Likert scale. The stem for the overall question addressing student skills asked, "To what extent did you develop the following skills from participating in the ERC." The scale ranged from 1: not at all, 2: very little, 3: some, 4: quite a bit, and 5: very much. The data used in this study was collected during the 2016–2017 (Year 1) and 2017–2018 (Year 2) academic years; response rates were 72% and 58%, respectively. The overall dataset contains 16 postdoctoral scholars and 76 graduate students. Table I breaks down the sample by gender, ethnicity, and academic standings.

TABLE I. SURVEY RESPONDENTS DEMOGRAPHICS

		Year 1	Year 2	Total
Gender	Female	21	17	38
	Male	21	30	51
	Prefer not to tell	2	1	3
Ethnicity	Caucasian	24	29	52
	Asian	13	9	22
	African American	2	3	5
	Hispanic	8	11	19
	Hawaiian or Pacific Islander	0	1	1
	Prefer not to tell	3	4	7
	Other	4	0	4
Academic Standings	Graduate Students	40	36	76
	Postdoctoral	4	12	16
Total Sample		44	48	92

Data analysis: All respondents were divided into two groups based on their participation in the ERC Summer Programs. Group 1 is associated with those who participated in at least one ERC Summer Program, including REU, RET, and YSP. Group 2 included all respondents who did not participate in any ERC Summer Program. The sample sizes for each group can be seen in Table II. The dataset violated both homogeneity variance and normality assumptions for ANOVA analysis resulting in the application of Paired T-Test and Kruskal-Wallis Rank Sum Test to study whether participating in an ERC Summer Programs affected the skills development of postdoctoral scholars and graduate students.

TABLE II. SAMPLE OF POSTDOCTORAL SCHOLARS AND GRADUATE STUDENTS PARTICIPATING IN ERC SUMMER PROGRAMS.

Group	Year 1	Year 2	Total
1. Participation least one ERC summer programs	12	7	19
2. No participation in ERC summer programs	32	41	73

Results: Hypothesis tests seen in Table III indicated that there was a significant difference between groups for mentorship skills development. No significant differences were observed between groups for the development of collaboration, communication, or leadership skills. Both the paired t-test and the Kruskal-Wallis Rank Sum test associated with mentorship skills demonstrated a p-value < 0.05. This indicates strong evidence to reject the null hypothesis of no significant difference existing between the two groups, i.e., there is a statistically significant difference in the mean score level of mentorship skills development between those who did participate in ERC Summer Programs and those who did not participate. All other tests produced p-values > 0.05.

TABLE III. HYPOTHESIS TESTS RESULTS

Skill	Group	Mean	Paired t-test p-value	Kruskal-Wallis Rank Sum Chi-Squared	Kruskal-Wallis Rank Sum p-value
Mentorship	1	4.316	0.003	8.817	0.003
	2	3.534			
Leadership	1	3.974	0.870	0.023	0.880
	2	3.932			
Collaboration	1	3.947	0.440	0.385	0.530
	2	4.137			
Communication	1	4.680	0.300	0.596	0.440
	2	4.123			

B. *Phase 2: Qualitative Study*

Data collection: Postdoctoral scholars and graduate students who participated in at least one ERC Summer Program were invited to participate in a 20-30 minutes interview during the Spring semester. The semi-structured interview used an interview protocol that included open-ended questions aimed to encourage the interviewees to share their ERC involvement, perception of mentorship, skill development, and recommendations to improve the Summer programs.

Interviewees included any postdoctoral scholar or graduate student who participated in an ERC Summer Program as a mentor. These individuals were potential survey respondents from the quantitative study but may have opted to not complete the anonymous survey. Eight potential participants (response rate of 53%) agreed to participate in the interview. The sample of interviewees included two postdoctoral scholars and six graduate students from three different institutions (Table IV). The three involved institutions were coded using the Carnegie classifications: A is a large Southwest Public Research University; B is a medium South-Central Private Research University; C is a large South-Central Public Research University. Each interview was audio recorded; two interviews were conducted remotely over the phone and six interviews were completed in person.

TABLE IV. IDENTIFIIERS FOR EACH INTERVIEWEE

Summer program	Institution	Interviewee	Standing
REU	A	1	Postdoctoral
		2	Graduate student
	B	3	Graduate student
	C	4	Graduate student
RET	A	5	Graduate student
	B	6	Graduate student
		7	Postdoctoral
	C	8	Graduate student

TABLE V. EXAMPLE STATEMENT FOR EACH EMERGENT CODE

Code	Example Statement
Unique Experience	"I have not mentored someone who has no basic lab skills." – A1 "It was kind of challenging to introduce a project [to someone] with totally no research experience." – B6
Development as Mentors	"I think every time you mentor someone new, you learn something new, you learn new perspectives." – A1 "I developed a high level of boldness and confidence in mentoring of students." – C4
Useful for Career	Having that experience is very important for future career whether it is academia or industry actually" – A1 "This [realization that people learn and communicate in different ways] will help me in my career in academia." – A2
Planning Better	"[I should have] planned better. I gave him a lot of stuff to read. I know it might not be the best way to start." – A1. "I didn't have any plan for my mentee at first. Planning is very important. You can get a lot of work done through mentees if you plan it right." – B3
Learn through Practice	"I don't think anyone could tell me [what the best way to mentor is] beforehand. I learned it through mentoring others" – A1. "Content can be taught in the classroom through showing the slides, but the skills will be more learned when you practice it." – B3
Clear Communication	"[I learned it is very important to] be able to communicate through verbal communication, also email." – A1. "The first thing I learned was to communicate properly. One sentence can mean many different things." – A2
Leadership Skills	"Improved upon on my leadership skill." – A2 "Hands-off approach can be really good, and micromanaging isn't." – A5
Listening Skills	"Listen, having an ability to understand where someone is coming from and where they are going to." – C4 "Listening, being considerate of their needs, or their short comings, or their strengths, and weakness. It is important to get to know the individual [whom you are working with] enough" – C8
Negative Experience	"Many [mentors] thought their time would be wasted." – B3 "Cause if I am going to have to baby someone, then I will just do it myself. It's twice the work if I have to teach someone else and continue to watch them" – C8
Limited Development	"I would say it was minimal, my mentees were great workers." – A5 "I would say [the score is too high], at least for me." – B7
REU vs. RET	"There were some differences in their motivations and attitude." – B6 "I hope I get a RET this year not a REU. [RET] is different than an undergrad, I think. An undergrad would need a lot more [mentoring]" – C8

Data analysis: Each interview was recorded and transcribed. The transcripts were then reviewed by two coders to identify a set of emergent codes and to establish internal validity. The transcripts were then reread and coded individually by each coder. Example salient utterances were then used to provide examples for each code.

Results: The following codes emerged from the data: unique experience, development as mentors, useful for career, planning better, learn through practice, clear communication, leadership skills, and negative attitude. Example statements made for each code can be seen in Table V. At least two interviewees were coded for each emergent code.

VI. DISCUSSION

The purpose of this paper was to establish a quantitative baseline of individual skill gains for engineering postdoctoral scholars and graduate students participating in an ERC. The established baseline was then used to conduct qualitative assessments to further investigate emergent significant differences between those who did and did not participate in ERC Summer Programs. The only significant difference were higher gains in mentorship skills for those participating in the ERC Summer Programs.

This significant finding lead the research team to interview those postdoctoral scholars and graduate students who participated in the ERC Summer Programs as mentors to further understand this quantitative finding. All mentor interviewees clearly identified the development of different skills – mentorship, communication, and leadership – through participating in the ERC Summer Programs. The potential reasons for this development could be that they were challenged to adjust themselves to fit a new experience or learned new things from mentoring other people. For instance, three out of eight interviewees learned that better planning could lead to better success and that clear communication is a key for mentoring. Four of eight interviewees also identified listening skills as a vital part of mentoring. It was also mentioned that different people, not just mentees, have different ways of learning and communicating. Our preferences in how we individually communicate may not be the same for others.

Another interesting takeaway was the mismatch in perceived attitude toward mentoring practice between the interviewees and their colleagues. Their belief, likely founded on lab perception or lab conversations, explained why the majority of postdoctoral scholars and graduate students have not yet participated in any of the ERC Summer Program opportunities. One interviewee, who did participate and considered himself strongly benefiting from the mentoring experience, still believed that it would be a waste of time to mentor someone who needs a lot of teaching and monitoring.

The qualitative findings also showed that mentorship skill differs from other skills despite their natural interconnection. This could explain the findings of the quantitative study that ERC associated postdoctoral scholars and graduate students who participated in at least one ERC Summer Program significantly rate their level of mentorship skill development higher than their colleagues who did not participate in any ERC Summer Program opportunities, but still showed equivalent gains in communication, collaboration and leadership skills.

An intriguing takeaway from the qualitative study was differences noted between those who participated in the REU and RET programs. The interviewees who mentored within the REU program expressed considerable growth in their mentorship ability and skills, while the interviewees from the RET program noted limited or moderate progress on such an ability. The possible cause for this contrast might be that mentees in the RET programs need less guidance and mentoring in general due to their on average greater life experiences; the majority of RET mentees are middle or high school teachers. They are likely more self-motivated, mature, and experienced compared to REU mentees who are typically late-teen, early twenties undergraduates. Another potential factoring into these findings is the length of each program.

Some potential changes for the ERC Summer Programs were also recommended by interviewees with one RET mentor suggesting that extending the RET program for a couple weeks would lead to a more complete research experience for the participants. Another RET mentor suggested some different personnel assigning policy to obtain better mentor-mentee matching.

VII. CONCLUSION & IMPLICATION

The overall goal of this research was to better understand mentoring opportunities for postdoctoral scholars and graduate students. Vygotsky's theory of social constructivism was introduced to situate and frame the investigation. The analysis of mentors involved in a short-term, lab-based, Engineering mentor model within an ERC environment provides some basic insights into its effect on the mentors. The study showed that both postdoctoral scholars and graduate students, who participated as mentors in Summer programs, such as REU, RET and YSP, believe they made more progress in their mentorship skill development compared to their colleagues who did not participate in the offerings. This finding matched the sample of mentors involved in a long-term undergraduate research mentorship experience [25]. Communication, collaboration, and leadership skills also found to be significantly impacted by Dolan and Johnson were not shown to be significantly different between groups in this study. This finding does not contradict Dolan and Johnson, but instead suggests that these related professional skills are not unique to those who participate in the ERC Summer programs or that more time is needed to further advance these skills.

The significant difference in gains reported for mentorship skills by ERC Summer Program mentors suggests that participation in such programs is advantageous to the professional growth of postdoctoral scholars and graduate students regardless of their future career. A major hurdle associated with more postdoctoral scholars and graduate students participating in such programs is recognizing the value of such a time investment by the potential mentor and their advisor. The three most common responses to a lack of participation in the ERC Summer Programs by survey respondents were "do not have time", "not interested", and "my advisor does not allow/recommend". Our findings will hopefully enable postdoctoral advisors and graduate programs to support offering and encourage participation in mentorship opportunities. Higher value associated with such opportunities will hopefully remove the negative stigma attached to time required to participate, while encouraging programs to devote more resources toward mentoring opportunities for postdoctoral scholars and graduate students.

VIII. LIMITATIONS AND FUTURE STUDIES

This initial effort is not without limitations. First, the sample size for this study was limited to the number of participants in the ERC during its first two years and the response rate of those participants. The small sample size might affect the accuracy of the statistical analysis. Increased sample size as the ERC continues to operate will help increase the statistical power in evaluating the impact on skills development in future assessments.

Second, documenting mentors' prior mentoring experiences would be helpful in better understanding observed gains. It is possible that mentors with rich prior mentoring experience could perceive limited development of their mentorship abilities compared to their counterparts who have limited or no prior experience. The observed impacts of the mentoring experience associated with this ERC would be additionally impacted by the prior research experience of the mentees. Interviewees mentioned that mentees who have participated in REU or RET programs before required less mentoring or interaction compared to first timers. This difference resulted in a very different mentoring experience for the mentors. Such information will be collected in future iterations of this assessment.

Third, we observed contrasting perceptions when the mentors in the REU and RET programs were separated. This suggests a potential study separating REU and RET respondents' data to provide a more nuanced understanding of specific ERC Summer Program impact on postdoctoral scholars and graduate students.

Finally, this study is also based on self-evaluation, including self-reported survey responses and self-described program experiences from postdoctoral scholars and graduate students. Personal bias and misevaluation inevitably exists within the dataset. A future step for this research will be to conduct interviews with corresponding mentees or conduct mentor-mentee dyad interviews to provide a check of the mentor's perceptions. This additional data would provide multiple perspectives that allow for a broader representation of how participating in a mentorship experience affects postdoctoral scholars and graduate students' skills development.

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