“Help Being Passed From One Person to the Next”: Factors Defining the Development, Challenges, and Successes of Faculty Peer Mentoring Relationships During Mentee Transitions to Engineering Education Research

STUDIES IN ENGINEERING EDUCATION

EMPIRICAL RESEARCH

VIRGINIA TECH PUBLISHING

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ABSTRACT

Background: Formal and informal faculty peer mentoring relationships are important components of the development, growth, and trajectory of faculty. Yet this nuanced process of faculty peer mentorship remains an underexplored social phenomenon, especially regarding faculty transitions into engineering education research (EER) fields. Awards from the National Science Foundation like the NSF Research Initiation in Engineering Formations scaffold this process by providing an opportunity for engineering faculty to conduct funded EER projects with the guidance of an experienced mentor.

Purpose/Hypothesis: Dynamics in faculty peer mentoring relationships influence their development. Here, we explore faculty peer mentorship in EER and define factors impacting the mentoring experience of faculty transitioning to conduct EER. We answer: How are engineering faculty participating in a specific NSF program trained and integrated into the EER community?

Design/Method: We conducted semi-structured interviews with 18 grantees, including ten mentors and eight mentees. Data analysis followed an iterative thematic coding procedure to identify concepts that helped explain the mentorship experience of mentors and mentees.

Results: We define aspects of faculty peer mentoring relationships: power dynamics, mentorship location, and team composition. These three elements of grantee teams emerged as themes which influenced, both positively and negatively, the experiences of grantees.

Conclusions: By considering these factors when entering a formal peer mentoring relationship, prospective mentors and mentees preparing for small grant opportunities supporting the development of new faculty conducting EER can better anticipate challenges or needs in their mentoring relationships. These results can be extended to similarly structured mentoring contexts and inform research on other peer mentoring relationships in academic contexts.

KEYWORDS:
peer mentoring; faculty development; faculty mentoring; workplace culture

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INTRODUCTION

In the 21st century, engineering education research (EER) has emerged and is evolving as a field of inquiry (Borrego & Bernhard 2011; Klassen & Case 2022), including an ongoing process of establishment and legitimization as a discipline. This process includes the adoption of consistent terminology within the field (e.g., Finelli et al. 2015), the development of standards for methodologies (e.g., Beddoes 2023) and reporting practices (e.g., Walther et al. 2017), and the publication of comprehensive volumes and analyses of EER literature (e.g., Johri & Olds 2014; Johri 2023; Xian & Madhavan 2014).

Efforts to promote the engagement of new scholars and practitioners in EER have also emerged. It has been proposed that training both prospective and current instructors in pedagogical techniques and education research is a path to improving educational outcomes (Trask et al. 2008), especially in engineering (Adams et al. 2014). Some graduate students are trained in EER methods (Benson et al. 2010); however, graduate EER departments have only recently been established. Many notable universities with engineering programs do not offer EER graduate degrees. It is estimated that there are approximately 50 graduate programs conferring EER degrees worldwide, most of which have emerged within the last two decades (Froyd & Lohmann 2014; Lopez & Garcia 2020). Thus, as institutions continue to develop EER departments and resources for the traditional graduate pipeline, other paths to improve the development of EER scholars are required.

EER researchers have historically found paths into the field in non-traditional ways, most frequently as engineering or social sciences faculty members developing interests in EER and transitioning their research practices (Allendoerfer et al. 2007; London et al., 2021; Smith-Orr et al. 2019). Engineering faculty on this path face conceptual and methodological challenges in learning the methods and language of EER (Borrego 2007; DeMonbrun et al. 2019; Linder et al. 2022). Mid-career transitions to EER have been studied across many different programs in many different countries. Documented barriers in these international contexts include conceptual difficulties, shifts in identities, and building social capital (Dart et al. 2021; Goldsmith et al. 2023; Mirabelli et al. 2023; Seniuk Cicek et al. 2023). These transitioning researchers and practitioners require support when building identity and knowledge in EER.

Among the many varieties of mentoring in education, community approaches for instructing engineering faculty in EER-informed practitioner techniques, such as communities of practice, are considered successful paths to initiation in crossing the EER scholarship-to-practice barrier, though these approaches typically focus on best teaching practices, rather than EER research methods (Adams et al. 2014; Finelli & Millunchick 2013).

One community-based approach which targets EER research methods is the National Science Foundation's Professional Formation of Engineers: Research Initiation in Engineering Formation (NSF PFE: RIEF, hereby shortened to NSF RIEF) grant program. The NSF RIEF helps established engineering faculty develop expertise in EER methods through the support of a mentor familiar with social sciences research methods. The success of the NSF RIEF program is built on productive relationships and subsequent long-term engagement in EER by mentees. One aim of the program is to construct sustained engagement of new EER scholars. The National Science Foundation has supported other similar efforts to engage new EER scholars, such as the Research Initiation Grants in Engineering Education (RIGEE) award. The RIGEE grant required Primary Investigators (PIs) to be novices to EER methods, but did not require a mentorship plan (Plimpton 2006). Other structures supporting mentorship such as the PEER Collaborative National Network's "Unconference" (Pawley et al. 2014) have emerged to support new researchers in EER.

NSF RIEF mentors and mentees are typically co-investigators on a funded project, and both are typically faculty members engaged in peer mentorship. In an academic context, peer mentoring is mentoring between individuals at a similar rank or position, such as between first year and higher year graduate students or between faculty of a similar rank (Lorenzetti et al. 2019). Peer mentorship at the level of faculty is understudied. It has been studied among faculty of medicine (e.g., Files et al. 2008) but not widely in other academic settings, particularly in engineering contexts. Thus, the NSF RIEF offers a unique environment to study peer mentoring between engineering faculty.

To understand how new EER scholars are successfully trained with peer mentorship support, we conducted interviews about the strategies and experiences of mentors and mentees involved in NSF RIEF projects. The interview was designed to elicit factors which impacted the development, challenges, and successes of these peer mentoring relationships. Our qualitative analysis revealed nine themes which together can characterize the experiences of NSF RIEF mentoring relationships supporting faculty research transitions to include EER. Additional publications and presentations from this project describe in more detail the development of the study and resources resulting from this project (Jensen et al. 2020, 2021; Mirabelli et al. 2020) and the experiences and motivations of mentees on RIEF teams and their mid-career transitions to conduct engineering education research (Ko et al. 2021; Mirabelli et al. 2023).

BACKGROUND AND THEORY

COGNITIVE APPRENTICESHIP MODEL

The cognitive apprenticeship model (CAM) is the guiding theoretical framework of our research design and the overarching project. We chose the model for its potential to depict how non-EER faculty might gain expertise in a new discipline. The model focuses on learning cognitive or metacognitive skills and developing expert-like thinking and guidance from a mentor (Collins et al. 1989). Central to the model are a list of strategies that a mentor can use to teach cognitive processes (Dennen & Brunner 2008). Further additions to CAM theories include how participation in communities of practice lead to gaining skills and knowledge (Dennen & Brunner 2008, p. 428; Wenger 1998).

The CAM strategies promote expert-like thinking skills by encouraging mentees to experience thinking processes more independently. Techniques such as modeling, in which the mentor explains their thinking process when confronted with a task, or coaching, where the mentor provides guidance on tasks as needed (Collins et al. 1989) are less independent. Techniques such as reflection and articulation, where the learner assesses their understanding of a task and communicates their self-assessment from reflection (Dennen & Brunner 2008) are more independent. The strategy of exploration is the most independent, where the mentor encourages the learner to develop and test hypotheses or design and conduct tasks (Collins et al. 1989). Further modifications to CAM theories added specific coaching actions such as scaffolding, in which the mentor provides their apprentice with support to ease the apprentice's completion of tasks (Enkenberg 2001). Some CAM strategies have been applied directly to educational research (Dennen 2004), and CAM strategies have been researched for mentoring engineering graduate students (Maher et al. 2013). In the present study, we consider the NSF RIEF opportunity to represent a means by which mentees can join an EER community of practice and develop a level of expert-like cognition through the intervention of a mentor. We present some of the most common examples of CAM mentoring strategies in Table 1.

STUDIES OF MENTORSHIP IN ENGINEERING CONTEXTS

Studies of mentorship in engineering are largely contextualized around the training of graduate students, which are generally not peer relationships. Few studies have contextualized peer mentorship in engineering.

Crede et al. (2010) developed a community of practice for graduate engineering students which included direct mentorship by faculty members. The community focused on the development of teaching responsibilities and reported positive results in developing graduate participants into preparation to become engineering faculty.

Another study of engineering doctoral student mentoring programs used CAM theories and communities of practice to situate their results and suggested developing communities of practice to be among the best practices in developing doctoral students as future EER faculty (Adams et al. 2014).

STRATEGY NAME*	DEFINITION	EXAMPLES INSPIRED BY OUR STUDY OF NSF RIEF TEAMS
Articulation	An expert asks their mentee questions so the mentee can explain their problem-solving process.	A mentor asks their mentee to explain the steps they used to analyze some survey data.
Coaching	An expert directly observes their mentee and provides guidance and instruction.	A mentor sits in on a mentee's practice interview and gives feedback and tips.
Exploration	An expert helps their mentee to pursue their own goals, potentially providing some structure.	A mentor asks their mentee to find an appropriate framework for their project's research questions.
Modeling	An expert directly demonstrates a task so it can be learned by the mentee.	A mentor provides an example of a funded EER grant to help prepare their mentee.
Reflection	An expert compares their problem-solving or knowledge with a mentee; similar to articulation, but shared.	A mentor and mentee co-review an EER paper and compare what they observed.
Scaffolding	An expert provides support based on their mentee's current knowledge and gradually reduces support while the mentee gains expertise.	A mentor provides a few example questions for an interview protocol to be drafted.

Table 1 Common CAM mentoring strategies.

*This list of strategies is drawn from an overview of CAM-related literature by Dennen & Brunner (2008).

Other studies describe successful programs and initiatives to support graduate students through mentorship (e.g., Spivey-Mooring & Apprey 2014), but these studies were not grounded in CAM theories, and many did not develop or discuss theories of mentorship.

STUDIES OF FACULTY PEER MENTORSHIP IN STEM CONTEXTS

Little work outside of medicine (e.g., Jacelon et al. 2003; Moss et al. 2008; Pololi & Evans 2015) has been conducted on mentorship between STEM faculty members. Further, this work often lacks theoretical considerations.

Peer mentoring between STEM women faculty in a three-year mentorship program was reported to improve the retention and success of participants and improved their socialization within their departments, where some participants felt that the mentoring groups were "uncomfortable" and described social challenges with the program being "just too 'squishy' for me as an engineer" (Thomas et al. 2015, p. 152).

Lechuga (2014) used self-determination theory (Ryan & Deci 2000) as a framework for studying mentorship between faculty members in STEM disciplines. Lechuga identified roles of disciplinary culture on mentoring preferences, suggesting that certain degrees of interpersonal interaction may be acceptable to social sciences researchers, but intrusive to STEM researchers. Examples of potentially intrusive mentoring for STEM researchers include providing emotional support, training in research methods, and advice in grant writing. Notably, although mentors and mentees in the study were faculty members, they often had "mentor-protégé relationships" (Lechuga 2014, p. 911), suggesting that these were not truly peer mentoring relationships.

METHODS

This manuscript represents a portion of a larger study which seeks to characterize the experience of NSF RIEF grantees and to support the development and sustained engagement of new engineering education researchers. In this work, we specifically emphasize the relationship formed as part of the faculty peer mentorship component of the grant. This research was approved by the University of Illinois Institutional Review Board #19398. The qualitative results in this manuscript center on the experiences of mentorship in the NSF RIEF program. A complementary study describes the experiences of first year NSF RIEF mentors and their motivations to conduct EER research as a mid-career transition (Mirabelli et al. 2023).

CONTEXT: THE NSF PFE: RIEF GRANT

The NSF RIEF award is an annual grant competition in the United States which supports research in the education of engineers. The NSF RIEF program has two goals: to support EER research efforts and increase the community of EER researchers (Plimpton 2020). At the time of data collection, the NSF RIEF award supported over 45 projects across 50+ institutions.

Principal Investigators of NSF RIEF grants are required to be engineering faculty members with interest, but without experience, in conducting EER. As part of the grant application process, prospective PIs must include a mentorship plan (Plimpton 2020) describing how the PI will receive mentorship in the EER concepts and methodologies requires to successfully complete their grant's aims and develop expertise in their project's requisite techniques.

RESEARCHER POSITIONALITY

Our research team was comprised of six investigators. At the time of data collection and analysis, we were: a PI and a co-PI, both faculty in engineering departments whose body of research includes EER; two EER postdoctoral scholars, a graduate student in an education program, and an undergraduate student in an engineering program. Each team member had at some point transitioned to conduct EER from an engineering discipline and thus provided unique experience with this study's context. We intentionally leveraged our experiences, including challenges faced, motivations for conducting EER, and lessons learned during early EER projects. For example, the PI and co-PI of the project team were recipients of a prior RIEF award in which the PI was the mentee, which offers a unique perspective and inspired our interest for studying this form of mentorship.

Some of the researchers in the project team were relatively inexperienced in qualitative research at the beginning of the project, including the first author, while other members of the project team provided qualitative expertise and support. During the development of the interview protocol, the first author led the development of the interview protocol to reduce bias, but the PI and co-PI reviewed the protocol based on their lived experiences and research expertise, examples of communicative validity (Walther et al. 2017). We consider our different experiences as academic researchers to be a strength of the project team, particularly because our varying EER perspectives were conducive to better understanding our mentor and mentee participants.

RESEARCH QUESTIONS

The overall goal of our larger project was to study the NSF RIEF as a pathway of entry to EER and to understand successful mentorship for new EER researchers. When a peer mentoring relationship between faculty is initiated, particular dynamics between the faculty mentors and mentees will influence the development of the relationship.

We consider the following traits to implicate successful NSF RIEF relationships: The mentee considers themselves to be receiving helpful mentorship towards competently performing EER goals; they perceive that the activities associated with the NSF RIEF grant are being successfully achieved within the project's proposed timeline; they evaluate the relationship as interpersonally positive. This definition is based on the perspectives of the participants when describing their experiences, and not the explicit goals of the NSF RIEF program.

Our study used multiple rounds of thematic coding to identify three themes that characterize how our participants described their NSF RIEF mentoring relationships. Each of these themes corresponds directly to one of three research questions about what actions and traits are present in successful mentoring relationships:

RQ1: What *structural elements* (e.g., institutional location of mentee and mentor, academic rank of mentee and mentor) support a successful mentee-mentor relationship between engineering faculty and engineering education researchers?

RQ2: How were *mentoring strategies or roles* (e.g., meeting frequency, task assignment, use of CAM strategies) typically described by NSF RIEF grantees?

RQ3: What *individual characteristics* (e.g., personal relationships between mentee and mentor, personality of each, research values held by each) support a successful mentee-mentor relationship between engineering faculty and engineering education researchers?

RQ2 was informed by our theoretical orientation, while RQ1 and RQ3 are questions whose answers were emergent from conducting the interviews and informed the direction of our thematic analyses.

RECRUITMENT AND SAMPLING

Participants were contacted using purposefully selected sampling (Tongco 2007) targeting mentors and mentees who had been awarded NSF RIEF grants. This allowed us to explore the development and experience of the relationship from both mentee and mentor perspectives without having to collect data on the process of negotiating this relationship. Using the NSF's publicly available search function (National Science Foundation n.d.), 98 potential participants were identified and contacted by email in Fall 2019. Participants were interviewed from the fall of 2019 through the early winter of 2020. All current and past recipients of the NSF RIEF award at the time of initial contact were considered eligible participants, regardless of whether their project had been completed at the time. Some project teams contacted had been funded recently but had not yet started to collect data. Former and current NSF employees who were also current or past NSF RIEF grantees were not considered eligible for participation.

Potential participants were sent a recruitment email requesting that they complete a brief demographics questionnaire. Some researchers suggest a minimum of 12 interviews are required to potentially reach saturation, which is related to theoretical saturation from grounded theory and loosely defined as information redundancy (Lincoln & Guba 1986). Saturation is achieved when no new information, codes, or themes are yielded from the information source (Braun & Clarke 2021). Therefore, our sample size was appropriate for a complete information source, and this was confirmed during our thematic analysis. That said, participant motivations for EER research, certain experiences of power dynamics and of the EER field, and other highly particular situations emerged, which we presented in a complimentary manuscript about this study (Mirabelli et al. 2023). Participants were offered a remunerative incentive in the form of entry into a lottery for a $100 gift card.

PARTICIPANTS

Participants were adults (i.e., 18 years or older) who self-selected as mentors or mentees involved with funded NSF RIEF awards. Of these participants, ten were mentees and eight were mentors. To properly capture the full experience of peer mentorship as a phenomenon, gathering the perspectives of both mentors and mentees was required for a complete information source from key informants (Rijnsoever 2017). Ten participants were in the first year of their grant, though an additional three more participants started work on their grant after their award date and described themselves as in their first year of grant work.

Generally, each interview represented only one perspective from a given NSF RIEF project's team. For example, a project may have had a mentor and mentee, but in most cases, only one participated in the study. In two cases, partnered mentors and mentees from the same NSF RIEF awards were interviewed, offering complementary perspectives. In one case, a mentee and their two mentors from the same project were all interviewed.

The participants were interviewed via an online video call with recorded audio. Table 2 provides some demographics of the study participants. Given the small number of total NSF RIEF awards at the time of data collection and the degree of personal and relational content discussed during the interviews, no departmental or institutional data is reported. All participants were assigned pseudonyms and had the option to select their own pseudonym. Participant pseudonyms by project are presented in Table 3.

Table 3 outlines all fourteen projects, including participant pseudonyms and project structures. We note that there exists a large degree of variation in the relationships between team members in projects represented by the sample. Mentees or mentors in teams with as many as four grantees are represented. Additionally, mentorship pairs include individuals who have never met in person or have been acquainted for over a decade, mentorship pairs exist at the same or different institutions, and mentorship pairs exist where the mentor is outranked in tenure status by their mentee.

STUDY SAMPLE (TOTAL *N* = 18)		
NSF RIEF Grantee Position		
	Mentee	10
	Mentor	8
	Number of NSF RIEF Grants Represented	14
Academic Rank		
	Tenured/Tenure-Track	14
	Non-Tenure Track, Teaching	3
	Non-Tenure Track, Research	1
*Gender Identity**		
	Man	6
	Woman	12
Ethnicity		
	Hispanic/Latinx	1
	Not Hispanic/Latinx	17
*Race**		
	Caucasian	12
	Asian or Pacific Islander	4
	Black/African-American	2

Table 2 Summary of study sample demographics.

*For each option, only one option could be selected. All demographic information collected was optional. Options from the demographic questionnaire with no responses have been omitted from this table.

PSEUDONYMS PER PROJECT	PARTICIPANT ROLE(S)	YEAR SINCE AWARD DATE
Mimi	Mentee	1st
Nancy	Mentee	2nd
Ashley	Mentee	1st
Ellen, Mark, and Tiffany	Mentee and 2 Mentors	2nd
Rose	Mentee	3rd
Abbie	Mentee	1st
Caitlyn	Mentor	3rd
Michael	Mentor	2nd
Zach	Mentor	2nd
Beth	Mentee	1st
Alex	Mentee	1st
Aimee and Ted	Mentee and Mentor	1st
Jack and Ramona	Mentee and Mentor	1st
Marie	Mentor	1st

Table 3 Summaries of projects from the interview pool.

DATA COLLECTION

The team developed two semi-structured interview protocols based on the participant role as a mentee or mentor. The interview questions were designed to explore the experiences of RIEF awardees with mentorship and the participant's goals towards outcomes of their peer mentorship relationship (i.e., career goals as an engineering education researcher). The interview was designed in anticipation of a thematic analysis (Creswell 2013).

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Two (for mentees) and five (for mentors) interview questions in the second section of each of the two interview protocols were based on CAM theory (Collins et al. 1989). To avoid biasing participant responses, we intentionally did not ask directly about the CAM framework and instead coded for described aspects of the theory (Bergen & Labonté, 2020). Sample interview questions include: "How did you divide tasks between your mentee and yourself?" (mentor protocol) and "To what extent has your mentor influenced your own mentoring approach?" (mentee protocol). For many questions, information for subsequent probing was suggested in the interview protocol, and the order of questions was not strictly adhered to when conducting the interviews to allow the participants to dictate the flow of the interview. The interviews were conducted remotely and audio was recorded. Word documents of interview dialogue were transcribed verbatim by an external service and the project team carefully reviewed transcripts for accuracy and removed potentially identifying information.

DATA ANALYSIS

The interview data were analyzed by multiple rounds of an iterative coding approach. The research followed the team collaborative coding procedure recommended by MacQueen et al. (2008). A visual representation of the coding procedure can be found in the supplementary materials.

First, three coders independently analyzed five different transcripts each in an open coding process to create a list of potential themes. In the second phase of analysis, the research team compared the potential themes and reached consensus through conducting several meetings and discussions, thus developing a preliminary form of a defined codebook. During this process, the team noticed disparate experiences between the mentor and mentee populations and created two separate codebooks to represent the results for those groups. While the emergent themes resulting from interviews with mentors and mentees were similar in some ways, the development of code definitions and usage guidelines varied in context for mentors and mentees. For example, an emergent theme for both mentors and mentees involved descriptions of the NSF RIEF project structure, however the guidelines developed for how that theme was captured varied for mentors' and mentees' contexts—i.e., mentors often described how task assignment was decided for team structures on the projects; mentees more commonly described meeting frequency and interacting with personnel.

To complete the second round of coding, each team member used the preliminary codebook to code a fraction of the interviews. All interviews were coded independently by two different members of the research team to ensure consensus. In the final round of coding, a separate coder used the codebook to code the interviews to independently verify the correct text was coded with the appropriate theme designation. In lieu of calculating intercoder reliability rating scores, we followed a negotiated agreement approach in which any inconsistencies or disagreements in coding were negotiated among the researchers until complete agreement was reached (Campbell et al. 2013). The final version of the codebooks consisted of a total of 16 codes representing emergent themes. This paper presents results from nine of these codes, while the remaining findings are presented in Mirabelli et al. (2023). The complete final mentor codebook can be found in the supplementary materials.

In a final round of analysis, we reviewed the text segments captured alongside codes related to mentorship strategies and re-coded data to capture when CAM strategies were being used by participants, and what mentoring actions were not captured as part of the CAM theory.

QUALITY

Several steps were taken to ensure the highest quality of work in the current study. Throughout the study, the research team consulted the Q3 framework developed by Walther et al. (2015) and expanded for use by the engineering education community (Walther et al. 2017). This framework endeavors to establish validation in qualitative EER research by defining six dimensions of quality as forms of validation (addressed below in italics) to consider throughout the qualitative research process and present when publishing qualitative research (Walther et al. 2017). The team considered its own positionality as presented above throughout the study to establish trustworthiness in our data collection and analysis. For example, two members of the project team had lived experience as prior NSF RIEF grantees and proposed the overall design of this study. To reduce bias due to their experiences, participants were contacted and interviewed by the first author, who was a graduate student at the time of data collection. However, the lived experiences of these two team members were leveraged as a form of *theoretical validation* during the design of the interview protocol and determination of the project's guiding research question and theory. During data analysis, these team members were able to use their experiences as past NSF RIEF grantees to support the achievement of *pragmatic validation* via the experience of resonance with the themes developed by the coding process.

To achieve *procedural and communicative validation* during data analysis, the team met frequently during the multiple coding phases of research, and for every applied code by each researcher, all discrepancies between individual coders were discussed among the team to come to consensus on the analysis. Multiple coders on the team were trained simultaneously and met to ensure that the coding process was done consistently during the data analysis. Additionally, in the development and piloting of the interview protocol, questions related to mentoring strategies defined in CAM literature were guiding ideas, however the questions were drafted in plain language such that the research would be grounded in participants' experiences, rather than in theory.

Throughout this project, *ethical validation* has occurred by following and restating the aims and goals of our project as funded by the NSF. As a measure of *process reliability*, the team kept meeting notes, including a detailed audit log of the project recorded by the first author, and sought to recruit the largest sample of grantees possible. After recognizing the prevalence of first-year grantees in the sample, the team acknowledged that limitation and opportunity provided by the sample and adjusted the research questions and focus of our analysis to appropriately study these participants.

LIMITATIONS

Our interview protocol, provided in the supplementary materials, attempted to elicit depictions of RIEF mentors' mentoring strategies without biasing responses by suggesting individual coping strategies. In hindsight, this protocol may have been unable to tease out some CAM mentoring strategies as effectively as asking about these more directly, and consequently the connections between our interview protocol and theoretical framework may be incomplete. We do, however, take note that when queried to describe their mentoring relationships and previous strategies without explicitly stated strategies, interpersonal and social dynamics were considered very important to our participants, suggesting limitations to cognitive-only depictions of mentorship.

Some participants shared perspectives from very early in their mentoring relationship and thus present an incomplete accounting of success throughout their NSF RIEF project. However, we assume that RIEF mentors and mentees thoughtfully consider their relationship long before beginning the research. The co-PIs must work together when writing the grant and determining the scope of their research, giving them an adequate basis on which they can reflect on their relationship. In this study, most first-year mentees had engaged with their mentors for approximately one year at the time of the interviews.

Our specific NSF RIEF grant sample exhibits context-specific bias such as access to funding, a pre-planned mentorship strategy, a focus on EER, and voluntary enlistment as co-PIs. This likely makes the experience of mentorship easier on NSF RIEF participants. Further research is needed to examine these results beyond the NSF RIEF and similarly funded opportunities.

Finally, mentors and mentee participants shared their thoughts and feelings about mentorship with our team. These participants described the success and mindset of members of their projects' teams, but they were likely not aware of all the feelings, concerns, and opinions about mentorship held by the other member(s) of their mentoring teams. Thus, some second-hand knowledge was considered. However, reality as voiced by individuals is important; while we do not offer insight as to the comparative reality between mentors and mentees, we are able to glean insight from their individual experiences and perceptions.

RESULTS

Findings from our interviews with participants are presented as nine thematic codes that relate to broad concepts consistently present in participants' interviews. Each thematic code was created with the goal of understanding and defining aspects of mentorship, including the characteristics of mentees and mentors. Our participants identified these aspects as challenges and successes in the NSF RIEF program. These nine codes were grouped to create three overarching themes, listed with three constituent codes. Each is directly related to one of our research questions (RQ): mentorship mechanics (RQ 1), mentorship roles (RQ 2), and characteristics for successful mentorship (RQ 3). Each code is defined in Table 4 with an associated theme and an exemplar quote. The codes are grouped within each theme and that theme's associated research question in the table.

Table 4 Summary of codes arranged by theme, with exemplar quotes.

*Code names appear in text in italics, while superordinate themes appear in plain text.

**Quotes are not transcribed verbatim in this table, e.g., filler sounds like "um", "uh", stammering, repeated words, and other verbalizations have been edited for clarity.

THEME AND ASSOCIATED RESEARCH QUESTION	*CODE NAME**	DEFINITION	EXAMPLE QUOTE**
Mentorship Mechanics RQ1: What structural elements support a successful mentee-mentor relationship between engineering faculty and engineering education researchers?	*Project Structure*	General discussion of project structure: e.g., mentors and their expertise, team personnel, advisory board, proposal design and funding outcomes, task assignment, etc.	*I love the advisory board that we have … I like to think of it as sort of an apprentice model, especially in this occasional research.*
	Mentoring Location	Participants discussing institutional distance as a factor impacting the relationship between mentor and mentee	*I don't regret leaving the institution, but I regret that we weren't in the same place. I think the project would have looked a lot different if we could have met weekly, in person.*
	Power Dynamics	Participants pointing out the ways in which power and position inform the unique mentorship relationship of the NSF RIEF grant (e.g., mentoring an administrator)	*Having this kind of relationship with somebody who's much further up the food chain than I am, that has made me develop an increased awareness of the way that may influence our interactions […] Mentoring a graduate student is different than mentoring a school head for sure.*
Mentorship Roles RQ2: How were mentoring strategies or roles typically described by NSF RIEF grantees?	*Technical Needs of Mentees*	Participants identify concepts, lessons, research methods, literature, etc., which the mentee must learn to proficiently conduct engineering education research	*The idea of having a theory or a theoretical framework and then choosing that and the ways in which that becomes operationalized and the methodology and then the research questions …is more new to her than all of this other stuff.*
	Technical Mentorship	Mentee participants identify resources, lessons, etc. provided by their mentor, or mentor participants discuss their intentional mentoring strategies	*I know I can go back to the resources that we shared and look through it and refresh our memory. But before, I wouldn't even have known where to look.*
	Mentoring Relationship	Participants discussing their mentoring relationship: its origin, its successes or shortcomings, its outcomes or effects of the relationship, interpersonal dynamics, etc.	*I think that they've helped me become a little bit more disciplined in how I think about how we're going to study this, and how we're going to talk about it, and how we're going to present results in a way that is, you know, sound: methodologically sound.*
Characteristics for Successful Mentorship RQ3: What individual characteristics support a successful mentee-mentor relationship between engineering faculty and engineering education researchers?	*Mentee Trajectories*	Mentor participants discussing their mentee's motivation for pursuing work in EER and how mentees have developed in terms of EER soft skills and perspectives towards EER	*She felt like,* "Ah, I'm an old dog. Can I learn new tricks?" *… And now I think she feels very confident.*
	Mentorship Views	Participants' personal views of mentorship: philosophies, orientations with their research goals, and how their project has impacted these views	*There's that recognition of making sure that I am both training them and allowing them to do their own thing. I don't want to handhold them all the time, right?*
	Mentor Motivation/ Background	Mentor participants' motivation for pursuing work in EER, including discussions of passion/curiosity, previous research work, EER skills	*I try to be a good colleague, a good citizen, a positive influence on those around me.*

THEME 1: MENTORSHIP MECHANICS

The first theme presented is mentorship mechanics, which includes the structural elements of mentoring relationships. These mentorship mechanics describe the *situation* (e.g., context and structure) of the mentoring relationship but not aspects of the *relationship* itself. For example, the institutional locations of the mentor and the mentee, in addition to the implications of distance between grantees, are important foci of this section. Other considerations in this section include the academic positions of the mentor and mentee and the structure of participants' NSF RIEF grants including grant personnel. The parent theme mentorship mechanics includes three thematic codes: *project structure*, *mentoring location*, and *power dynamics*. This overall theme of "mentorship mechanics" was named explicitly to evoke a sense of actions or rules involved with peer mentorships among engineering educators. These actions and rules strengthen an understanding of mentorship and its effects on mentoring relationships.

MENTORSHIP MECHANICS: PROJECT STRUCTURE

The first code we identified under mentorship mechanics is *project structure*, which includes the personnel on an NSF RIEF grant and the research design of the grant. The personnel of an NSF RIEF grant include the number of mentors and mentees, student workers, and other professionals. Additionally, the research expertise of personnel is included as part of the *project structure* and influences the mentoring relationships. The research design includes the methodologies employed by NSF RIEF teams and the setting, participants, and timing of the research. While there were a wide range of structures related to the personnel and research designs of the 14 projects represented by the study, this section consists of examples of how personnel and research design configurations created challenges or opportunities for our participants.

The expertise of mentors in NSF RIEF projects was frequently described. Mentees were all faculty members or administrators in traditional engineering roles who conduct research and/or teach in a single engineering discipline (e.g., mechanical engineering). Among the mentor participants, some were experts in engineering education, and some were experts in other social sciences domains. Among the engineering education experts, many mentors' engineering backgrounds aligned with the engineering disciplines of their mentees (e.g., both had PhDs in mechanical engineering). Participants discussed the alignment of their mentor's research interests and expertise with their own project. For some teams, misalignment between a mentee's interest and a mentor's expertise was a hindrance. Alex, a mentee, was curious about multiple methodologies but expressed he was unable to explore methods not familiar to his mentor. In another mentee's experience, their first proposal application to the NSF RIEF program was rejected due to reviewers' issues with the proposed mentor's lack of expertise in topics outlined by the proposal's mentorship plan. One mentee, Beth, mentioned the differing expertise of her two mentors multiple times during her interview. She shared that her choice of mentors with different backgrounds was deliberate, suggesting that Beth possessed insight into what mentoring needs she possessed and intentionally aligned her personnel to those needs.

The number of mentees and mentors in project teams influenced the style of mentorship. Those teams with more than one mentor and one mentee frequently discussed this aspect of project structure as significant. In general, NSF RIEF projects consist of 2–3 people, with one mentor and one mentee as the most common configuration in our sample. Some participants' projects had other configurations, such as teams including multiple mentees. Participants in projects with multiple mentors or mentees shared their thoughts regarding the structure of their peer mentoring relationships.

One project in the sample included multiple mentees, and the implications of this multiple mentee structure was discussed at length by two participants. One mentee, Aimee, appreciated working alongside another mentee while their mentor expressed excitement at seeing the strengths of the two mentees. The mentor, Ted, was particularly reflective about the role of team composition for his mentorship:

> I am really enjoying this two mentee, one mentor relationship that we have but I am very curious as to how this project would be different if it was a one-to-one, as opposed to one-to-two relationship. … I might be able to take a step back and reflect a little bit more deeply on whether or not it would have been beneficial to have just said, "I should only be mentoring one of you at a time," or if I should say, "Mentoring two is actually much better," because they also have each other to work with. (Ted)

During their interviews, both Ted and Aimee frequently recounted similar advantages of being involved with a project whose personnel includes multiple mentees. For example, both participants considered a two-mentee format to mentorship to be a positive opportunity for the mentees to learn together. Ted expressed that it seemed advantageous for the mentees to have peers on the same project, and he believed that his mentees' positive relationship was beneficial to both mentees' experience with the project. However, Ted wondered what might be lost by mentoring two individuals simultaneously, possibly at a detriment to supporting their individual strengths. These concerns were not expressed by his mentee who participated in this study.

Each participant with more than one mentor in their project's personnel discussed the advantages and disadvantages of having multiple mentors on a project. Benefits to projects with multiple mentors included improved access to mentorship, feedback, and question fielding for the mentee(s) and more coverage of expertise in EER topics by project mentors. However, participants reflecting on larger project teams noted risks involved with larger teams, such as efficient time use when meeting with a larger team, scheduling challenges, and the potential that interpersonal conflict (e.g., authorship disputes) could occur more easily with larger teams.

The number of mentors or mentees also proved consequential for teams with only one mentor and one mentee, particularly in terms of the expertise of personnel. Alex described the limitations of only having one mentor:

> In terms of qualitative stuff, it's been helpful to learn a little bit of those techniques and so on. I think, like, I want to try to get that quantitative side, which right now, my mentor doesn't have. (Alex)

Many mentees, including Alex, are faculty at institutions with limited resources for EER scholars. Some mentee's institutions included few or no engineering education scholars to provide mentorship or advice. For those mentees, their mentor may be the only source of guidance in EER literature and methods, thus limiting mentees who want to explore the field more broadly. Some teams addressed this challenge with advisory board members including experts to cover project-relevant methods or literature bases which were different from the mentor's experience. Advisory boards also afforded mentees an opportunity for networking, sometimes assisted by the mentor. For example, in Ramona (mentor) and Jack's (mentee) project, Ramona helped Jack identify two of their five advisory board members. However, most first-year grantees had not yet met with their advisory boards, thus the results include little evidence about how teams leveraged the expertise of their advisory boards.

Most projects in the sample also included graduate and undergraduate student researchers as personnel. Usually, these researchers were mentored primarily by an NSF RIEF mentee (Martin et al. 2024). A few participants referenced the implications of their experiences with these student researchers. Some participants voiced frustration about a lack of access to graduate student researchers with EER expertise and cited training engineering students in social sciences methods as challenging. In these cases, a lack of support from students caused the mentees to bear a larger research workload. Participants at institutions with access to graduate student researchers viewed the development of the students' CVs or publications to be a primary outcome of their NSF RIEF award. For those participants, the successful mentoring of graduate students as research assistants paid by NSF RIEF awards was an opportunity to reflect on mentorship and solidify EER knowledge.

MENTORSHIP MECHANICS: MENTORING LOCATION

The second code presented as part of the mentorship mechanics theme is *mentoring location*. We define this code as the institutional location of mentors and mentees on NSF RIEF projects.

Both mentors and mentees discussed institutional distance as a factor impacting their mentoring relationships. Mentorship at a distance was the mechanic most attributed to challenges between participants and the other members of their mentorship teams. For example, most students on NSF RIEF teams were mentored by the mentee. However, in a few cases a mentor and mentee were affiliated with different institutions and the students were instead managed by the project's mentor. Notably, these interviews occurred slightly prior to the emergence of the COVID-19 pandemic, when remote work and collaboration was more uncommon. Mentees described team members at different locations as detrimental to relationship development between mentors and mentees. Jack, for example, had not yet met his mentor in person at the time of his interview. Other participants struggled with teaching or learning from a distance. Caitlyn, a mentor, described her challenges with switching institutions during her project:

> I regret that we weren't in the same place. I think the project would have looked a lot different if we could have met weekly, in person. We continued to meet weekly or bi-weekly, remotely, but, for things like coding and just some of that more in-depth learning it would have… been better to be together in the same physical space to talk about things. (Caitlyn)

Caitlyn suggested that while her mentoring relationship included a structured pattern of meeting, spontaneous interactions to support a mentee learning did not readily occur in mentoring relationships across institutions. Both mentor and mentee participants described location as a barrier to finding common meeting times. For example, another triad all worked from different institutions and struggled to deal with time zone differences.

MENTORSHIP MECHANICS: POWER DYNAMICS

In addition to the implications of expertise and location on NSF RIEF teams, the academic rank of mentors and mentees affected mentoring relationships. NSF RIEF mentees are inexperienced with EER methods and need to learn from their mentors. However, mentees may be experienced researchers in their technical disciplines, fully tenured engineering professors, and/or even administrators (e.g., deans, department heads). Some EER mentors in our sample were not in tenure-track positions or were assistant or associate professors. In many pairings represented by this sample, mentees and mentors had the same academic rank. The implications of these differences in rank are included under the *power dynamics* code.

Power dynamics were influential on the drafting of several teams' proposals. As mentioned previously, some participants' initial NSF RIEF proposals were rejected because of expertise. Participants also expressed challenges securing funding based on their mentors' tenure status and amount of experience. Reviewers of those proposals indicated concern for teams including junior mentors or experienced mentors who were nonetheless outranked by their mentee. One mentor summarized reviewer concerns by saying, "You know, I'm a third-year assistant professor, how much expertise can I have?" Another mentor, Mark, ranked directly below his mentee at the same institution, and his concerns about the role conflict led to personnel adjustment on their project. He told his mentee:

> "I'm happy to mentor you, but I also need somebody else involved in this conversation, just from a power dynamics perspective." […] I was in a space where I was like, "We need to find a secondary external mentor who can guide you through aspects of this process and give you just outside perspective as well." (Mark)

Mark demonstrates another example of the benefits of projects with multiple mentors, as discussed above in the *project structure*. By being involved in a two-mentor project, Mark was able to limit role conflict.

In terms of the mentoring relationship involved with an NSF RIEF project, the proposal was typically the very first interaction between mentors and mentees. In Mark's quote above, the mentee produced most of the proposal and ideas that guided it. However, not every team with uneven academic rankings navigated that process as smoothly. One mentor participant, Zach, described drafting a proposal with a mentee who outranked him:

> The awkward thing about these is you're sort of equal partners in 'em, so you kinda stare at each other and go, "Who's gonna write the proposal, you know?" [...] There's usually somebody who's in charge. (Zach)

Zach also expressed that certain interactions with his mentee were "a little bit socially and politically awkward," because of his mentee's particularly high rank at their institution. That mentee's rank also led to limitations in terms of time available for conducting research on their project due to "significant responsibilities." Zach expressed concern about his mentee interacting with participants, given the potential for participants to feel uncomfortable, or to give biased responses (e.g., overly positive feedback) because of his mentee's high rank.

In the following presentation of results, these major mentorship mechanics—expertise, academic location, and power dynamics between grantees—will continue to be included as contextual issues which exist in the background of mentoring relationships.

THEME 2: MENTORSHIP ROLES

The second theme identified is mentorship roles, which includes the interactions between mentors and mentees, and the mentorship needs of the mentee. We define the roles of the mentoring relationship as foundational parameters of mentoring relationships. These include mentors' openness to mentoring or mentoring styles, specific strategies employed by the mentor, and the technical needs of the mentee. While the mentorship mechanics grouping was concerned with the *situation* of the relationship, mentorship roles describes the *relationship* itself. We will create an image of the mentorship roles as described by our participants by identifying the common *mentorship strategies* and *intentional mentoring plans* expressed by both mentors and mentees involved with these projects. The parent theme mentorship roles includes three thematic codes: *technical needs of mentees*, *technical mentorship*, and *mentoring relationships*.

MENTORSHIP ROLES: TECHNICAL NEEDS OF MENTEES

The first code presented is *technical needs of mentees*, which consists of the conceptual and methodological challenges faced by mentees on their first EER projects. Prior expertise of the mentors was a component of project structure and part of the *situation* involved with peer mentorship on NSF RIEF grants. Both mentors and mentees identified aspects of EER that were unknown to mentees prior to their projects, and the instruction of these aspects were part of their mentoring relationship. Most of the mentorship plans presented by participants were centered on strategies to meet the technical needs of mentees. Needs included overcoming conceptual methodological hurdles, learning to use new software and techniques, and workshopping through new and unfamiliar bases of literature. One mentor, Tiffany, summarized her mentee's needs:

> Just being able to read and digest literature was a huge barrier for her in the beginning. There are a lot of different ways to do qualitative methods. Some are helped by technology. Some people don't use a lot of technology. So, for instance, while we were doing our transcriptions and then starting to tag them for thematic analysis, we were debating back and forth [...] she ended up loving it, but it was a barrier for her to learn that approach and understand why this was helpful. (Tiffany)

Mentors typically presented similar analyses of mentees' technical needs and approaches to meeting them. Mentees described feeling less certain about describing their needs at times; some struggled to adopt new terminology and jargon specific to EER. Mentees and mentors alike noted that theoretical frameworks in EER were unfamiliar concepts for engineers. According to those participants, even mentees in the second or third years of their RIEF grants were still grappling to understand theoretical frameworks. Mentees also struggled to adopt terminology specific to EER and to assess the quality of new articles. Mentees fared somewhat better in grasping project

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methodologies, and a few felt confident in quickly attuning to quantitative methods in social sciences work. Common areas of methodological confusion for mentees included understanding theoretical frameworks, interpreting qualitative methods as researchers with quantitative training, and conducting interviews.

Mentees recognized that their transitions to EER were limited by the availability of resources they could find. One mentee, Rose, said:

> I'm imagining some sort of course that I can check into; some sort of, like, online course that's a weekly thing, that is not just dependent on my mentor knowing anything… so I can get the feed quickly and have reference material and know the state of EER and general practices of the field. (Rose)

Rose felt that, while the mentorship was critical to her development, she also desired formalized access to resources. Without these resources, she felt less aware of the broader field of EER.

MENTORSHIP ROLES: TECHNICAL MENTORSHIP

Most participants mentioned a need for more resources to support new EER scholars. Mentors developed strategies to train mentees in technical EER writing and methodologies in response to the technical needs of mentees. This process typically started before the grants were fully initiated. While some project teams were formed after the mentee had drafted a nearly complete NSF RIEF proposal, most participants began their mentoring relationships while drafting their grant proposals. The strategies used by mentors when writing the proposals varied significantly. Some mentors wrote a large portion of the literature review for the proposal, while others only provided feedback and comments. Most commonly, mentors provided literature or recommended theories related to their mentees' project ideas in the form of providing resources. Alex described his mentor's support during the proposal drafting process:

> That was very helpful to kinda get a sense of "Oh, this is what a proposal was." She did help a little bit with the – the structuring of the proposal part itself. Like, the data collection and, writing the methods. […] I didn't know exactly how to write that. (Alex)

Alex benefited from his mentor's expertise in qualitative methods, and his mentor made use of disseminating prominent qualitative research textbooks. According to mentees, mentors continued beyond the proposal to provide both resources and writing assistance to their mentees.

Notably, the discussion of "resources" in terms of learning EER methods differed between mentors and mentees. Mentees consistently centered language around resources as being comprised of specific books, papers, or lessons provided by mentors. However, the mentors view their own expertise as a resource. For example, the mentors Ramona and Tiffany both described themselves as a "resource" available to their mentees.

A recurring theme in the discussion of mentorship and project structures was the frequency and style of meetings between project team members. Ellen, Mark, and Tiffany, who were near the end of their project, provided an exemplary discussion of the same biweekly team meetings, which were important to the team, given that Tiffany was at a separate institution. Mentee Ellen described the meeting format by saying:

> I usually start the meeting by kind of, you know, saying this is what the graduate student and I have been working on. And then sometimes I would turn it over to the grad student to go into more detail on something. (Ellen)

Ellen described outlined the content for meetings with her mentors. Mark described these meetings as being driven by Ellen and her graduate student mentee: "They've done the bulk of the lifting on the data, and we've provided more guidance and feedback on how they're interpreting some of the data." As Ellen suggested in the quote above, the mentors provided feedback on Ellen's progress as needed during the meetings. Tiffany described these same meetings with: "I give them feedback, I try to provide high-level guidance and then say, you know, 'This is your project;

go do it.'" In general, the projects represented by the study held consistent meetings, either online or in-person as determined by location. Both mentors and mentees consistently described these meetings as strong sources of learning, particularly as an opportunity for mentees to overcome hurdles from between meeting times.

While not a direct outcome of intentional mentoring actions, mentee participants believed that interacting with mentors trained in a different field was a valuable way to learn about EER. Mentees consistently expressed the significance of opportunities to learn from interactions with their mentors, especially beyond their projects. For example, Nancy describes her interactions with her mentor's lab on projects outside of her NSF RIEF award:

> I read over it, gave some suggestions, participated in some of the discussions and she included me and a number of other people in the lab as co-authors on that. And so, just that willingness to look at everything that she's doing as, an opportunity to include rather than an opportunity to exclude. (Nancy)

Nancy's immersion in EER research and projects was improved by learning about topics outside of her own grant, which Nancy viewed as valuable to her development as an EER scholar. The value of mentor and mentee conversations was a consistent theme in both mentor and mentee interviews. Another mentee participant, Ashley, expressed the benefits of conversing with her mentor outside of meetings succinctly: "It's not anything they're doing intentionally; they're doing it because they're trained in this area. But it's the consistent usage of a lot of the vocabulary, so that you can really feel like you're understanding." And Ted, a mentor, remarked about his mentee's learning: "It's not all about the research project itself. They've done a really good job of asking questions." Participants frequently shared that interaction between mentors and mentees yielded more enjoyable and fruitful mentorship experiences.

MENTORSHIP ROLES: MENTORING RELATIONSHIPS

During the interview, mentors and mentees were prompted to describe their own mentoring style when it came to mentorship with other faculty or with student researchers. Some mentors' responses focused on specific mentoring strategies or philosophies, and all mentors and mentees gave answers related to the tone or style of their mentoring relationships.

The most common language used by all participants involved being either "hands on" or "hands off", and some participants attributed the style they preferred in a mentor. In a few cases, there was a misalignment between the mentor's self-described style and the mentee's preferred style, cited by a few mentees as a source of frustration.

Very few mentor participants used language consistent with CAM literature (e.g., explicitly saying "coaching" or "scaffolding"), but many of their descriptions of mentorship aligned with CAM strategies. Mentors frequently reflected on their role in promoting a positive mentoring relationship. Earlier, we described the awkwardness that the mentor Zach felt while interacting with his mentee, who outranked him. Zach explained how he and his mentee were able to overcome that struggle through their positive working relationship:

> She was naturally asking a lot of questions of like, "What's that? What's this?" And I think that speaks to the nature of the relationship, she was comfortable asking questions and asking questions to someone who in theory she's supervising. [...] She did a good job of deconstructing some of the other power dynamics that could have influenced the conversation. (Zach)

While Zach does not specifically allude to a CAM mentorship strategy here, he demonstrates positivity and encouragement to field his mentee's questions. Further, he demonstrates that a successful working relationship can be achieved despite challenges with power dynamics.

In one interesting example, the mentee Beth outranked her mentor and considered the effects of their collaboration on her mentee's career:

> [One of my mentors] is an assistant professor, so I hope that her working with the two of us more senior faculty here will help actually… You know, keep, help her keep her career really well on track and, and get her well-positioned for tenure and promotion. (Beth)

Beth describes a positive consequence of power dynamics on the working relationship between herself and her mentors. Highly ranking mentees such as Beth add to the uniqueness of the NSF RIEF faculty peer mentoring relationship, as mentee PIs may consider themselves in a position to also act as mentors for their teammates' careers, as Beth suggested above.

THEME 3: CHARACTERISTICS FOR SUCCESSFUL MENTORSHIP

The final theme identified is Characteristics for Successful Relationships. Mentorship Mechanics described the *situation* of mentoring relationships and Mentorship Roles described the *relationship* itself. This third theme, however, relates to the *individuals* involved in mentoring relationships. Three codes emerged as significant characteristics: the mentors' perspectives of mentees' careers, all participants' views about mentorship itself, and the mentors' motivations for mentoring.

CHARACTERISTICS FOR SUCCESSFUL MENTORSHIP: MENTEE TRAJECTORIES

Mentors invoked descriptions of not only their relationships with their mentees, but of the personal and professional growth initiated by their projects and relationships. Most mentors described transitions within their mentees, such as gaining independence in proposing project ideas and taking interest in specific theories or methodologies. Some mentors speculated about the future trajectories of their mentees. Tiffany, for example, said of Ellen: "She really loves reading the focus group transcripts. And I think she's gonna be more qualitative." Mentors in later stage projects such as Mark and Tiffany also noted how quickly their mentee was able to independently conduct EER compared with their prior student mentoring experiences.

While mentees rarely discussed the emotional disposition of their mentors, it was common for mentors to describe the levels of confidence, excitement, anxiety, or frustration experienced by their mentees. Mentors also were quicker to describe the motivation of their mentees. For example, Marie said:

> He is really committed to having a positive impact on students and making sure that whatever we do in this research project is beneficial to students. And so, he is less inclined to collect data just for research's sake. He wants to make sure that any data collection instrument also, you know, has a formative impact on their education, and I think that's great. (Marie)

Marie expressed understanding of her mentee's motivations, both in terms of their project's technical output and its implications on students. Mentors frequently contextualized their mentees' motivations and used this understanding to better guide their mentees in accomplishing their goals.

CHARACTERISTICS FOR SUCCESSFUL MENTORSHIP: MENTORSHIP VIEWS

Participants' views regarding mentorship constituted success when they experienced personal growth because of reflections about their NSF RIEF mentorship. Other participants experienced insights into mentorship or new areas of research because of interacting with other personnel on their grant.

The most common trend among mentors describing their views on mentorship was an opportunity to experience mentorship with a faculty member instead of a student. Thus, mentors could see differences between their faculty and student mentees and look inward at their own mentorship. Caitlyn described her experiences:

> Working closely with someone, you just learn a new working style, right? … How do they write? How do they do these things? How do they run meetings? How do they organize

> themselves? It's always a peek into someone's world. [...] It has helped me to see another version and realize that my graduate students and their peers with different advisors might be having very different experiences. (Caitlyn)

Caitlyn's realization here is profound; the mentorship roles between different mentors and mentees yield complex experiences, something Caitlyn might not have realized unless both she and her mentee had been people who frequently mentor others.

Some mentors also became more curious about mentorship as a phenomenon due to their experiences in the program. Marie, for example, realized that she had developed an academic interest in mentoring:

> It would have been interesting to read about other styles and, and think, "Okay, well, maybe under these circumstances, maybe I should try this; or under these circumstances maybe I should try that." (Marie)

At the end of her interview, Marie also continued to speak with the interviewer and expressed a desire to learn about CAM strategies and the research design of this study.

Mentees' perceptions of mentorship also changed because of their experiences with peer mentorship. Ashley was prompted to consider her own mentoring style and if it had changed during her progress in her NSF RIEF grant, and she described her evolving perspectives, saying: 'Mentor' has a deeper meaning than 'advisor' and 'coach' and 'instructor.' She believed that helping a mentee develop skills was important to her. Ashley said that, "Being able to grab at very useful and rich resources to guide that person's growth" was important to her own mentoring, and something she expressed receiving from her own mentors. Ashley also described realizing that the differences between mentorship in social sciences and engineering were not particularly different. She said that if she mentored new EER researchers, she would introduce them to literature and "ground them, and start to sort of step into the space, just like we do," when she teaches, and that her mentoring style could readily extend to both domains.

CHARACTERISTICS FOR SUCCESSFUL MENTORSHIP: MENTOR MOTIVATION AND BACKGROUND

Finally, mentors experienced feelings of success during their grant, where success is based on outcomes related to their motivations to be co-PIs in NSF RIEF grants. Some participants described a "commitment to students" (Marie) which drove them to EER work initially, and an ability to further support students by conducting more projects and support new researchers. Ramona was particularly excited to work with her mentee and build upon her interest in interdisciplinary work:

> I found it to be pretty cool when he approached me and asked me to be a part of the project. Primarily, because I'm also bridging into this space of interdisciplinary collaboration in engineering. 'Cause, I'm trying to have my engineering students come to understand and appreciate, that engineers do not only work with engineers. There are times when you have to engage with people who are experts in your own right. (Ramona)

Ramona's background in interdisciplinary research was well-suited to the mentorship context of the NSF RIEF grant and offered her an opportunity to replicate a lesson from her own commitment to students.

Mentors also expressed that their interest in EER research was further satisfied by partaking in NSF RIEF grants. Obtaining funding, working on projects of interest, and sharing their research interests with newer scholars were all draws of the NSF RIEF to mentor participants. But within this theme, Mark was perhaps the most poignantly excited as he reflected on how young the field of EER is, and that his mentee could now enjoy an open and flexible space to explore and research:

> We are swimming in a sea of ideas. There is not a shortage of things to look at. He hasn't got a fundamental concept of how do we best teach engineering subject. There's still a lot of unanswered questions in those spaces, but I think the joys of engineering

> education as a young field is it's not a space that feels so prescriptive to me and that we are locked into. (Mark)

IMPACT OF NSF RIEF ON MENTORS' PERSPECTIVES

Although it is not explicitly a theme related to mentoring relationships, one emergent finding was that participants frequently described their perspectives of the NSF RIEF grant positively. Mentors described the opportunity to develop a mentoring relationship with another faculty member as an opportunity to reflect on their own mentoring style and on mentorship in general. Ramona said:

> I think if you're being mentored and then in fact, you're mentoring someone, ...but, it's probably coming from someone else... Now I feel that there's a whole chain going on here. You know, expertise and knowledge, and help being passed from one person to the next. (Ramona)

Ramona's comment yields the spirit of layered mentoring, in which expertise proliferates through a community through participation. In addition to appraising their mentee's interests and improvement, mentors also discussed the NSF RIEF award and consistently lauded it as being an important opportunity for prospective engineering education researchers. One important feature was the NSF RIEF's impact on mentees' tenure prospects, CVs, and the value of getting the responsibilities and potential of large, funded projects. Mentees agreed with this. For example, Ellen praised the NSF RIEF program in her interview, saying, "The idea of having mentors, I don't know who ever came up with it, it's really great. Because, you know, the things you can learn from good mentors, it's amazing!"

CAM STRATEGIES DESCRIBED BY PARTICIPANTS

Finally, we explored the data for descriptions of mentoring actions which constituted strategies within the CAM framework. Mentors were not prompted to describe specific CAM strategies but were prompted to describe the strategies they used to mentor their co-PIs. Mentees, similarly, were prompted to describe how their mentors were teaching them technical EER methods, or how they planned to. Both mentors and mentees infrequently described or named explicit strategies specifically aligned with specific CAM mentorship techniques, such as coaching or reflection. A few mentors described scaffolding elements of methodology work or writing. Michael (mentor) used the term "scaffolding" several times to describe his instruction of his mentee. Aimee described that her mentor Ted first conducted interviews for his mentees (modeling) and then observed them conducting interviews and gave feedback (coaching) and suggestions. Ted, in his interview also referred frequently to his mentees as "apprentices" and referenced a few theories of mentorship, however, he was the only mentor to do so. Ashley's mentor assigned journal reflections from each meeting and an agenda for leading group meetings, an example of the reflection and articulation strategies. However, these strategies were mostly presented as implicit through mentors or mentees describing task assignments and meeting styles. Most CAM strategies identified during our coding phase were examples of exploration, such as with the resources provided, described above. The other most common CAM strategies which were described included scaffolding, such as in the case of Ted's practice interviews; modeling, such as in the case of participants whose mentors wrote sections of the grant; and exploration, such as in cases where participants were given resources or open-ended research questions to form and explore. Direct coaching, prompts for reflection, and modeling were strategies defined in our literature review that were rarely described.

DISCUSSION

Briefly, we will summarize the findings presented above, discuss their alignment with and against the CAM framework and other prior research related to faculty peer mentorship in EER, and offer implications for faculty considering transitioning to EER via a peer mentoring relationship.

ALIGNMENT WITH PREVIOUS THEORETICAL RESEARCH

Mentoring techniques within the cognitive apprenticeship model (Collins et al. 1989) were described implicitly by participants as intentional mentoring strategies. Mentors rarely gave specific examples of mentoring strategies in their reflections, and mentors did not frequently name any theories of mentorship used in their own mentoring practice. They also more frequently described assessments of where their mentees were in their learner-to-expert transitions. Mentors recognized their mentee's trajectories in developing cognitive prowess as EER researchers. They also described specific techniques implicitly that are presented in our results as coaching participants through interviews or guiding participants through explorations technical resource sharing.

CAM theories adequately describe the process of learning during a mentoring relationship within the domain of cognitive tasks. However, CAM theories neglect certain interpersonal elements which may contribute to the success of mentoring relationships (Dennen 2013). Many participants drew conclusions about research progress and interests based on affective observations such as excitement, joy, or frustration. Mentors leveraged their emotional and motivational understanding of their mentees to better address their needs, elements which are not present in the basic form of CAM theories. Mentoring programs which use CAM strategies to describe learning may benefit from turning to additional theories of mentoring. To make a more complete depiction of mentoring relationships among expert domains, the CAM model may require revisions incorporating strategies which describe the relationship between mentor and mentee.

Non-peer engineering faculty mentorship programs are somewhat common (e.g., Dunham et al. 2012; Long et al 2018; Mendez et al. 2020; Montelone et al. 2003), including as part of early-career faculty development efforts (Huerta et al. 2022). Research on peer mentorship among engineering faculty, especially regarding EER field transitions, is less common. We found dissonance between our findings and Lechuga's (2014) interpretation of invasive mentoring practices for STEM faculty members. Both mentors and mentees described appreciating supportive and emotional connections, and many mentees described a positive interpersonal relationship as one of the best aspects of their NSF RIEF project. These examples were considered by Lechuga to be invasive for STEM faculty, but not to social sciences faculty. Instead of siloing by discipline, mentoring programs that train on interpersonal relationships should encourage the benefits of a positive relationship between mentor and mentee, while encouraging healthy boundary-setting by all members of a mentoring relationship.

MENTORSHIP MECHANICS

Among the three themes, Mentorship Mechanics presented the largest quantity of potential challenges to successful mentoring relationships. In general, mentees in faculty peer mentoring relationships already possess a set of skills necessary to succeed in research, which is also described in faculty mentoring literature (Dart et al. 2021). As PhD researchers, they are experienced mentees in an academic context and already have knowledge of how to learn under a mentor's guidance. This prior experience in a mentoring relationship demonstrates how this style of mentorship is unique. Thus, most mentor-mentee teams were able to work through challenges related to learning by leveraging the mentees' existing skills. Power dynamic issues were best mitigated by conversations between mentors and mentees or changes to team personnel. Mentorship location was the only major factor without a consistently presented solution, except to plan virtual meetings before the start of grant work.

Team composition played an interesting role in the structure of the NSF RIEF projects we sampled. Martin et al. (2022) describe another NSF RIEF project in which the dynamics of mentorship among faculty peers and a graduate student is discussed. They anticipated an experience of hierarchical mentorship, but in fact the NSF RIEF mentee and graduate student mentee were able to sometimes co-learn. The graduate student was sometimes directly mentored by the NSF RIEF mentor, and all parties described learning directly from each other. We find resonance between the descriptions of mentorship in Martin et al. and the case of Ted and Aimee's three-grantee project, in which a larger mentoring network produced additional benefits.

MENTORSHIP ROLES

The theme of Mentorship Roles included aspects of the mentoring relationship between NSF RIEF grantees and included the interpersonal and technical strategies and lessons imparted between mentors and mentees.

While it did not occur often enough to constitute a finding, interpersonal dissonance caused by strains in professional or personal relationships or caused by differences based on the mentor and mentees' interests, race, gender, etc. also present other possible interpersonal challenges to mentoring relationships; however, these conflicts were infrequently alluded to by participants. Dissonance from misalignment between mentors' mentoring styles and mentees' preferences in working habits could cause dissonance is also reflected in mentorship literature, particularly in engineering disciplines (e.g., Barnes & Austin 2009). However, as observed with Marie's experience with her disorganized mentee, these differences can be opportunities for reflection or growth.

Mentorship Roles connect directly to prior studies of challenges involving mid-career transitions into EER. Technical needs, including understanding theories, models, and frameworks in EER research, and learning quantitative and qualitative techniques are common themes in the literature (e.g., Borrego 2007; Finelli & Millunchick 2013). The discussion of our complimentary manuscript (Mirabelli et al. 2023) includes several bulleted examples of resources that facilitate mid-career transitions to EER for engineering faculty.

CHARACTERISTICS OF MENTORS AND MENTEES

Mentors and mentees experienced personal and professional satisfaction when mentee learning was successful and when reflection about mentorship occurred. Participants with compassion for students and deep interests in EER content experienced the most satisfaction while conducting NSF RIEF grants. This satisfaction applied to both mentors and mentees.

ACTIONABLE MENTORING STRATEGIES

We suggest some of the following behaviors and habits, with an example or two from the broad mentorship literature, for faculty entering new mentoring relationships as either mentees or mentors. These tips will be helpful for new EER researchers, future EER mentors, and program officers supporting mentorship programs supporting mentee development as an EER researcher.

- Co-learning: Both the mentee and mentor should be learning from each other and their relationship should include mutualism and co-beneficence (e.g., Aderibigbe et al. 2014).
- Discuss mentoring preferences, mentoring mechanics, and preferred mentoring styles early on. Consider power dynamics between mentors and mentees and how these may influence the mentoring relationship (e.g., Tuma & Dolan 2024).
- Flexible mentoring style: Both the mentee and mentor should be open to adjusting the mentoring style to find a good fit for their needs (e.g., van Ginkel et al. 2015).
- Take part in a conflict resolution workshop. People have different conflict management styles. It can be helpful to recognize your own and others conflict styles to better reach solutions and communicate effectively (e.g., Brockman et al. 2010).

FUTURE AND SUPPLEMENTARY WORK

The ways in which first-year NSF RIEF mentees describe their transition and entry into EER through the NSF RIEF award was a significant finding of this larger work. Our second, complementary paper describes the career transition, the process by which mentees designed their NSF RIEF proposals and how the projects support their sustained engagement with the EER community (Mirabelli et al. 2023).

Future and ongoing work to create communities of practice to support NSF RIEF grantees and other novice members of EER spaces is underway, such as the *Journal of Engineering Education*'s mentored reviewer program (Benson et al. 2021; Jensen et al. 2022). Further research to understand the motivations and barriers for entering EER (Ko et al. 2021), either in traditional research pipelines or career transitions will help expand and diversify the community. We recommend that such work consider using frameworks such as CAM to influence its development, such that experiences of mentorship, communities of practice, or other forms of training can be more thoughtfully considered.

CONCLUSIONS

The themes identified in this work can be readily considered by faculty interested in mid-career transitions to EER or faculty interested in facilitating colleagues' entry into the EER field. Faculty interested in pursuing NSF RIEF awards can consider the mentorship mechanics between potential co-grantees when determining what factors may influence the development or quality of the relationship. Consideration and open discussion should be had between mentee and mentor about mentorship roles and mentorship characteristics. These discussions should include preferred mentorship style, goals and priorities, and motivations for research and collaboration. They should also include factual preferences related to team compositions and institutional locations.

Further, the ways in which participants overcame uncomfortable situations with power dynamics in their mentorship supports encouragement for mentoring relationships to not be strictly hierarchical. A common view of mentorship is "top down", where "senior" people mentor "junior" people, or mentors interact with protégés, but there are ways for us all to contribute to mentoring and strengthening our community. Mentors gain both knowledge and satisfaction from mentoring relationships and the structure of mentoring relationships within teams is more complicated than a single chain of people.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **RIEF Mentorship Paper Supplemental Materials 1.** RIEF Mentee/Mentor Interview Protocols. DOI: https://doi.org/10.21061/see.155.s1
- **RIEF Mentorship Paper Supplemental Materials 2.** RIEF Mentorship Coding Flowchart. DOI: https://doi.org/10.21061/see.155.s2
- **RIEF Mentorship Paper Supplemental Materials 3.** RIEF Mentor Codebook. DOI: https://doi.org/10.21061/see.155.s3

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COMPETING INTERESTS

The authors have no competing interests to declare.

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