Martin *et al.*
International Journal of STEM Education (2024) 11:13
https://doi.org/10.1186/s40594-024-00473-8

International Journal of STEM Education

RESEARCH

Open Access

Using collaborative autoethnography to investigate mentoring relationships for novice engineering education researchers

Julie P. Martin[1*], Deepthi E. Suresh[2] and Paul A. Jensen[2]

Abstract

Background The National Science Foundation Research Initiation in Engineering Formation (RIEF) program aims to increase research capacity in the field by providing funding for technical engineering faculty to learn to conduct engineering education research through mentorship by an experienced social science researcher. We use collaborative autoethnography to study the tripartite RIEF mentoring relationship between Julie, an experienced engineering education researcher, and two novice education researchers who have backgrounds in biomedical engineering—Paul, a biomedical engineering faculty member and major professor to the second novice, Deepthi, a graduate student. We ground our work in the cognitive apprenticeship model and Eby and colleagues' mentoring model.

Results Using data from written reflections and interviews, we explored the role of instrumental and psychosocial supports in our mentoring relationship. In particular, we noted how elements of cognitive apprenticeship such as scaffolding and gradual fading of instrumental supports helped Paul and Deepthi learn qualitative research skills that differed drastically from their biomedical engineering research expertise. We initially conceptualized our tripartite relationship as one where Julie mentored Paul and Paul subsequently mentored Deepthi. Ultimately, we realized that this model was unrealistic because Paul did not yet possess the social science research expertise to mentor another novice. As a result, we changed our model so that Julie mentored both Paul and Deepthi directly. While our mentoring relationship was overall very positive, it has included many moments of miscommunication and misunderstanding. We draw on Lent and Lopez's idea of relation-inferred self-efficacy to explain some of these missed opportunities for communication and understanding.

Conclusions This paper contributes to the literature on engineering education capacity building by studying mentoring as a mechanism to support technically trained researchers in learning to conduct engineering education research. Our initial mentoring model failed to take into account how challenging it is for mentees to make the paradigm shift from technical engineering to social science research and how that would affect Paul's ability to mentor Deepthi. Our experiences have implications for expanding research capacity because they raise practical and conceptual issues for experienced and novice engineering education researchers to consider as they form mentoring relationships.

Keywords Collaborative autoethnography, Mentoring, Faculty, Graduate student, Engineering education research, Research Initiation in Engineering Formation (RIEF)

*Correspondence:
Julie P. Martin
julie.martin@uga.edu
Full list of author information is available at the end of the article

Introduction

Research initiation projects contribute to capacity building in the field of engineering education research

Engineering education research (EER) is a rapidly expanding discipline that has quickly built research capacity in a short period. While the first PhD programs and departments were formed less than 20 years ago, the Engineering Education Community Resource wiki now identifies 56 universities with graduate programs in engineering or STEM education (Research in Engineering Education Network, n.d.). The field has also built research capacity by training traditional engineering faculty in social science research skills. Funding agencies, journals, and conferences have sponsored such trainings (Borrego et al., 2008; Jesiek et al., 2008). An early effort to this effect in the United States, including early efforts sponsored by the U.S. National Science Foundation (NSF), was the Rigorous Research in Engineering Education (2004–2006; Borrego, 2007).

Novice engineering education researchers must embrace a paradigm shift. Borrego (2007) describes this shift in terms of research steps that are implicit in technical engineering research but must be explicitly considered in social science research. These steps include "framing research questions with broad appeal", applying appropriate theories, "fully considering operationalization and measurement of constructs", learning to appreciate qualitative and mixed methods (in contrast with quantitative engineering methods), and working from an interdisciplinary perspective (Borrego, 2007, p. 91). The shift also requires novice engineering education researchers to be enculturated into a new research community (Borrego, 2007).

Making the necessary paradigm shift is likely to be different for EER students than for experienced engineering faculty learning to conduct EER for the first time. While graduate programs in engineering education generally require students to enter with a bachelor's or master's degree in a technical discipline, these students spend time taking foundational coursework, learning social science methodologies and methods, and being advised and/or mentored by experts in the field. Engineering faculty members who aim to learn EER skills do not have the advantage of coursework and other formal training experiences. In fact, the required paradigm shift and enculturation into EER may be harder for engineering faculty because the norms of technical research have been deeply ingrained in these individuals and they have spent their careers building networks in their technical research area. On the other hand, faculty who study a topic related to their technical expertise may be able to bring their lived engineering experience to the EER and the related application of social science methods in a unique way.

NSF has invested in building EER capacity via "research initiation" projects, which provide funding for engineering faculty to be mentored in conducting EER by an experienced social science researcher. The NSF's significant investment—about $23 million in the Research Initiation in Engineering Formation (RIEF) and its predecessor, the Research Initiation Grants in Engineering Education program—reflects the importance of mentored training experiences for engineering faculty for building research capacity (NSF, 2020). RIEF projects are funded for 2 years up to $200,000 (NSF, 2020). The grants require a technical engineering faculty member to propose a project inspired by their role as an engineering educator (NSF, 2020). Because NSF recognizes that engineering faculty as novice social science researchers, the program requires mentoring by an experienced social science researcher who must collaborate on the proposal submitted to the RIEF program. The proposal requires a robust research design and a mentoring plan, and proposal reviewers are instructed to give equal weight to both elements.

The requirements of the RIEF program leave a good deal up to the discretion of the faculty involved in the mentor–mentee relationship. The mentoring plan need not address the role of student trainees. Mentoring pairs are self-selected, the only requirement being that the mentee be a novice engineering education researcher and the mentor be an experienced member of the field with the purpose of learning EER skills. All other aspects of the RIEF program's mentoring relationship are left up to the mentor and mentee, and awardees are left to define and manage their mentoring relationship while simultaneously developing the research skills needed to complete the proposed project. There is no oversight of mentoring pairs after projects are funded.

Brief review of mentoring literature

Mentoring in the RIEF context is unique within the higher education mentoring literature

While the mentoring literature is vast (with hundreds of thousands of articles published in the last four decades), researchers generally agree on what characterizes a mentoring relationship. A recent National Academies of Sciences, Engineering, and Medicine report (2019) defined mentorship as "a professional, working alliance in which individuals work together over time to support the personal and professional growth, development, and success of the relational partners through the provision of career and psychosocial support" (p. 2). Mentees, also called protégés, are less experienced, often younger, individuals who learn from a mentor's experience, knowledge, and wisdom (Mullen & Klimaitis, 2021), with the goal of

"learning to operate more effectively without the support and guidance of the mentor" (Eby et al., 2013, p. 443). Eby and colleagues pointed out that while mentors and protégés should have "an emotional bond", mentoring relationships differ from other types of close relationships in that mentors serve as "a role model", have greater experience than the protégé, and provide "guidance" to the protégé. Likewise, they noted that mentors should be "tailoring the support provided to the unique developmental needs of the protégé" (Eby et al., 2013, p. 443), an element Jacobi (1991) also emphasized (p. 525). In higher educational settings, mentors typically provide instrumental support (i.e., research training) and psychosocial support (i.e., encouragement), resulting in mentee outcomes such as higher levels of persistence, academic achievement, identity development, scholarly productivity, professional development, and psychological health (Eby et al., 2013).

Mentoring is important at all levels of STEM higher education. Among undergraduates, mentoring promotes science identity and career paths (Atkins et al., 2020; Robnett et al., 2018), career satisfaction (McCallum et al., 2018), social capital development (Martin et al., 2020; Mondisa, 2020), and retention (Zaniewski & Reinholz, 2016). Studies of high-quality mentoring of undergraduates during research experiences show it promotes research skills and research self-efficacy (Ahn & Cox, 2016; Byars-Winston et al., 2015). In graduate school, mentoring helps STEM students navigate expectations, build community, reduce feelings of isolation, learn academic success strategies, build confidence, and become more competitive in the job market (Moreira et al., 2019). Mentoring helps postdoctoral scholars to develop increased efficacy for securing academic positions and to learn professional skills needed in the professoriate such as grantsmanship (Yadav & Seals, 2019).

Mentoring in professional contexts is intended to help the mentee advance their career through personal and professional development. Workplace mentors provide instrumental and psychosocial supports and form trusting, interpersonal relationships with mentees (Eby et al., 2013). Mentors often provide instrumental actions such as orientation to the organization, professional socialization, sponsorship, exposure, and visibility (Allen et al., 2004; Eby et al., 2013) and also provide psychosocial supports such as acceptance and confirmation (Allen et al., 2004). Mentees enjoy numerous intangible and tangible career benefits, including career satisfaction and commitment, stronger intentions to stay with the organization, and higher compensation and promotions (Allen et al., 2004).

Academic workplace mentoring is a specific type of professional mentoring. In the academy, workplace mentoring often includes faculty discussing teaching, service, and research responsibilities; work-life balance; promotion processes; and career progression with a more experienced peer (Nick et al., 2012; Shieh & Cullen, 2019; Thomas et al., 2015). Academic workplace mentoring can be formal or informal, with assigned or self-selected mentor–mentee pairs (Lunsford et al., 2017, p. 326). Mentees gain job skills and confidence and improve their productivity, which results in higher career satisfaction and leads to promotion and retention (Lunsford et al., 2017). On the other hand, the absence of mentoring, mismatched mentor pairs, or negative experiences with a mentor can result in faculty mentees making "significant career miscalculations" that negatively affect their career advancement (Espino & Zambrana, 2019, p. 477).

We know little about the unique case of RIEF mentoring relationships, which contain elements of academic mentoring and workplace mentoring. In one of the few studies specifically investigating RIEF mentoring relationships, Mirabelli and colleagues (2020) found that RIEF mentorship can help mentees become familiar with the EER literature, increase their likelihood of making meaningful contributions to the field, and facilitate their connection to the EER community. However, the same study noted that when mentors and mentees held differing academic ranks this can create complex power dynamics and that many RIEF mentoring relationships involve mentors and mentees who are not co-located, which creates challenges (Mirabelli et al., 2020). Nonetheless it was clear that RIEF mentoring addresses some of the challenges of entering a new discipline outlined by Borrego (2007), including the need to make a paradigm shift from engineering to the social sciences. Jensen and colleagues (2023) found that RIEF mentees described making the paradigm shift as feeling like a graduate student (novice) again with associated imposter syndrome (2023, p. 101).

Yet understanding how RIEF relationships positively promote enculturation and address the requisite paradigm shift will help the EER community grow additional capacity by helping mentors and mentees intentionally design their relationship and its activities. To this end, our study focuses on the mentoring relationship made possible by funding from the NSF RIEF program between an experienced engineering education researcher and two novice researchers as they move from biomedical engineering to EER. As Mirabelli and colleagues (2020) noted, such transitions offer a unique "opportunity to study the path from novice to expert from the context of apprentices who already possess scaffolds to be expert researchers" (p. 9), and thus this study has broad application to mentoring research.

We use autoethnographic methods to illuminate intra- and inter-personal struggles with the paradigm shift from

engineering to social science research as well as the novice researchers' enculturation in the EER community. To the best of our knowledge, our work is the first to use a collaborative autoethnographic methodology to study research mentorship in engineering education. Thus we hope that in addition to its other offerings this study will help other engineering education researchers design collaborative autoethnographic mentoring studies by considering our successes as well as our missteps.

Research questions

- In what ways do RIEF mentors support their mentees in learning engineering education research?
- How do RIEF awardees build an effective mentoring model that includes faculty and student mentees who are making a paradigm shift to social science research?

Mentoring theoretical frameworks: cognitive apprenticeship and Eby et al.'s mentoring model

The cognitive apprenticeship model is rooted in social learning theory and is characterized by *guided participation* of the mentee by the mentor (Dennen & Burner, 2008) with several key elements (Table 1). In cognitive apprenticeship, mentees initially observe processes through *legitimate peripheral participation* and eventually move to active participation in authentic tasks, which is called *situatedness* or *situated learning* (Dennen & Burner, 2008; Lave & Wenger, 1991). To help the mentee achieve the shift from peripheral participation to active participation, the mentor makes implicit expert processes explicit to the mentee in ways that allow the mentee to observe, reflect on, and then practice them (Dennen & Burner, 2008). Mentors demonstrate their thought processes through *modeling* tasks with increasing complexity, guiding the mentee through their *zone of proximal development*, or the "space between a learner's current skill level and the next skill level that the learner cannot reach without assistance" (Dennen & Burner, 2008, p. 426). Modeling can be behavioral, where the mentee observes the mentor conducting a specific action, or cognitive, where the mentee observes the mentor demonstrating the reasoning behind the action (Dennen & Burner, 2008). The process of modeling is considered most effective when it is explicit (Cooper, 1999). Mentees become more adept as they learn to complete discrete tasks and incorporate mentor feedback, and their zone of proximal development naturally shifts.

Mentors use *scaffolding* combined with gradual withdrawal, or *fading*, as mentees become more independent (Dennen & Burner, 2008). For example, scaffolding may take the form of the mentor providing hints and feedback to the mentee while the mentee performs an authentic task (Collins et al., 1989). As a mentee becomes more adept and their zone of proximal development shifts, the mentor might engage in fading by providing fewer hints and less frequent feedback (Collins et al., 1989).

Community of practice is another hallmark of cognitive apprenticeship. A community of practice is a group of people who "engage in and identify themselves with a common practice" (Dennen & Burner, 2008, p. 428). As mentors model expert processes for mentees and mentees shift their zone of proximal development, mentees move from the periphery to becoming fully participating members of the community of practice (Dennen & Burner, 2008).

Eby and colleagues' (2013) process-oriented model of mentoring includes *instrumental support* (information and skills provided by the mentor), *psychosocial support* (e.g., encouragement), and *relationship quality* (satisfaction with the relationship). Instrumental and psychosocial supports help create a mentor–mentee interpersonal bond characterized by emotional connectedness and

Table 1 Elements of cognitive apprenticeship

Cognitive apprenticeship term	Definition *Taken verbatim from* Dennen and Burner (2008, p. 427–428)
Situatedness (also called situated learning)	Active learning that takes place in an authentic task or setting (p. 428)
Legitimate peripheral participation	Observing a holistic process from the periphery (p. 428)
Guided participation	The social element of cognitive apprenticeship (p. 428)
Scaffolding	Support that is provided to assist learners in reaching skill levels beyond their current abilities; essential to scaffolding is fading the support in response to the learners' acquisition of the skill that is being supported (p. 426)
Modeling	Demonstrating thought processes (p. 426)
Zone of proximal development	A dynamic region that is just beyond the learner's current ability level (p. 426). Note that the zone of proximal development moves with the learner's development
Community of practice	A group of people—either formally or informally bound—who engage in and identify themselves with a common practice (p. 428)

trust. The three elements reinforce each other. Greater instrumental supports lead to the mentee perceiving higher psychosocial support and higher relationship quality. And, as relationship quality increases, the mentor is likely to provide more instrumental and psychosocial supports. The processes portion of the model is depicted in Fig. 1.

We used these theoretical frameworks to guide the study's data collection and analysis. We developed reflection prompts and interview questions based on the theories and developed codes (reported in Table 3), which we used to analyze the data.

The nature of our mentoring relationship

Following the advice of Clutterbuck (2013), we (throughout this paper, we use "we" when it refers to all three of us and our names when it refers to any subset of us three) aim to explicate the nature of the overarching mentoring program and our mentoring relationship, our working definition of mentoring, and our expected outcomes.

In the mentoring plan required as part of the proposal, Paul and Julie chose to reflect on our intentions and motivations for entering the mentoring relationship during the writing of the research proposal. We read mentoring literature and drew on Eby et al.'s (2013) mentoring model and the cognitive apprenticeship model (Dennen & Burner, 2008) to access a common language with which to characterize aspects of the mentoring relationship.

We describe our relationship using five of Mullen and Klimaitis's (2021) nine (nonexclusive) mentoring types. In some ways, our relationship represented *formal* mentoring because it was a required component of the RIEF program. In other ways, it falls within the informal in that our pairing was self-directed and guided only by a mentoring plan of our own choosing. We are not co-located and rely primarily on email and Zoom for our communications, so it also falls under *electronic* mentoring. Our relationship can also be characterized as *multilevel* and *diverse* mentoring because it consists of a tenured faculty member in engineering education, a pre-tenure faculty member in biomedical engineering, and later, a graduate student in biomedical engineering doing EER.

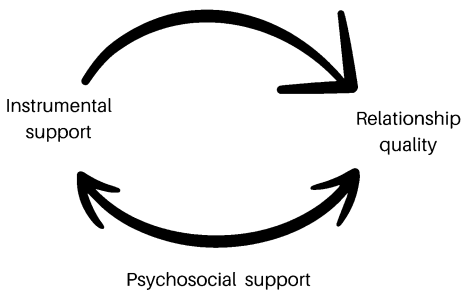

Fig. 1 Process portion of Eby et al.'s mentoring framework, adapted from Eby et al. (2013)

The initial contact between Paul and Julie was in November 2019, after which we spent several months writing the research proposal, including the mentoring plan, together. Our plan included meeting weekly by Zoom throughout the course of the RIEF research project; visiting each other's universities to give seminars and meet with colleagues; attending conferences together to help Paul develop a network of engineering education researchers; and Paul becoming an honorary member of Julie's research group, virtually attending their regular meetings. We established general plans for modes and timing of our communication. As one of our first joint activities, we used the StrengthsFinder tool (Gallup, n.d.) to explore our personalities and work styles. Julie provided Paul with readings relevant to the methods and theory used in the research proposal, and we made plans to study our mentoring relationship via autoethnography. It was approximately six months from submission of our proposal until we heard that NSF had selected our proposal for funding. The NSF funding began in September 2020, and we began meeting weekly by video conference.

By the time the funding started, about six months after the onset of the COVID-19 pandemic, our universities had disallowed travel, and we were each teaching online in the Fall semester of 2020. Since we had always planned that most communications would be remote, this changed little in our interactions. However, plans for us to travel to each other's universities to give seminars, to attend the American Society for Engineering Education annual conference in person, and to take an in-person qualitative research short course together in another state in 2020 and 2021 had to be shelved. As well, our original plan was to meet in person during the first months of the project and we were not able to meet in person for more than 20 months. The continuation of the pandemic from 2020 into 2021 also had ramifications for conducting the research project funded by the RIEF program. Because it was initially difficult to recruit student participants, we focused our energy on the autoethnographic portion of our work together, following a suggestion made by Roy and Uekusa (2020).

Although we included funds in the budget to hire a graduate research assistant from Paul's biomedical engineering research group to work on the project (Deepthi), the proposal's mentoring plan did not include her as a mentee, in part because NSF did not require it. We initially conceptualized our tripartite, multilayered relationship as depicted in Fig. 2. Because Paul was Deepthi's major advisor and provided biomedical research mentoring as well as general career mentoring, we had assumed

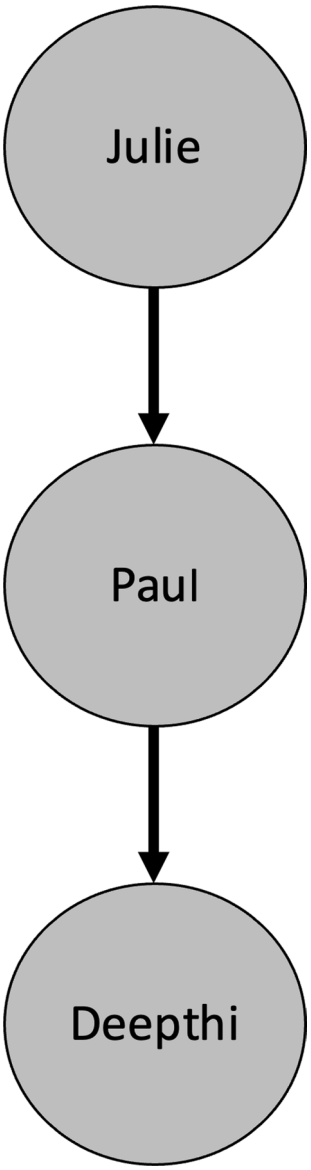

Fig. 2 Initial mentoring model. Julie mentors Paul, who in turn mentors Deepthi

that his role as her mentor would translate to the new EER project.

Author positionality

Following Secules et al.'s (2021) direction to the EER community, we reflected on how our identities and motivations for this project have influenced the way we carried out the work. Collectively, we are drawn to the topic of mentoring because mentoring has played an important role in each of our personal and professional lives, and because we have had both positive and less-positive experiences with academic mentoring. We chose autoethnography to study our relationship because we believe that studying ourselves from an emic (insider) perspective yields unique insights that an outside researcher could not accomplish. Collaborative autoethnography also appeals to us as a methodology because we believe that deeply reflecting on our own mentoring experiences has the potential to help us improve our current and future mentoring relationships. Therefore, we approached data collection (written reflections and interviews) with a willingness to be vulnerable, although we ultimately discovered that our vulnerability had its limits. As described in the Methodology section, we were initially quite hesitant to share our feelings reflected in those data with each other. That initial hesitancy reflected, in part, the power dynamics that we could not completely dispense with even though we aimed to share power among our team, and when we finally shared our reflections and interview transcripts and began to analyze our data corpus, it lessened. The transformative learning each of us experienced as trust among the team grew and we each reflected deeply on our own current, past, and future mentoring roles during the data analysis was another advantage of our methodology. Based on this experience, we have carefully considered how to communicate our work and have determined when to exhibit vulnerability in our findings in the hope that our mistakes and shortcomings will help others improve their own mentoring relationships. Our individual statements below describe additional individual motivations for entering the mentoring relationship we are studying.

Julie: Formally and informally mentoring graduate students, postdocs, and early-career faculty is one of the greatest joys of my career, and I knew that mentoring Paul would be just as rewarding. I also knew that it would stretch me to improve and reflect on my mentoring. In the two years prior to writing the RIEF proposal with PauI, I was the NSF program officer for the program, where I ran RIEF review panels and made awards. This caused me to develop a powerful belief in the program and commitment to it that prompted me to want to participate.

Paul: I had completed about half of my junior faculty years when I started the RIEF project. Because I am established in bioengineering with talented graduate students, external funding, and publications, I feel secure in my technical research skills and knew I could be open about my lack of EER expertise and my developmental level in the field. I knew this openness would be a good foundation for an effective RIEF project. I was (and am) excited about EER research—not least because I want to be able to translate the discoveries from the EER project into my teaching—and was confident that project participation would expand the skills I need.

Deepthi: During my first several years of graduate work in Paul's research lab, I conducted research solely in the field of bioengineering, where Paul was very familiar with the skills I need to be successful. Paul and I shifted into engineering education at the same time, which means that the dynamic was be different. Participating as the graduate research assistant for the RIEF project is giving me the transferrable skills I need to conduct an EER master's thesis project. I also was excited about the RIEF project because learning more about mentor–mentee relationships will improve my near-peer mentoring and mentoring with my future students.

Methodology

We used a collaborative autoethnographic research design to study our mentoring relationship. Autoethnography is a qualitative methodology that "seeks to describe and systematically analyze (graphy) personal experience (auto) in order to understand cultural experience (ethno)" (Ellis et al., 2011, p. 273). In collaborative autoethnography, a team of researchers work together to investigate their personal experiences for a common purpose (Chang et al., 2013). Chang and colleagues (2013) described the benefits of collaborative autoethnography as "(1) collective exploration of researcher subjectivity; (2) power-sharing among researcher-participants; (3) efficiency and enrichment of the research process; (4) deeper learning about self and other; and (5) community building" (p. 25). Collaborative autoethnographic studies often involve lengthy, sometimes multi-year time periods of data collection and analysis (Roy & Uekusa, 2020).

Collaborative autoethnography's potential to support transformative learning, such as we experienced, is one of its advantages. Blalock and Akehi describe transformative learning as "ongoing dialogue of transformative experiences with self, others, and the world" (2018, p. 93) that result in "changes in mind-sets [that] shift how individuals see the world" (p. 91). These scholars posit that collaborative autoethnography engages the "messy and vulnerable processes" (p.95). They also point out that topics related to identity development, such as Paul and Deepthi's identity as engineering education researchers, often foster transformative learning experiences.

In recent years, engineering education researchers have used autoethnography and collaborative autoethnography in a limited number of other contexts (e.g., Brewer et al., 2015; Colquitt, 2021; Haverkamp et al., 2019; Holly, 2020, 2021; Martin & Garza, 2020; Seniuk Cicek et al., 2020; Vega, 2021). Burt and colleagues (2023) recently used collaborative autoethnography to investigate how a principal investigator supervised a revolving group of 23 students over a period of four years. While this context is tangentially related to mentoring, their study focused on the expert researcher's supervisory practices rather than on research mentoring relationships (Burt et al., 2023). Collaborative autoethnography has also been used in higher education more broadly to study mentoring in other contexts such as doctoral education and transitions to early career faculty life (e.g., Duffy et al., 2018; Malin & Hackmann, 2016; Serafini et al., 2023; Teasdell et al., 2021). We believe our study is the first to use a collaborative autoethnographic methodology to study research mentorship in engineering education.

Quality

We followed Patton's (2014) quality considerations for autoethnography, contemplating how reflexivity, substantive contribution, esthetic merit, impact, and expression of a reality apply to our study. In addition, we considered Hughes and Pennington's (2016) relational ethics criteria for autoethnography. We provide a summary of how we applied these criteria in our study in Table 2.

Data collection

Our collaborative autoethnography employed a concurrent collaboration mode (Chang et al., 2013) that spanned the initial 24 months of the funded RIEF project that brought us together and four months of the no-cost extension granted by NSF, for a total time period of 30 months taking place from September 2020 to February 2023.

During this period, we mixed individual and collective activities that included the following data types: archival materials, self-reflections and personal memories, self-analysis, and interviews (Chang et al., 2013). We utilized archival materials in the form of our NSF proposal and annual reports. In particular, we used our initial mentoring plan as well as Paul's and Julie's reflective statements about their motivations for entering the mentoring relationship, our goals, and mentoring approaches from the submitted proposal. We wrote reflective journal entries every couple of months, though we did not share them with each other until we began the data analysis in January 2022; these documents totaled 52 pages. We employed a "sounding board" in the form of a fourth researcher who conducted individual and joint interviews (Chang et al., 2013, p. 58). This researcher did not add their lived experience to our dataset but rather asked probing questions that helped us each connect our individual experience to those of the others. We chose the critical incident interviewing method in order to promote rich, thick description in our findings (Flannagan, 1954). The interviewer used the technique to draw out specific examples of significant events that occurred during the course of our project, asking follow-up questions as needed to get to the specific moments in time

Table 2 Quality criteria for autoethnography and application in our study

Quality criterion	Application in our study
Reflexivity	We included first-person positionality to explicate our current positions in the EER community and foreground the power differentials in our mentoring relationships. Our statements of goals provide additional perspective on the mentoring relationships among us
Substantial contribution	We grounded the study in relevant frameworks and demonstrated alignment between theoretical constructs and our reality. We included the perspectives of both mentor and mentees in our mentoring triad
Esthetic merit	We use "esthetic" and "evocative" thick descriptions of our shared experiences and our individual responses to them (Ellis et al., 2011, p. 277). We trimmed a long list of critical incidents to a digestible list of three critical incidents for publication
Impact	While impact is best judged post-publication, we anticipate that insights generated from our autoethnographic product may help mentors and mentees deepen their relationships through consideration of how the other perceives shared experiences and subsequent improved communication
Expression of a reality	We present our findings via a narrative describing critical incidents that feel credible because we have included multiple (and sometimes conflicting) viewpoints, misunderstandings, and even awkward moments in our relationships
Relational ethics	We were "cognizant of the promise and potential problems" (Hughes & Pennington, 2016, p. 24) of revealing sometimes conflicting viewpoints, misunderstandings, and awkward moments, and discussed our comfort level with these revelations multiple times during the data analysis (process) and writing phases (product) of the project. We intentionally omitted incidents from the paper that one or more of us felt violated privacy or that we were uncomfortable making public. We chose not to include proper nouns for people or academic units where the events we relayed might paint them in an unfavorable light

This table was previously published (Martin et al., 2022) and is reproduced with permission

that each interviewee associated with their more general response. The interviews totaled 4 h 52 min and comprised 82 transcript pages.

Analysis

We began the analysis by each reading and reflecting on our own written reflections and interview transcripts. We combined the long-standing notion of *critical incidents* in qualitative research [defined by Grove and Fisk (1997) as "one that makes a significant contribution, either positively or negatively, to an activity or phenomenon", p. 67] with autoethnographic *epiphanies*, which Ellis and colleagues (2011) defined as "remembered moments perceived to have significantly impacted the trajectory of a person's life" (p. 275). We defined critical incidents as an event or process to which we ascribed importance with respect to the RIEF project and the mentoring relationship, rather than our lives in general, and acknowledged that they could last weeks or months. We independently reviewed our own written reflections and transcripts from the interviews with the sounding board member of our research team, and from there developed lists of the most personally salient incidents of our mentoring relationship and the most salient quotes or passages of reflection text related to each incident by identifying quotes or text from our own reflections and interviews. We familiarized ourselves with each other's written reflections and interview transcripts and combined our individual lists into a larger, collaborative list with quotes and reflection text retained. Rather than capturing a single moment in time, our critical incidents consisted of longer time periods that lasted weeks or months. We noted overlaps in our individually defined critical incidents, and we had many conversations where we compared and contrasted our written and verbal recollections of events, drew analytic schematics, and made tables of critical incidents. These efforts yielded a conference paper (Martin et al., 2022), after which we continued to refine our list of critical incidents to a digestible list for journal publication by considering only those that (1) reflected the ways in which mentoring helped Paul and/or Deepthi learn EER skills and (2) contributed to the evolution of our mentoring relationship. We eventually scoped this article to include the three incidents that best represented these two criteria. In writing the findings section by critical incident, we followed the autoethnographic practice of writing about epiphanies in order to evoke esthetic merit and represent multiple expressions of reality described in Table 1 (Patton, 2014) and aimed to capture a coherent narrative of the trajectory of our relationship.

We included the most relevant raw data—that is, text from the reflections, interviews, and grant documents. We then mapped aspects of each critical incident to a priori codes from our guiding frameworks; those codes are shown in Table 3 and appear in bold font throughout the section.

Results and discussion

A timeline of critical incidents and key points in our relationship is depicted in Fig. 3.

Table 3 A priori codes from Eby et al.'s (2013) mentoring model and the cognitive apprenticeship model (Dennen & Burner, 2008)

A priori codes	
A. Eby et al.'s mentoring model	**B. Cognitive apprenticeship model**
1. Instrumental supports 2. Expressive action (psychosocial support) 3. Relationship quality	4. Situatedness (situated learning) 5. Legitimate peripheral participation 6. Guided participation Scaffolding Modeling Zone of proximal development (ZPD) 7. Community of practice

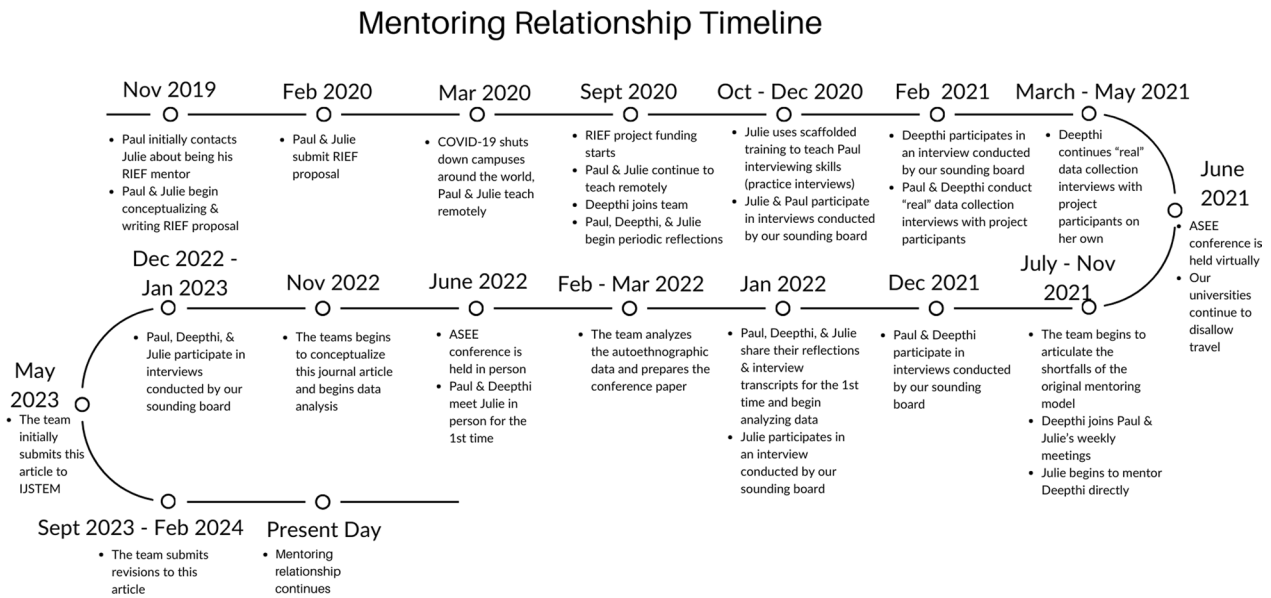

Fig. 3 Mentoring relationship timeline

Critical incident 1: Paul and Deepthi learn EER interviewing skills

Our funded RIEF project design used interviews with students, faculty, and working engineers as the primary method of data collection. Julie provided scaffolded training for conducting interviews at the beginning of our collaboration. She designed Paul's interview training to be a low-stakes exercise by mentoring him in conducting several practice interviews that would not become part of the project's data corpus. At this time, we were operating under our initial mentoring model (Fig. 2) and Deepthi did not participate in these practice interviews. Since Paul had no prior experience interviewing research participants, he reflected on the concept of using interviews as a qualitative research method when he said, "I'm really excited. I really want to learn this. It seems like magic. It seems like a superpower to be able to [conduct interviews]." [Paul's November 2020 interview].

Julie designed the practice interviews to be an authentic task (situated learning)—one where Paul was legitimately conducting interviews with increasing levels of responsibility. The practice interviews moved Paul from legitimate peripheral participation as an observer with a small role in the first two interviews to guided participation. This aligns with Dennen's (2013, p. 816) description of modeling as "demonstration followed by imitation". Imitation is not as simple as mimicry (Tharp & Gallimore, 1988), but rather is characterized by the learner adopting similar strategies in related contexts (p. 816). This approach was effective because each step of the scaffolding stretched Paul beyond his zone of proximal development—first through his learning to ask questions of interview participants, then by his leading the interview questioning, then by his conducting interviews without Julie present.

Prior to the practice interviews, Julie shared resources about types of interviews and interviewing techniques, a type of instrumental support, before Paul participated in the authentic task of watching Julie and conducting practice interviews (situatedness/modeling). During the first

practice interview, she realized that those materials were of limited use. She later recounted this during an interview for this autoethnography,

> *I noticed . . . that some of the stuff that I was sending didn't seem to be particularly useful, . . . because [human subjects] research is different in real life than how you might plan it out. [Julie's January 2022 interview]*

In her December 2020 reflection she wrote: "[It] was definitely the case [that the interviews we conducted were not textbook]. Yeah, what I should have told [Paul] is to throw the textbook out and hang on for a wild ride." In debriefing after the practice interviews Julie and Paul would laugh about how the "textbook training" she had provided prior to situatedness of the authentic task of conducting interviews turned out to be of limited use.

Paul discussed the scaffolded training in his January 2021 reflection, writing, "The idea of practice interviews was great. I wouldn't have thought of it. We don't do practice experiments in the biomedical engineering lab."

Julie's gradually decreasing role and feedback during the practice interviews and debriefs is consistent with faded scaffolding as Paul gained independence as an interviewer (Collins et al., 1989). Her reflections on the process were as follows:

> *We've conducted two [interviews] with me as the lead and Paul asking follow-ups, then debriefing and discussing both the content of the interview and how it relates to [the theory], as well as pointers and discussion about asking follow-up questions that keep the interview on track. . . Later this week . . . we are switching roles. Paul is going to lead and I'm going to ask follow-up questions, or as we joked in our last meeting, I'm going to "bail him out". [Julie's December 2020 reflection]*

The joke about Julie being present to "bail him out" if he failed is an indication of the guided participation and faded scaffolding elements of the training process. Paul was gradually developing qualitative research skills: in order to conduct interviews on his own, he would eventually need to simultaneously follow the semi-structured interview guide, develop meaningful follow-up questions on the spot, and mentally map participants' responses to the guiding theoretical framework so he knew when participants were provided data that would answer the research question.

Paul's thoughts about the practice interviews were as follows:

> *[T]he interviews were surprising. I guess I expected them to be more difficult because of mechanical issues [e.g., asking questions clearly, or getting participants to talk]. They flowed pretty well, but . . . now I'm concerned that other interviewees won't be so responsive/helpful, and there isn't much I can do about it. [Paul's January 2021 reflection]*

Paul and Julie debriefed together after each step in the process. Paul asked questions about technique and together they mapped the data that had been gathered to the guiding theoretical framework for the RIEF project. They discussed what each felt went well and Julie offered suggestions for next time. Julie reflected on this process:

> *The debriefs between interviews seemed to really help him/us reflect on how things went and what to do next time. . . We talked about how to focus questions on the theoretical aspects and I suggested having the [social cognitive theory] framework diagram [we are using for the RIEF study] printed out. [Julie's January 2021 reflection]*

In interviews for this paper conducted by our sounding board, Julie and Paul both agreed that the instrumental support of scaffolded training with fading support was effective. Paul described it as "definitely constructive", writing: "I think I'm ready to do an interview on my own; I certainly could if there was no other option. I guess it's one of those things you just need to do" [Paul's January 2021 reflection]. Paul compared his experience as a research mentee engaging in situated learning to the way research mentees in his discipline of biomedical engineering are trained. "I don't work alongside my students in the lab much, but maybe I should", he wrote in his January 2021 reflection.

At each debriefing, Julie also provided Paul with psychosocial support (expressive action), which involved pointing out Paul's developing strengths as an interviewer. She reflected on whether her feedback to Paul struck the right tone when she wrote, "A lot of my expressive support is done with humor (or at least I think it's humor). I'm interested to know if that makes him feel supported or [if] I should change my tone" [Julie's December 2020 reflection].

Paul's reflections written a month later reveal that he felt Julie's feedback was appropriate and that he enjoyed her humor: "Julie was great during the interviews. She pushed me enough, and sort of dropped me in with a 'no turning back' attitude. I think she read me well" [Paul's January 2021 reflection]. Paul's description of Julie "dropping him in" reveals that as a mentor she provided him a push such as those described in studies on cognitive apprenticeship. Because the two did not share their ongoing reflections until much later, Paul did not know that Julie had wondered about the effectiveness of her

expressive support, and Julie did not know that he found her feedback helpful until they each read the other's reflections almost a year later. When they found out, they both agreed that it would have been useful to be more open with each other at the time.

Nonetheless, Paul also expressed how the legitimate peripheral participation and guided participation in the practice interviews caused him some anxiety about conducting the "real" interviews that were the data collection mechanism for the funded project—a feeling of which Julie was not aware at the time.

> *I guess I'm supposed to feel better having interviewed someone, but I'm more anxious. It was different than I thought, in part because it depends so much on the personality of the interviewee. Who knows how the real interviews are going to go. [Paul's January 2021 reflection]*

Conducting the "real" interviews felt like a higher-stakes activity than doing the practice ones (an indication that Paul was operating in his zone of proximal development); but Paul's concern about the RIEF project participants not being as responsive as the practice interviewees was relieved once he started the actual data collection interviews, which went smoothly. Paul's reflection additionally revealed that he was also nervous about the data analysis phase, which he and Julie had not yet discussed. Paul attributed his concerns about analyzing the interviews to his biomedical engineering data analysis experience, where data analysis requires a different skill set than data collection. Paul worried that knowing how to collect EER data did not imply he that had the skills to analyze the same data.

After Julie completed the practice interviews with Paul, he expressed anxiety about subsequently training Deepthi in a similar manner. He wrote, "Julie was there for my practice interviews, so I should do the same with Deepthi... now I need to figure out how to mentor someone in EngEd [EER] techniques. That's terrifying" [Paul's January 2021 reflection]. Paul's word choice of "terrifying" indicates that he did not consider himself qualified to mentor Deepthi in data collection techniques for the project. Indeed, Julie had conducted hundreds of interviews over a period of nearly 20 years while Paul had only done a total of four or five interviews over a period of a few months. This was one indication that our mentoring model needed revision even though we were not aware of it at the time because we were not sharing our reflections with each other.

Deepthi was also anxious about conducting interviews on her own. She reflected:

> *I am really nervous about beginning the interviews. . . I have never even observed an interview, much less conducted one myself. I've mentioned this to Paul, but he could be busy or may just not know how to remedy this until we have interviews for me to observe. Either way, I definitely look forward to being trained on this so that I don't feel as overwhelmed. [Deepthi's March 2021 reflection]*

But despite the low-stakes training Paul had received from Julie, he did not arrange any practice sessions for Deepthi. Rather, Deepthi observed Paul conduct one "real" data collection interview, they debriefed, and then Deepthi began taking over more and more of the interviews herself. By the fourth interview, Paul was only observing Deepthi as she conducted the interview, participating minimally himself. From there, she did the rest on her own.

Paul, Deepthi, and Julie discussed why the training Paul provided for Deepthi resulted in her feeling ready to conduct interviews independently, as did the training Julie gave Paul, even though it was not in a similar low-stakes environment. Paul provided Deepthi with a situated learning experience, albeit one that was different from the scaffolded training interviews Julie organized for Paul. Rather than arranging practice sessions, he modeled the interviewing techniques he had learned from Julie—that is, demonstration followed by imitation (Dennen, 2013, p. 816). By having Deepthi observe and slowly participate in "real" interviews, Paul provided Deepthi with guided participation experiences. But Deepthi did not at first experience legitimate peripheral participation as Paul had. Instead, Paul provided her with an element of modeling and scaffolding.

Comparing Deepthi's reflections from March 2021 and June 2021 revealed that the guided participation and subsequent full participation still helped her gain a good deal of confidence:

> *It has really pushed me to be more self-sufficient and take more initiative, which is both fun and scary. . . I have worked with participants to set up and conduct interviews and will soon conduct my first solo interview. Paul's guidance and example has really helped me in this, and Paul has explained/relayed what he learned from Julie when she was teaching him how to do it. [Deepthi's June 2021 reflection]*

She further reflected on her lack of practice interviews when she said, "I've learned the value of just letting a mentee take over as that is one of the fastest ways to learn" [Deepthi's June 2021 reflection]. In some ways, the quick move from guided to full participation had a

similar effect as the "push" Paul felt from Julie during his scaffolded training.

Another explanation for Deepthi's confidence despite having less training than Paul may have to do with Julie's "expert blind spot" as a subject matter expert in EER when it came to training Paul (Nathan & Petrosino, 2003, p. 906). Here, we are using the phrase "expert blind spot" as it is commonly characterized among educators as the subject matter experts. Julie wrote that having done interviews for years made it difficult to remember the experience of a first-time interviewer and that the practice sessions helped her as much as Paul to realize what kinds of instruction he needed:

> *The first [interview] kind of blew him away. . . Seeing [Paul's] reaction to that was amusing because he was expecting something totally different—this pointed out what I have trouble seeing because it's been so long since I first did an interview and I've done so many over the years that I feel like I've seen it all (participants crying, etc.). It's easy to forget what the experience can be like as a newcomer and I appreciate being able to see these aspects of research through his eyes. [Julie's December 2020 reflection]*

Since Paul had the perspective of a novice, he instructed Deepthi by modeling some techniques that he learned from Julie. Ultimately, though, he was not able to offer legitimate peripheral participation experiences because he still lacked the expertise required to recognize a mentee's zone of proximal development in EER. His reflections also displayed low sense of self-efficacy in teaching EER practices (Lent & Lopez, 2002). The combination of these two circumstances led Paul to provide Deepthi with training outside of her zone of proximal development.

Importantly, in addition to the training he provided, Paul's psychosocial support also boosted Deepthi's confidence. She said in an interview for this paper, "Paul has been extremely encouraging and supportive about how I'm conducting the interviews."

Critical incident 2: We discuss challenges inherent in our original mentoring model

Our decision to submit a conference paper precipitated sharing our reflections and interview transcripts with each other in January 2022. This became a turning point in our transformative learning. We had been engaging in ongoing dialogues about Paul and Deepthi's transition to EER and our mentoring relationship, but reading each other's reflection and interview content gave us a deeper perspective on each other's previously unshared inner thoughts. Reading these documents revealed two unspoken tensions: the true degree of Paul's struggle to make the paradigm shift from engineering research to EER (a struggle that is common among technically trained researchers making the shift; Borrego, 2007), and Paul and Deepthi's misgivings about our initial model. Prior to the resulting "messy and vulnerable" conversations (Blalock & Akehi, 2018, p. 95), Julie was oblivious to both of these tensions. One particularly touchy topic of these conversations involved trust. We all agreed that while we trusted each other, we had withheld significant concerns during our prior discussions. As a result of direct discussion about trust and how we communicated, our trust in our relationship grew, which enabled us to be more honest with each other and address vulnerable topics in a more timely and sensitive manner.

For example, Paul characterized the paradigm shift as "intimidating" in one interview with our sounding board researcher. He said: "[I] originally [thought] that engineering education [research] largely followed the scientific method... and what I've come to realize is that everything I know about the scientific method... doesn't apply" [Paul's November 2020 interview].

He went on,

> *I thought being a scientist for however long [nine years] would really help me out. [I thought that] I've just got to learn to do science in a different context. And that's not at all the case and [I] find that a lot of—almost all the stuff I know about doing good engineering or doing good science, it doesn't apply at all. That's not how you structure things [in EER]. That's not how you think about [engineering education] problems. That's not how you design things to help answer those questions. No, it's starting over and learning a new way of thought. It's learning the new process. [Paul's November 2020 interview]*

Paul described the use of theory in EER as an example of one way he was unable to translate his prior ways of doing scientific research into learning the social science paradigm. He also referred to the challenge of learning to operationalize constructs:

> *You have to think about your theories. Your theories might be bunk and you've got to find a new theory, then you'll see if your theory works. You can make up your own theory. And then you [have] got to come up with an instrument. . . You've got to make sure you can measure the thing [you want to measure]. [Paul's November 2020 interview]*

Reflecting on how different EER is from what he is used to, Paul added, "Oh my goodness."

The challenges Paul encountered in the project aligned well with those outlined by Borrego (2007). He declared the transition to be "mind blowing", saying in

his November 2020 interview, "I don't really know what to make of it." During that interview he also said he felt "[t]hat I'm basically a first-year grad student in terms of what I understand about the field and need to be treated as such." Paul's assertion that he feels like a graduate student again aligns with statements by other RIEF mentees (Jensen et al., 2023). These comments reveal his shifting identity and mindset changes, and they are indicative of transformative learning.

Paul's struggle to shift research paradigms points to a challenge for RIEF mentors in identifying appropriate zones of proximal development for faculty mentees who are novice engineering education researchers with prior scientific training. While Julie was effective in scaffolding specific research tasks (such as interviewing techniques) in ways that helped Paul expand his zone of proximal development, mentoring a novice into a new research paradigm is more difficult than mentoring within an existing paradigm because of the magnitude of the necessitated shift. Comparing Paul's experience to Deepthi's suggests that established scholars may particularly struggle. Having completed doctoral work and become an expert in their discipline through years of membership in their disciplinary community of practice and lacking the benefit of coursework and a graduate student community of practice may be a disadvantage.

The university where Paul was employed and where Deepthi was pursuing her graduate work does not have an engineering education PhD program or a significant EER community, though they have since changed institutions. In-person activities from our original mentoring plan such as trips to visit each other's campuses and attend conferences together were cancelled or postponed due to COVID-19. These activities were meant to engage Paul in a wider community of practice of engineering education researchers. Instead, he virtually attended Julie's research group meetings and got to know her students and postdocs. However, the cancellation of in-person activities that could have cemented his research community membership meant that Paul relied almost exclusively on Julie to teach him everything he needed to know to conduct the RIEF-funded research study. And the use of the mentoring model depicted in Fig. 2 meant that we had not initially planned for a similar introduction to a community of practice for Deepthi.

Upon reading each other's reflections, we also discovered that Paul and Deepthi had been worried all along that our initial mentoring model was not working. Despite being an effective mentor to Deepthi in biomedical engineering, the difficulties Paul faced with making the paradigm shift to social science research meant that he was unable to provide the expert perspective needed to mentor Deepthi through a similar shift and to train her in techniques he had just learned himself. As early as two months into the project, November 2020, Paul's reflections referenced concerns about this. In an interview that same month for this paper Paul said:

> *Bringing a grad student into this will be, I don't know how that's going to go. . . That's going to be challenging because I am Deepthi's mentor, but I don't really know what I'm doing. Navigating that and making sure that Deepthi doesn't feel this is just ridiculous, like it's a circus going on—that, I think, will be a challenge. And I don't know, we, I don't think Julie and I really talked about how we involve Deepthi and how we how we handle that. So, I think that's our biggest issue. [Paul's November 2020 interview]*

Likewise, Paul and Julie discovered that Deepthi had written about her misgivings and frustrations with the initial mentoring model. For example, she wrote in her February 2021 reflection, "I've also encountered more questions of my own that sometimes Paul doesn't know the answers to, which teaches me that even my own mentor may not know everything." A couple months later, in April 2021, she wrote:

> *I learned lately that Paul and Julie meet more often than I realize. . . This makes me feel out of the loop and unaware of decisions being made on the project. . . I would find it really beneficial to be included in more of these discussions rather than each person relaying their own set of information to each other.*

While the three of us were actively discussing our mentoring relationship, we did not discuss Paul's concerns until 14 months later, in January 2022, when we finally shared our written reflections. We feel it is ironic that three people who were actively trying to understand their mentoring triad could have failed to recognize the discrepancies between the members' perspectives. We could have recognized the discrepancies if we had shared our reflections with each other earlier, and we began to do so from that point. Our failure to communicate was complicated by Paul's dual role of mentor and mentee. We all wanted to believe that Paul could mentor Deepthi in EER practices because he was already her major advisor in biomedical engineering, but though he had high levels of self-efficacy in mentoring, none of us accounted for his low, albeit increasing, levels of self-efficacy in engineering education (Lent & Lopez, 2002). Paul continued to mentor Deepthi regarding her biomedical engineering degree program and career plans, but worried about his ability to mentor in EER; meanwhile, Deepthi and Julie worried about overstepping the boundaries of the major advisor–student relationship. By acting under the assumption that

Paul's general mentoring capabilities meant he would be able to immediately mentor in engineering education, we did not provide Deepthi with the mentoring she needed from the beginning.

The combination of learning about Paul's struggles to shift research paradigms and the concerns he and Deepthi had about our initial mentoring model led us to decide that it had been misguided. It also made Julie feel that she should have realized the flaw in our plan from the beginning, which hurt her identity as a mentor. However, the vulnerable conversations we had as a result helped Julie grow as a mentor and contributed to a shift in her worldview about mentoring researchers who are experiencing similar paradigm shifts.

Together we arrived at a more realistic plan, depicted in Fig. 4: Julie would mentor Paul and Deepthi in EER. Paul remained Deepthi's major advisor and would continue to provide valuable expressive support for her EER. Julie would take over providing Deepthi with more instrumental supports for EER, with Paul contributing when his budding knowledge allowed.

But even as we revised the model in late 2021, we still did not fully understand why the original model had not worked. We then turned to existing literature on communication and relationship dynamics. Lent and Lopez (2002) illustrated the role of relational self-efficacy in how people interact in close relationships. They found that Person A chooses to interact with Person B based on (1) Person A's self-efficacy in the context of the activity, (2) Person A's perceptions of Person B's efficacy in that context (other-efficacy), and (3) Person A's beliefs about how Person B views Person A's efficacy (relation-inferred self-efficacy or RISE). In our case, the three of us each considered these three forms of efficacy when choosing our interactions. When we felt low self-efficacy, high other-efficacy, or low relation-inferred self-efficacy, we typically communicated less and assumed the others knew what they were doing. When those beliefs were reversed, we would step in, offer suggestions, and in general communicate more.

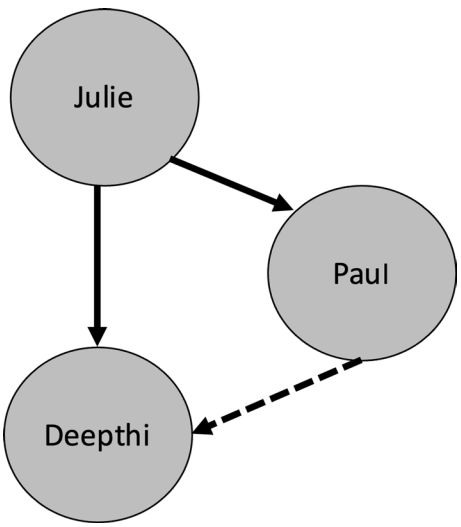

Fig. 4 Revised mentoring model

We felt we now understood why Julie did not want to overstep Paul's mentoring boundaries as Deepthi's major advisor, why Paul did not want to admit his mentoring concerns, and why Deepthi felt she was not originally receiving the instruction she needed. That is, we were privately evaluating our own self-efficacy, each team member's efficacy, and how each team member perceived their own efficacy. Because Julie perceived Paul's efficacy in mentoring to be high, she did not want to overextend her relationship by instructing his mentee. Similarly, because Paul had high levels of self-efficacy in mentoring and believed that Julie and Deepthi perceived him to be a good mentor, he did not want to acknowledge his concerns about mentoring Deepthi to them. And finally, because Deepthi perceived both Paul's and Julie's mentoring efficacy to be high, she was left wondering why there were gaps in her instruction. She never asked about it because she felt she must trust mentors with such high mentoring efficacy. The problem was, we had only considered each person's efficacy perceptions in the context of mentoring. If we had considered each other's efficacies in EER, we likely would have reached the conclusion that we needed to revise our mentoring model much earlier.

When we discussed how our relationship fit with Lent and Lopez's relational efficacy model, we noted a key difference: Paul and Julie considered not only the three forms of relational efficacy described in the model, but also their perception of their mentees' self-efficacy. At the same time neither considered their mentors' self-efficacy beliefs. Deepthi acted based on *her* perception of Paul's and Julie's efficacies, but typically did not consider *their* perception of their *self*-efficacy, except when it was expressed in reflections and discussions. Similarly, Paul did not consider *Julie's* self-efficacy beliefs when interacting with her, even though he considered *Deepthi's* self-efficacy beliefs when interacting with her. He acted in ways that he thought would help Deepthi's self-efficacy beliefs match how he perceived her efficacy. Julie, in turn, acted based on her perceptions of both Paul's and Deepthi's self-efficacies and efficacies. We believe this difference between Lent and Lopez's model and our relationship is the difference between a close relationship and a mentoring relationship. With the addition of this consideration their model was very helpful to us.

Our revised mentoring model also reflected aspects of Higgins and Kram's (2001) developmental network

concept. Rather than a mentee having a single career mentor (a single dyadic relationship), the developmental network model that views mentoring as a "multiple relationship phenomenon" (p. 264) that leverages a few mentors (developers). Given that Deepthi had existing strong ties with Paul (her primary developer) and developed strong ties with Julie, we see our new mentoring model as fitting the traditional developmental network typology characterized by strong ties and interconnected developers. Much as in Higgins and Kram's description of a traditional developmental network, aspects of our tripartite relationship included redundant information for Deepthi, as Paul and Julie both provided expressive support and professional development guidance typical of faculty–graduate student relationships (Higgins & Kram, 2001).

Critical incident #3: We begin to operate under a new mentoring model

Once we recognized that our initial mentoring model was not working well, we established several ways in which Julie could more directly provide mentoring to Deepthi to fill in the gaps in our initial conceptualization. One major change we made was in our approach to meetings. Initially, Julie and Paul had been meeting each week to work on the RIEF project, then Paul and Deepthi met separately, and Paul relayed what he had learned. As we realized how ineffective this meeting strategy was, Julie and Paul began to include Deepthi in their weekly meetings starting in September 2021. The new meeting strategy eliminated the need for Paul to remember what he learned from Julie and attempt to translate it to Deepthi. It also promoted Deepthi's legitimate peripheral participation and guided participation by directly making her part of project decisions. Deepthi compared the new and old approaches:

> *Recently I've been included in their meetings with each other. But before I was included in them, I really felt like they would meet and decide what's going to happen and then hopefully one of them will relay that information to me. And I would feel pretty frustrated at times because I would feel out of the loop and then all of a sudden [it] would be like, "OK, we need this done." And so, now that I have a little bit more ground to stand on, I think I want to start asking what needs to get done, who's going to do them, and can I say yes or no, like, do I have a say in it. [Deepthi's January 2022 interview]*

Julie also reflected on how much better she felt the new mentoring model was working when she said:

> *I don't want to have to talk about something with Paul and explain something to him and then have him turn around and explain it to Deepthi, when we all could just talk about it and get all the questions answered and all the ideas on the table. I think that has worked well. [Julie's January 2022 interview]*

Deepthi enjoyed working on the RIEF project so much that she decided to switch her master's degree topic from a technical biomedical engineering topic to one related to EER. Julie began mentoring Deepthi through guided participation and provided instrumental and expressive support to Deepthi for both the RIEF project and her master's thesis. Julie's experience was much like that of teaching an independent study course where the instructor works one-on-one with the student who is learning about a particular topic. Julie reflected on how much she valued providing expressive and instrumental support to Deepthi in her January 2022 reflection:

> *I made some specific suggestions for Deepthi on next steps for her master's project that I hope will be helpful as she starts the analysis and begins to write the paper. I plan to continue to help out with resources and guidance this semester. I hope Deepthi knows how invested I feel in her success. . . I need to tell her that specifically.*

While Deepthi does not recall a specific conversation about Julie's investment in her success, she later recalled feeling that it was obvious in the way Julie always prioritized her needs, her requests to meet, and checked in with her on both her master's degree project and the RIEF project.

A few months after Julie began mentoring Deepthi, Deepthi reflected:

> *I met with Julie one-on-one to discuss interview coding, which was very informative. She also has been helping me set deadlines so that I'm making more progress on my thesis, because I was struggling to manage my time and get started on it. [Deepthi's September 2021 reflection]*

Julie considered the help with setting deadlines as an aspect of scaffolding. She used deadlines to model the thought processes that are involved in making research decisions in engineering education.

By January 2022 Deepthi's zone of proximal development had grown as she engaged in situated learning under Julie's mentorship:

> *With Julie's help I've learned to code transcripts, and across the seven transcripts I coded, I can tell my confidence grew. . . I'm really proud that I finished coding the transcripts and that Paul and I*

have been able to have discussions about them as a whole. I couldn't have done it without Julie's advice and guidance, and now I feel a lot more prepared [to conduct additional data analysis]. [Deepthi's January 2022 reflection]

Similarly, in an interview that same month Deepthi said:

Well, for myself it's just kind of learning the general process that engineering ed[ucation] researchers go through whenever they're in a project. Like I learned how to develop the research questions, execute the actual interviews in data collection, I learned how to code interviews. . . Learning all of that was my proudest achievement of the past year. [Deepthi's January 2022 interview]

By working directly with Julie on both the RIEF project and her thesis project, Deepthi was actually gaining more experience in qualitative data analysis than Paul. She noted, "He hasn't coded interview transcripts before so if he ever had questions about that I would be the expert instead of him, which is so weird to think" [Deepthi's December 2022 interview].

Deepthi also reflected about the expressive support she was receiving from Paul under the new model, writing, "[He] has simply been encouraging about my progress and enthusiasm in this new field, which bolsters my own courage" in February 2021 and then "Paul has been giving me a lot of positive feedback" in May. In September 2021 she wrote in her reflection, "Paul is continually giving me more responsibility and freedom, which is always a confidence-booster."

As we wrote this paper, Paul described how he felt about the new mentoring model, saying, "It felt like I was taking an exam, and suddenly the proctor said I only needed to finish the questions I knew the answer to. I could still try to answer the other questions, but Julie was going to fix my answers before it was graded." Paul remembered feeling guilty that he could not provide Deepthi much instrumental support for EER even though he was providing expressive and instrumental support in other areas, such as how to navigate graduate school, manage her time, or balance work and life. Whereas Paul initially felt guilty about having a "gap" in his mentoring abilities, agreeing to the new mentoring model provided a transformative learning experience for him that allowed him to reconceive his role as a vital member of Deepthi's developmental network.

One unanticipated consequence of Julie directly mentoring Deepthi was the challenge Deepthi experienced with two mentors (Julie as her EER mentor and Paul as her major advisor) with different mentoring styles. She called this experience "eye-opening":

Julie's mentoring style and work style is nothing like Paul's. And so, it was weird having to work under both of them. And feeling like pleasing one wasn't necessarily pleasing the other or, I don't know—I felt a little bit torn between the two work styles—but I think I handled it well. And so, I do want to figure out a way where I don't feel like I'm torn between the two of them.
[Deepthi's December 2022 interview]

She elaborated on one salient aspect of Paul's and Julie's different styles—Julie's desire to model the research process by helping students set internal deadlines, and Paul's differing philosophy that students should be self-motivated and therefore not need him to set internal deadlines:

I struggled with Paul for a long time, because I really wanted deadlines and I wanted like—I wanted more structure, I guess. . . I was always like, "I want deadlines, I just want somebody to tell me when I need things done by." . . . And Paul's work style is very like, "I want you to be self-motivated, I don't want to require things from you that you're not prepared to give." . . . And then, since like having this relationship with Julie, I told her that I wanted deadlines, so when she gives me them, I feel good. I feel like I have a goal. . . But at the same time, if she gives me a deadline that I didn't ask for, suddenly I'm like, "Oh, I like it better the way Paul was doing it." [Deepthi's December 2022 interview]

The cancelled in-person activities Julie and Paul had planned to help move him "inbound" from the periphery of the EER community of practice to becoming a fully participating "insider" (Dennen & Burner, 2008, p. 428) would have also benefitted Deepthi. Since those events were not possible due to the pandemic, Julie virtually involved Deepthi in her research team. Deepthi virtually attended research team meetings, seminars, and social events such as Julie's department's trivia night; she even invited Deepthi to sit in on one class period for a course she was teaching. Deepthi reflected on Julie's role in connecting her to a community of practice, writing, "I have appreciated all the effort put into helping me assimilate into the eng[ineering] ed[ucation] community... Julie has also welcomed me into her class and treated me as a true part of her group; I feel a sense of camaraderie from [her research group] that helps me to express ideas and concerns as they come up" [Deepthi's February 2021 reflection].

Fortunately, we were all able to attend the 2022 American Society for Engineering Education conference together, where Deepthi and Paul connected with many other researchers in the field as Deepthi expressed a desire to do. At the conference, we presented an early version of this paper. While the pandemic had made it difficult, it was a realization of a plan that Deepthi articulated months later, saying, "And now that I finally feel like I'm learning how to do research in the [engineering education] field, I want to connect with other researchers and learn how to talk about what I am doing" [Deepthi's December 2022 interview].

Summary and conclusions

The RIEF program and Julie, Paul, and Deepthi's mentoring relationship are examples of the field's capacity-building efforts to train engineering faculty and graduate students to conduct EER. By studying this relationship, our work makes at least three contributions to the field of engineering education.

Our first contribution lies in explicating the mechanisms by which an expert mentor can help novice engineering education researchers learn skills necessary to conduct research in the field. We described how aspects of Eby et al.'s mentoring model and the cognitive apprenticeship model of mentorship explain how a mentor can effectively scaffold learning during guided participation in order to move mentees through their zone of proximal development. We illustrated the positive effect of the mentor providing both instrumental and expressive supports to the mentee(s).

Secondly, we engaged in deep exploration of our RIEF mentoring relationship, finding unanticipated complexity when the relationship involved both a faculty and a student mentee who were previously unfamiliar with EER. Our initial mentoring model was not as effective as we thought it would be because Paul was too new to EER to model and scaffold Deepthi's learning to an appropriate zone of proximal development. While he was still able to provide experiences of guided participation, plenty of expressive support, and limited instrumental support, our initial model fell short because we did not recognize that as a novice himself, Paul was not able to accurately assess the location of Deepthi's zone of proximal development. Because the zone of proximal development depends on the progress of the mentee's learning, Paul needed more EER expertise to accurately instruct a mentee in EER (Dennen & Burner, 2008). While we realize now that it was unreasonable to think that someone who is making a paradigm shift from engineering to EER can effectively mentor someone else who is also a novice, there were some benefits to Paul's mentoring of Deepthi before we changed the model, as he lacked the expert "blind spot". There is also the advantage of providing peer-like support to the learning process. These benefits were retained via the revised conceptualization in Fig. 2. We note that our mentoring relationship roles and interactions will continue to shift as Paul and Deepthi improve in managing the paradigm shift and become more encultured within EER.

Lastly, our work demonstrates the benefits of using collaborative autoethnography to study research mentorship in engineering education. Our research team experienced the methodological benefits of collaborative autoethnography outlined by Chang and colleagues (2013). Our collective exploration enabled deep learning about ourselves and mentors and mentees and has influenced how we engage in those roles in other relationships and contexts. As a team, we communicate more openly and our commitment to our relationship is stronger than it would have been without continual self-reflection and collective exploration as participant-researchers. For example, we find that we now catch ourselves when we might be failing to communicate because of relational efficacy assumptions, and we speak up about our needs in those moments. In developing this manuscript and the prior conference paper, we have shared power with each other and worked through potential power dynamics that are typical with other methodologies. We each agree that the insights from our collaborative autoethnography would not have been available if we had employed an individual autoethnographic method or a methodology where the roles of researchers and participants were separate.

Implications

Our work raises two questions that mentors and mentees in general and those designing programs like RIEF that aim to build research capacity in the social sciences specifically must address. The first question is: how do mentees and mentors navigate the separation of mentoring roles? It is widely recognized that mentees benefit from a community of mentors who each offer different kinds of expressive and instrumental support. However, the cognitive apprenticeship model presumes a mentor has technical skills and structures the learning environment to develop the same skills in the mentee (Dennen & Burner, 2008). We initially found it difficult to map our tripartite mentoring relationship onto models that define mentoring relationships by the flow of knowledge or social capital from mentor to mentee. In our case, Paul had neither technical knowledge nor social capital to offer Deepthi. Instead, mentoring relationships can be defined by the mentor's asymmetrical concern for the mentee's development. Paul and Deepthi were at the same developmental level, but Paul worried about ensuring Deepthi's

development as her mentor. Deepthi commented on Paul's developmental level but did not feel responsible for his development.

Our work suggests that mentees will consider anyone who should be concerned for their development as a mentor, even if that mentor does not pass on knowledge directly to the mentee. These "indirect" mentors must signal their concern for the mentee's development and stay abreast of their development. For example, graduate students need a faculty advisor who is concerned and aware of their progress even if they are functionally a cognitive apprentice to a postdoc in their research group. Similarly, department heads need to express their concern for a junior faculty's development even if the department has assigned a formal mentoring team for new faculty. Mentors without technical expertise must help their mentees assemble a mentoring team (also called a mentoring network or map; Christou et al., 2017) to address these deficiencies, but the mentors cannot delegate their concern for the mentee's technical development.

The second question raised by our work is: how do programs support graduate student mentees who are mentored by faculty without formal training in the mentees' new research fields? Institutions frequently provide career development activities for junior faculty on mentoring graduate students. However, these programs assume the mentor has sufficient technical expertise in their project area but limited formal mentoring experience. In our case, Deepthi was Paul's sixth graduate mentee when the RIEF project started. Paul knew how to mentor engineering graduate students but had no knowledge of engineering education or of the differences between the mentoring norms between engineering and engineering education. Julie and Paul each reported spending the same amount of time mentoring Deepthi as they spent with their other students, suggesting trainees in the RIEF program may require twice the mentoring time commitment as a student mentored by an established faculty member in either field. This time commitment was unexpected and not reflected in the mentoring plan we submitted as part of our project proposal. Outside experts (such as Julie) need to be asked up front if they are willing to be more involved than a traditional dissertation committee member or collaborator. Future applicants to RIEF or similar capacity-building programs should be aware of the unique mentoring challenges that arise when switching fields and plan accordingly, particularly when there are multiple layers of mentoring involved.

Abbreviations

RIEF Research Initiation in Engineering Formation
EER Engineering education research
NSF National Science Foundation
STEM Science, technology, engineering, and math

Acknowledgements

We thank Dr. Renee Desing for serving as our sounding board, including conducting the interviews with the author team and reviewing a draft of the paper. This material is based upon work supported by the National Science Foundation under Grant Nos. 2024736/2403968 and 2025059. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. Table 1 and several quotes are reused with permission from our conference proceedings paper: Martin et al. (2022, June 26–29). Perceptions of shared experiences in mentoring relationships: a collaborative autoethnography. In *2022 ASEE Annual Conference & Exposition*. ASEE.

Author contributions

JPM led the author team in designing the research study and writing the manuscript. JPM, DS, and PJ were researcher-participants. They each participated in generating and jointly analyzing autoethnographic data, codeveloping findings, drawing conclusions. Each author contributed to manuscript drafts and have read and approved the final manuscript.

Funding

This material is based upon work supported by the National Science Foundation under Grant Nos. 2024736/2403968 and 2025059. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to the autoethnographic nature of the study.

Declarations

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Engineering Education Transformations Institute, University of Georgia, Driftmier Engineering Center, 597 DW Brooks Drive, Athens, GA 30602, USA. [2]Department of Biomedical Engineering, University of Michigan, Carl A. Gerstacker Building, 2220 Bonisteel Blvd, Ann Arbor, MI 48109, USA.

Received: 17 May 2023 Accepted: 9 February 2024
Published online: 23 February 2024

References

Ahn, B., & Cox, M. F. (2016). Knowledge, skills, and attributes of graduate student and postdoctoral mentors in undergraduate research settings. *Journal of Engineering Education, 105*(4), 605–629. https://doi.org/10.1002/jee.20129

Allen, T. D., Eby, L. T., Poteet, M. L., Lentz, E., & Lima, L. (2004). Career benefits associated with mentoring for protégés: A meta-analysis. *Journal of Applied Psychology, 89*(1), 127–136. https://doi.org/10.1037/0021-9010.89.1.127

Atkins, K., Dougan, B. M., Dromgold-Sermen, M. S., Potter, H., Sathy, V., & Panter, A. T. (2020). "Looking at myself in the future": How mentoring shapes scientific identity for STEM students from underrepresented groups. *International Journal of STEM Education, 7*, 42. https://doi.org/10.1186/s40594-020-00242-3

Blalock, A. E., & Akehi, M. (2018). Collaborative autoethnography as a pathway for transformative learning. *Journal of Transformative Education*, *16*(2), 89–107.

Borrego, M. (2007). Conceptual difficulties experienced by trained engineers learning educational research methods. *Journal of Engineering Education, 96*(2), 91–102. https://doi.org/10.1002/j.2168-9830.2007.tb00920.x

Borrego, M., Jesiek, B. K., & Beddoes, K. (2008, October 22–25). Advancing global capacity for engineering education research: Preliminary findings [Paper presentation]. In *IEEE 38th Annual Frontiers in Education Conference*, Saratoga Springs, NY, United States. https://doi.org/10.1109/FIE.2008.4720448.

Brewer, M. M., Sochacka, N., & Walther, J. (2015, June 14–17). Into the pipeline: A freshman student's experiences of stories told about engineering [Paper presentation]. In *2015 ASEE Annual Conference & Exposition*, Seattle, WA, United States. https://doi.org/10.18260/p.24355.

Burt, B. A., Stone, B. D., Jr., Hemmings, Y., Kleba, J., Glasco-Boyd, D., & Washington, B. (2023). How a principal investigator supervises a student research group: An autoethnographic longitudinal examination. *Teachers College Record, 125*(2), 3–34. https://doi.org/10.1177/01614681231161234

Byars-Winston, A. M., Branchaw, J., Pfund, C., Leverett, P., & Newton, J. (2015). Culturally diverse undergraduate researchers' academic outcomes and perceptions of their research mentoring relationships. *International Journal of Science Education, 37*, 2533–2554. https://doi.org/10.1080/09500693.2015.1085133

Chang, H., Ngunjiri, F. W., & Hernandez, K.-A. (2013). *Collaborative autoethnography* (Vol. 8). Routledge.

Christou, H., Dookeran, N., Haas, A., Di Frances, C., Emans, S. J., Milstein, M. E., Kram, K. E., & Seely, E. W. (2017). Establishing effective mentoring networks: Rationale and strategies. *MedEdPORTAL, 13*, 10571. https://doi.org/10.15766/mep_2374-8265.10571

Clutterbuck, D. (2013). Where next with research in mentoring? *International Journal of Mentoring and Coaching in Education*. https://doi.org/10.1108/IJMCE-09-2013-0048

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 454–494). Lawrence Erlbaum Associates.

Colquitt, D. (2021). *Pursuit is purpose: A critical autoethnography of one Black man's journey through engineering education* [Doctoral dissertation, Purdue University Graduate School]. Purdue University Hammer Research Repository. https://doi.org/10.25394/PGS.17149211.v1.

Cooper, M. A. (1999). Classroom choices from a cognitive perspective on peer learning. In A. M. O'Donnell & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 215–233). Lawrence Erlbaum.

Dennen, V. P. (2013). Cognitive apprenticeship in educational practice: Research on scaffolding, modeling, mentoring, and coaching as instructional strategies. In D. Jonassen & M. Driscoll (Eds.), *Handbook of research on educational communications and technology* (2nd ed., pp. 804–819). Routledge. https://doi.org/10.4324/9781410609519

Dennen, V. P., & Burner, K. J. (2008). The cognitive apprenticeship model in educational practice. In J. M. Spector, M. D. Merrill, J. van Merriënboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 425–439). Routledge. https://doi.org/10.4324/9780203880869

Duffy, J., Wickersham-Fish, L., & Rademaker, L. (2018). Using collaborative autoethnography to explore online doctoral mentoring: Finding empathy in mentor/protégé relationships. *American Journal of Qualitative Research, 2*(1), 57–76. https://doi.org/10.29333/ajqr/5794

Eby, L. T. D. T., Allen, T. D., Hoffman, B. J., Baranik, L. E., Sauer, J. B., Baldwin, S., Morrison, M. A., Kinkade, K. M., Maher, C. P., Curtis, S., & Evans, S. C. (2013). An interdisciplinary meta-analysis of the potential antecedents, correlates, and consequences of protégé perceptions of mentoring. *Psychological Bulletin, 139*(2), 441–476. https://doi.org/10.1037/a0029279

Ellis, C., Adams, T. E., & Bochner, A. P. (2011). Autoethnography: An overview. *Historical Social Research/historische Sozialforschung, 36*(4), 273–290. https://doi.org/10.12759/hsr.36.2011.4.273-290

Espino, M. M., & Zambrana, R. E. (2019). "How do you advance here? How do you survive?" An exploration of under-represented minority faculty perceptions of mentoring modalities. *The Review of Higher Education, 42*(2), 457–484. https://doi.org/10.1353/rhe.2019.0003

Flannagan, J. (1954). The critical incident approach. *Psychological Bulletin, 41*, 237–358. https://doi.org/10.1037/h0061470

Gallup. (n.d.). *CliftonStrengths*. https://www.gallup.com/cliftonstrengths/en/254033/strengthsfinder.aspx. Accessed 16 Nov 2023

Grove, S. J., & Fisk, R. P. (1997). The impact of other customers on service experiences: A critical incident examination of "getting along." *Journal of Retailing, 73*(1), 63–85. https://doi.org/10.1016/S0022-4359(97)90015-4

Haverkamp, A., Butler, A., Pelzl, N. S., Bothwell, M. K., Montfort, D., & Driskill, Q. (2019, April 14–22). Exploring transgender and gender nonconforming engineering undergraduate experiences through autoethnography [Paper presentation]. In *2019 CoNECD: The Collaborative Network for Engineering and Computing Diversity*, Crystal City, VA, United States. https://peer.asee.org/31764. Accessed 16 Nov 2023

Higgins, M. C., & Kram, K. E. (2001). Reconceptualizing mentoring at work: A developmental network perspective. *Academy of Management Review, 26*(2), 264–288.

Holly, J. S., Jr. (2020). A critical autoethnography of a Black man teaching engineering to Black boys. *Journal of African American Males in Education, 11*(2), 25–42.

Holly, J., Jr. (2021). Equitable pre-college engineering education: Teaching with racism in mind. *Journal of Pre-College Engineering Education Research, 11*(1), 9. https://doi.org/10.7771/2157-9288.1282

Hughes, S. A., & Pennington, J. L. (2016). *Autoethnography: Process, product, and possibility for critical social research*. Sage Publications.

Jacobi, M. (1991). Mentoring and undergraduate academic success: A literature review. *Review of Educational Research, 61*(4), 505–532.

Jensen, K., Martin, J. P., Miller, I., & Suresh, D. (2023). Beyond skills: Building research capacity through building social networks. *Australasian Journal of Engineering Education Special Issue: Engineering Education Research Capability Development., 28*(1), 97–109. https://doi.org/10.1080/22054952.2023.2230068

Jesiek, B., Borrego, M., & Beddoes, K. (2008, July 2–5). Expanding global engineering education research collaboration [Paper presentation]. In *The European Society for Engineering Education (SEFI) Annual Conference*, Aalborg, Denmark.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lent, R. W., & Lopez, F. G. (2002). Cognitive ties that bind: A tripartite view of efficacy beliefs in growth-promoting relationships. *Journal of Social and Clinical Psychology, 21*(3), 256–286. https://doi.org/10.1521/jscp.21.3.256.22535

Lunsford, L. G., Crisp, G., Dolan, E. L., & Wuetherick, B. (2017). Mentoring in higher education. *The SAGE Handbook of Mentoring, 20*, 316–334. https://doi.org/10.4135/9781526402011.n20

Malin, J. R., & Hackmann, D. G. (2016). Mentoring as socialization for the educational leadership professoriate: A collaborative autoethnography. *Mentoring & Tutoring: Partnership in Learning, 24*(2), 158–178. https://doi.org/10.1080/13611267.2016.1170561

Martin, J. P., & Garza, C. (2020). Centering the marginalized student's voice through autoethnography: Implications for engineering education research. *Studies in Engineering Education, 1*(1), 1–19. https://doi.org/10.21061/see.1

Martin, J. P., Stefl, S. K., Cain, L. W., & Pfirman, A. L. (2020). Understanding first-generation undergraduate engineering students' entry and persistence through social capital theory. *International Journal of STEM Education, 7*(1), 1–22. https://doi.org/10.1186/s40594-020-00237-0

Martin, J. P., Suresh, D. E. & Jensen, P. (2022, June 26–29). Perceptions of shared experiences in mentoring relationships: A collaborative autoethnography [Paper presentation]. In *2022 ASEE Annual Conference & Exposition, Minneapolis*, MN, United States. https://strategy.asee.org/41058. Accessed 16 Nov 2023

McCallum, C., Libarkin, J., Callahan, C., & Atchison, C. (2018). Mentoring, social capital, and diversity in earth system science. *Journal of Women and Minorities in Science and Engineering, 24*(1), 17–41. https://doi.org/10.1615/JWomenMinorScienEng.2017018878

Mirabelli, J., Barlow, A., Ko, M., Cross, K., & Jensen, K. (2020, June 22–26). Work in progress: A qualitative study of mentorship, training needs, and community for new engineering education researchers [Paper presentation]. In *2020 ASEE Virtual Annual Conference*. https://doi.org/10.18260/1-2—35601.

Mondisa, J. L. (2020). The role of social capital in African American STEM mentoring relationships. *Journal of Women and Minorities in Science and*

Engineering, 26(2), 125–153. https://doi.org/10.1615/JWomenMinorScienEng.2020022267
Moreira, R. G., Butler-Purry, K., Carter-Sowell, A., Walton, S., Juranek, I. V., Challoo, L., Regisford, G., Coffin, R., & Spaulding, A. (2019). Innovative professional development and community building activity program improves STEM URM graduate student experiences. *International Journal of STEM Education, 6*, 34. https://doi.org/10.1186/s40594-019-0188-x
Mullen, C. A., & Klimaitis, C. C. (2021). Defining mentoring: A literature review of issues, types, and applications. *Annals of the New York Academy of Sciences, 1483*(1), 19–35. https://doi.org/10.1111/nyas.14176
Nathan, M. J., & Petrosino, A. (2003). Expert blind spot among preservice teachers. *American Educational Research Journal, 40*(4), 905–928.
National Academies of Sciences, Engineering, and Medicine. (2019). *The science of effective mentorship in STEMM*. National Academies Press. Accessed 16 Nov 2023
National Science Foundation. (2020). *PFE: Research initiation in engineering formation* [Solicitation No. 20-558]. https://beta.nsf.gov/funding/opportunities/pfe-research-initiation-engineering-formation-pfe. Accessed 16 Nov 2023
Nick, J. M., Delahoyde, T. M., Del Prato, D., Mitchell, C., Ortiz, J., Ottley, C., Young, P., Cannon, S. B., Lasater, K., Reising, D., & Siktberg, L. (2012). Best practices in academic mentoring: A model for excellence. *Nursing Research and Practice*. https://doi.org/10.1155/2012/937906
Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice.* Sage Publications.
Research in Education Engineering Network. (n.d.). *Engineering education community resource wiki.* Retrieved January 22, 2024, from http://engineeringeducationlist.pbworks.com/w/page/27578912/Engineering%20Education%20Community%20Resource
Robnett, R. D., Nelson, P. A., Zurbriggen, E. L., Crosby, F. J., & Chemers, M. M. (2018). Research mentoring and scientist identity: Insights from undergraduates and their mentors. *International Journal of STEM Education, 5*, 1–14. https://doi.org/10.1186/s40594-018-0139-y
Roy, R., & Uekusa, S. (2020). Collaborative autoethnography: "Self-reflection" as a timely alternative research approach during the global pandemic. *Qualitative Research Journal*, *20*(4), 383–392.
Secules, S., McCall, C., Mejia, J. A., Beebe, C., Masters, A. S., Sánchez-Peña, M. L., & Svyantek, M. (2021). Positionality practices and dimensions of impact on equity research: A collaborative inquiry and call to the community. *Journal of Engineering Education, 110*(1), 19–43. https://doi.org/10.1002/jee.20377
Seniuk Cicek, J., Paul, R., Sheridan, P. K., & Kuley, L. (2020). Researchers explore their roles as participant-researchers in characterizing the lived experiences of graduate students in engineering education research in Canada: A collaborative autoethnography. *Canadian Journal of Science, Mathematics and Technology Education, 20*, 98–115. https://doi.org/10.1007/s42330-019-00075-5
Serafini, A., Calderone, S., Lozano, M., & Martinez, M. A. (2023). A critical safe, supportive space: A collaborative autoethnography of a woman's academic mentoring circle. *International Journal of Mentoring and Coaching in Education, 12*(1), 47–61. https://doi.org/10.1108/IJMCE-07-2021-0075
Shieh, C., & Cullen, D. L. (2019). Mentoring nurse faculty: Outcomes of a three-year clinical track faculty initiative. *Journal of Professional Nursing, 35*(3), 162–169. https://doi.org/10.1016/j.profnurs.2018.11.005
Teasdell, A., Lee, S. J., Calloway, A. M., & Adams, T. R. (2021). Commitment, community and consciousness: A collaborative autoethnography of a doctoral sister circle. *Journal of African American Women and Girls in Education*. https://doi.org/10.3102/1572907
Tharp, R., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning, and schooling in the social context*. Cambridge University Press.
Thomas, D., Lunsford, L. G., & Rodrigues, H. (2015). Early career academic staff support: Evaluating mentoring networks. *Journal of Higher Education Policy and Management, 37*(3), 320–329. https://doi.org/10.1080/1360080X.2015.1034426
Vega, R. M. (2021). *A consultant self-exploration: An autoethnography addressing educational change efforts in Chilean engineering education* [Unpublished doctoral dissertation]. University of Pittsburgh.
Yadav, A., & Seals, C. (2019). Taking the next step: Supporting postdocs to develop an independent path in academia. *International Journal of STEM Education, 6*, 15. https://doi.org/10.1186/s40594-019-0168-1
Zaniewski, A. M., & Reinholz, D. (2016). Increasing STEM success: A near-peer mentoring program in the physical sciences. *International Journal of STEM Education, 3*(1), 1–12. https://doi.org/10.1186/s40594-016-0043-2

Publisher's Note

Julie P. Martin is the Director of the Engineering Education Transformations Institute and a professor and in the College of Engineering at the University of Georgia.

Deepthi Suresh is a PhD student in biomedical engineering at the University of Michigan.

Paul Jensen is an assistant professor of biomedical engineering at the University of Michigan.