

(Mis)alignments between postdoctoral and supervisors' perceptions of mentorship competencies in engineering and computer science

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Abstract

Background: Postdoctoral training holds an increasingly important place in preparation for leading academic and research positions. While little empirical research has described postdoctoral training beyond the sciences, across all fields, “misaligned expectations” are often touted as a key source of postdoctoral strife.

Purpose/Hypothesis: This article describes mentorship competency beliefs within engineering and computer science fields, which increasingly engage in postdoctoral training.

Design/Method: An embedded mixed-methods design was used to quantitatively identify mentorship profiles from survey data using latent profile analysis (LPA) from a sample of $n = 118$ postdoctoral scholars and $n = 165$ postdoctoral supervisors. Qualitative thematic analysis of interviews with $n = 29$ postdoctoral scholars and $n = 20$ postdoctoral supervisors was used to identify meaning in the differences between quantitative profiles. The combination of LPA with thematic analysis enabled the triangulation of distinct postdoctoral mentorship profile definitions.

Results: LPA identified six postdoctoral fellow profiles and four supervisor profiles, which became clearly definable through thematic analysis. Postdoc profiles included Technical Manager, Autonomy Focused Advisor, Stretched Mentor, Well-Rounded Mentor, Exemplar Mentor, and Leader-Mentor, while supervisor profiles included Autonomous Mentor, Reflective Mentor, Research Lab Mentor, and Confident Leader-Mentor. Some of these are aligned, but several are not, giving insight into the phenomenon of “misaligned expectations” in postdoctoral literature.

Conclusions: The mentorship profiles illustrate the misalignment in expectations, which leads to negative mentorship experiences for many postdoctoral scholars.

KEY WORDS

computer science, engineering, mentorship, mentorship competency assessment, postdoctoral

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1 | INTRODUCTION

In the United States, the number of postdoctoral scholars in science and engineering increased from 30,196 in 2000 to 47,203 in 2020 (National Center for Science and Engineering Statistics [NCSES], 2023), reflecting the national and global need for highly skilled researchers and leaders. Even as researchers have given increased attention to graduate training and mentorship, postdoctoral training and mentorship have attracted little research beyond the sciences (e.g., Karalis Noel et al., 2022; Layton et al., 2020). Unlike in the sciences, in engineering postdoctoral training has only recently become an expectation for future academic employment. The number of engineering postdoc scholars in the United States dramatically increased from 3313 in 2000 to 8462 in 2020 (NCSES, 2023), illustrating a desire for postdoctoral training from academic and industry employers (National Science Board, 2016). This trend leads to the need to evaluate the expectations, training, and mentorship practices in postdoctoral training. In some disciplines, such as engineering and computer science (ECS), postdocs rely on their supervisor as their primary mentor (Rida et al., 2023). In this article, we recognize that supervisors and mentors are not synonymous. In this context, supervisors are those practitioners or academics advanced in careers, prepared to provide research guidance, and often the principal investigators on grants funding a postdoctoral position. While supervisors may also be mentors, mentors offer interpersonal relationships, research and career coaching, and psychosocial support beyond that of a supervisor (National Academies of Sciences Engineering and Medicine, 2018; Rida et al., 2023). We refer to “supervisors” here rather than “mentors” to distinguish between the roles and potential distinction between individuals who fill these roles for postdocs in ECS. We do this by acknowledging that the supervisor is assumed to play the mentor role but may not have the skills, ability, or inclination to mentor postdoctoral scholars effectively. Further, postdoctoral scholars may choose additional mentors for a variety of reasons.

In studies of mentorship and leadership, it is evident that shared expectations and shared conceptions of a role are important to having a productive mentorship experience for both stakeholders. Intervention and recommendations for postdoctoral supervisor matching (as well as doctoral matching) emphasize the importance of “fit” in a research team and strong communication with supervisors, aligning with the proposition that for a productive relationship to exist, there must be some alignment in the communication styles, working styles, and expectations of both the supervisor/mentor and the mentee. While postdoctoral education literature is clear that “misaligned expectations” cause the bulk of issues with postdoctoral training, there have not been many studies that captured or characterize the different conceptualizations of mentors (in how they mentor) and mentees (in what they expect from a mentor) to articulate precisely where the misalignments and miscommunications may exist. Instead, most literature leaves the issue broadly as “misalignment.” To this end, the purpose of this article is to describe the different conceptualizations of postdoctoral mentorship from the points of view of both postdoc supervisors and postdoc scholars and explore the potential for misalignment between these concepts of postdoctoral mentorship.

2 | LITERATURE REVIEW

Existing literature converges on the essential role of individualized and high-quality mentorship in postdoctoral training (Arredondo et al., 2022; Bhattacharjee, 2006; Lee et al., 2007; Pfund et al., 2006; Ranieri et al., 2016; Scaffidi & Berman, 2011). Most of this literature uses STEM fields broadly or focuses on biological and biomedical sciences, which have deep histories of postdoctoral requirements for career progression (Huang et al., 2016; Karalis Noel et al., 2022; Layton et al., 2020; McConnell et al., 2018; Miller & Feldman, 2015; Ranieri et al., 2016; Rida et al., 2023; Scaffidi & Berman, 2011; Sun et al., 2023). Literature focused on postdoc experiences in engineering remains nearly nonexistent with a few notable exceptions (Denton et al., 2022; Main et al., 2021; Mendez et al., 2022; Zerbe et al., 2023), requiring broader attention to STEM postdoctoral literature. However, the literature surrounding postdoctoral education in the broader science and engineering domains can generally be categorized into three main themes around which the remainder of this literature review is structured: (i) illuminating issues in postdoctoral education experiences; (ii) assumptions of mentorship in postdoctoral positions; and (iii) methods to measure mentorship competency.

2.1 | Illuminating issues in postdoctoral education experiences

While, in general, the postdoctoral stage is rarely the focus of most educational literature, some reports of postdoctoral experiences have been characterized as negative and even potentially harmful (Camacho & Rhoads, 2015;

Mendez et al., 2021; Omary et al., 2019; Yadav et al., 2020). Literature points to lab culture and supervisor practices that create adverse environments ranging from benevolent to abusive (Mendez et al., 2021; Omary et al., 2019; Yadav et al., 2020). One proposed solution seeks active support and mentorship as postdoctoral scholars move into and through new professional development experiences (E. O. McGee, 2016), often suggesting that multiple mentors may be needed to meet the various needs of individual postdocs (Nerad, 2011). However, given the funding structures and the lack of a formal committee (as in doctoral studies), the postdoc is typically an unstructured experience.

Overwhelmingly, literature shows that job insecurity and unclear employment structures contribute to negative experiences in which postdocs feel stuck and unable to improve their position (Scaffidi & Berman, 2011). This stuckness may be caused by the power dynamics between faculty members and postdocs, relative liminality of the postdoctoral position as a short-term position with only short times to develop social networks at a new university, and potential desperation to achieve strong recommendations from supervisors to aid future competitive job applications. Indeed, increasingly there are either formal or unspoken disciplinary “requirements” for successful faculty positions that a candidate has held one (or more) postdocs. The inherent nature of the position as transitional and preparatory for a different employment position makes addressing these concerns complicated and unpredictable for postdocs and their supervisors.

Postdocs from historically marginalized groups suffer negative career consequences from poor and inadequate mentorship as well (Mendez et al., 2021), which is a critical stage in broadening participation in the professoriate. Existing literature demonstrates problematic differences in experience based on gender, race/ethnicity, and nationality such that socially marginalized groups experience the same kinds of marginalization and discrimination during postdoctoral training that are symptomatic of the dominant sociocultural context (Case & Richley, 2013; Eaton et al., 2020; Huang et al., 2016; Ysseldyk et al., 2019). For example, within biomedical training spaces, the social-ecological environment reflects existing marginalization that creates barriers to success for marginalized postdocs through hierarchies, inequalities in mentorship, and overreliance on individual mentors, which foster adverse environments (Lambert et al., 2023).

As a result, marginalized postdocs experience microaggressions, bias, and stereotypes based on gender and race, which result in fewer professional development opportunities, and may feel a lower sense of belonging (Yadav et al., 2020). Experiences of marginalization also lead to differences in mentorship experiences (Mendez et al., 2021). Gender-based discrimination and sociological hurdles diminish women's mental health, life satisfaction, and perceived control, which link to decreases in the effectiveness of postdoctoral training (Case & Richley, 2013; Ysseldyk et al., 2019). Conversely, literature shows that when postdoctoral training balances teaching, research, and professional development, women and marginalized-race postdocs are more likely to continue in academia and transition into faculty positions (Rybarczyk et al., 2016). While this work does not specifically focus on marginalized populations, we enter into the research being aware that our findings should also be sensitive and speak to remedy the marginalization and suppression of oppressed voices in US society.

2.2 | Assumptions on mentorship in postdoctoral positions

Another reason why there are substantial issues in postdoctoral mentorship is a pervasive assumption that the role of the supervisor is inherently also acting as a “good mentor.” While the terms “supervisor” and “mentor” are not synonymous, the intention of postdoctoral training assumes that principal investigators with postdoctoral scholars fulfill both roles (Bahnson et al., 2022a). Within the concept of postdoctoral mentorship, responsibilities beyond research supervision include lab supervision and mentorship roles, helping students and postdocs socialize into their field, and providing opportunities for grant-writing and professional development (Bahnson et al., 2022a; Rida et al., 2023). However, unclear responsibilities, role definitions, and expectations between supervisor and postdoc can often generate friction in the relationship (Bahnson et al., 2022a; Su & Alexander, 2018; Zhu et al., 2021). Postdocs need specific and timely clarity in expectations and the support to meet expectations to succeed in meeting their supervisor's expectations and in preparation for their future career. Without writing coaching and strategy, publication expectations may lead to disappointment and frustration (Anderson et al., 2022). Indeed, high publication rates for postdocs are associated with increased success in future faculty careers (Main et al., 2021), with the postdoc experience recognized as an increasingly important pathway to engineering academic careers (Mendez et al., 2022).

Underdeveloped support and misalignment in expectations result in missed career development opportunities, conflict, frustration, and poor work-life (Bahnson et al., 2023; Omary et al., 2019). Individual development plans (IDPs) provide one opportunity to address misalignments (e.g., Vanderford et al., 2018) but require commitment and intention

from both the postdoc and supervisor to be genuinely effective (Bahnson et al., 2022a). Funding agencies (e.g., NSF and NIH) increasingly require postdoctoral mentoring plans to receive grant support for postdoctoral scholars, but literature and practice have not established straightforward, effective ways to translate IDPs or mentoring plans into practical and effective mentoring, motivating increased research attention on postdoctoral training, mentorship, and development. Despite agreement around the importance of mentorship, little research has focused specifically on characterizing effective and ineffective mentor relationships between postdocs and their supervisors (McConnell et al., 2018; National Academies of Sciences Engineering and Medicine, 2018), leading to a need to understand how mentorship manifests within postdoc supervisorship roles.

2.3 | Measuring mentorship competency

Mentorship competency represents the skills and characteristics needed by faculty mentors to successfully mentor research trainees (Fleming et al., 2013). Fleming et al. (2013) working as the Clinical and Translational Science Awards Mentor Working Group, developed a measure that could assess the outcomes of a national trial of a mentorship intervention. Mentorship competency reflects the skills and abilities of research mentors to serve trainees by maintaining effective communication, aligning expectations, assessing understanding, addressing diversity, fostering independence, and promoting professional development (Fleming et al., 2013).

A few measures of mentorship have been developed or assessed for use with postdocs and postdoc supervisors. Mentorship Competency Assessment (MCA) is one of the few scales designed to capture mentor and mentee estimates of mentors' skills and abilities as mentors (Fleming et al., 2013). Initially developed for postsecondary STEM contexts, the initial validity and reliability assessments included postdocs and supervisors in the same assessment. The initial MCA included 26 items across the six areas of mentorship (Fleming et al., 2013). Subsequent uses of MCA in agriculture (Orsini & Stedman, 2019) and health sciences (Mickel et al., 2018; Stiltner & Kutz, 2018; Wiskur et al., 2020) demonstrated the utility of the assessment. Hyun et al. (2022) provided new evidence of the validity of MCA with a sample of participants enrolled in mentorship training and found an eight-factor structure and recommended dropping five items to maintain the original MCA's six-factor structure, proposing the MCA-21 (Hyun et al., 2022).

As part of a more extensive multi-method investigation, our team has assessed the original 26-item MCA for use with ECS postdocs and supervisors as a special domain and educational stage context. The MCA for ECS supervisors and postdocs (denoted MCA-ECS.S and MCA-ECS.P) retained 17 and 14 items, respectively (Bahnson et al., 2023). Initial exploratory factor analysis and Cronbach's reliability measures strongly supported including items in a single factor that retained items from all six mentorship areas measured by the original MCA (Bahnson et al., 2023). Initial analyses demonstrate the importance of each competency item in assessing the overall measure of mentorship ability in ECS. The scales measure a global mentorship competency for supervisors and postdocs that is practical, but, simultaneously, individual items better assess particular mentorship skills (Bahnson et al., 2023). Initial scale validity assessments have demonstrated that the scale is distinct from similar constructs, such as leadership (Bahnson et al., 2023; Godshalk & Sosik, 2000).

2.4 | Introducing the current study

We posit that while alignment is good regardless of discipline, there are likely disciplinary differences in these conceptions and expectations that are important to articulate. Given the lack of ECS-specific literature, the potentially negative postdoc experiences in other STEM fields, and the emergence of postdocs as a training role for leading engineering and computer scientists, we sought to investigate the mentorship competence beliefs of postdoc supervisors and experiences of postdocs. Therefore, for this study, we were interested in capturing dominant mentorship profiles for ECS supervisors and postdoctoral scholars through quantitative measures. We then demonstrated how these profiles manifest using qualitative data. We use latent profile analysis (LPA) to identify similarities in behavior to identify groups of supervisors and postdocs to generate profiles of participants who share similar mentorship practices (supervisors) and mentorship experiences (postdocs). The research reported here seeks to answer the following research questions:

1. How many and what profiles exist in the mentorship style for postdoc mentors based on self-assessment and mentee assessment? What is the frequency of each profile?

2. What are the characteristics of each profile?
3. How are the identified profiles for supervisors and postdocs similar or distinct, and how do they align?

The answers to these research questions provide information on the unique experiences of postdocs and supervisors in ECS. This information can inform individual postdocs and supervisors, provide conceptual discussion points for postdoc-supervisor pairs, and guide the development of postdoc mentorship training at institutional levels. Further, the methods used to answer these questions employ a novel method useful in other aspects of ECS education.

3 | THEORETICAL FRAMEWORKS

Leadership research has a long and diverse history (Derue et al., 2011; Parker & Welch, 2013). Research on leadership has typically embraced two paradigms: trait-based or behavioral-based theories. Trait-based theories (e.g., gender, personality, intelligence) focus on the traits a leader has to employ in leading others. Behavior-based theories (e.g., task-oriented, relationship-oriented) focus on the behaviors leaders use when leading others. Derue et al. (2011) developed an integrated model to conceptualize how leader traits influence leader behaviors that determine leader effectiveness. Similarly, Parker and Welch (2013) identified dozens of existing and emerging theories reflecting a continued expansion and interest in how leadership functions. While many of these concepts could be used to study postdoc-supervisor relationships or leadership strategies effective for postdoc mentorship, we focus on the relationship between postdoc and supervisor with the knowledge that each postdoc position is intentionally unique requiring a starting point that includes negotiation over the role itself in addition to mentorship and leadership needs.

Our research builds on a framework of mentorship competency. Supervisors who are expected to mentor require a broad range of skills and abilities to fulfill a mentor role. The mentor role represents a constellation of abilities potentially utilized in a mentorship relationship. A mentor provides a mentee with social, material, leadership, and experience resources through this mentorship relationship. In this, we take the MCA as a representation of a mentorship theoretical construct—good mentors will be able to recognize their strengths and weaknesses, and mentees can recognize their mentor's strengths and weaknesses. We would suggest that many mentors are not *tremendously* strong in *every* area of mentorship. Instead, mentor and mentee match on skills available and skills needed can create a structure for a successful mentorship relationship. Two specific theories inform this construct of mentorship: *social exchange theory* and *leader-member exchange*, to identify the role negotiations and relationship-shaping exchanges that require mentorship competency in the development of postdoc-supervisor relationships.

Social exchange theory proposes that humans interact on the basis of the exchange of social and material resources and needs with assumptions of the future return of resources (Blau, 1964; Emerson, 1976; Homans, 1958). As such, postdoctoral supervisors offer guidance, social capital, financial compensation, and physical requirements for research, publication, and recommendations while receiving highly specialized work, supervision of labs, research output, and publications. The resources exchanged represent value for both parties, supporting a mutually beneficial social relationship.

Leader-member exchange (LMX) theory explains a similar leader (supervisor)/member (postdoc) relationship in terms of the roles defined and social exchanges (Sears & Hackett, 2011). LMX posits that member experiences connect inherently to the leader's perspectives (G. Graen et al., 1973). The theory represents the apprenticeship model of postdoctoral training and the power dynamics inherent to postdoc supervision and mentoring. Each postdoc and supervisor negotiate roles through social exchanges that define the interaction between the two individuals, ostensibly in service to shared research priorities. In LMX theory, relationship development is predominantly explained through role definition or social exchange (Sears & Hackett, 2011). Social interaction develops the roles explicitly and inexplicitly, leading to mutual recognition of each role, including expectations for performance and completion of role-based tasks (Sears & Hackett, 2011). Other LMX researchers focus on the social exchange and affective processes that build and strengthen the leader-member relationship by developing trust, loyalty, and support (Liden & Maslyn, 1998).

A supervisor's ability to develop and maintain an appropriate exchange of social and material resources while clearly defining and enacting roles contributes to mentorship competency. Each supervisor/postdoc pair arrives at relationships distinct from other pairs based on the particular pair's skills, needs, resources, role agreement, and research goals. Based on this theoretical construct, we seek to identify and describe profiles of mentorship competency as described by supervisors and postdocs. Theoretically, and ideally in practice, supervisor and postdoc mentorship competency profiles will align. However, based on previously discussed literature, we expect to find some mismatch between mentorship assessment profiles.

4 | METHODS

4.1 | Overview and research design

As part of a more extensive IRB-approved investigation into ECS postdoctoral mentorship practices, this study investigates the mentorship profiles of postdoctoral supervisors and postdoctoral scholars as part of a mixed-methods phase. In a larger scale quantitative phase, the MCA scale provided standardized survey questions for mentorship beliefs and practices for mentors and mentees tailored to the respective stakeholder group. After the survey, qualitative interviews were conducted with selected participants. LPA was conducted on the survey data to identify clusters that could be described with the qualitative themes that emerged from the interview participants representing each profile. Because of the complexity and multi-phase nature of the methods employed, fine-grain detail of the latent profile triangulation method is presented in prior work (Bahnson et al., 2023).

Figure 1 depicts the parallel sequential mixed-methods exploratory-explanatory design for the research reported in this study. The figure illustrates the data collection, analysis, and profile characterization for supervisor (Sup.) and postdoc (PD) data flows through triangulation of profile descriptions and profile comparison. Each data flow begins with the survey and exploratory analysis to identify mentorship profiles to answer Research Question 1 (*How many and what profiles exist in the mentorship style for postdoc mentors based on self-assessment and mentee assessment? What is the frequency of each profile?*). Interview analysis follows to characterize differences in mentorship profiles in answer to Research Question 2 (*What are the characteristics of each profile?*). Triangulation and profile comparison provide an opportunity to identify similarities, differences, and potential for misalignment between supervisor and postdoc profiles in answer to Research Question 3 (*How are the identified profiles for supervisors and postdocs similar or distinct, and how do they align?*).

4.2 | Recruitment, participants, and procedures

Recruitment of faculty members began with email invitations to recent National Science Foundation (NSF) awardees in engineering (ENG) and computer science (CISE). Eligible faculty participants were required to have mentored (or be currently mentoring) at least one postdoctoral scholar. Faculty were asked to forward participation information to their current and recent postdocs. Postdoctoral scholar participants were recruited through snowball sampling from faculty, social media posts, and advertisements through the National Postdoctoral Association digital newsletter. Survey responses were collected using secure Qualtrics online survey software. After consenting to participate in the survey and providing position and demographic data, participants completed an adapted version of the MCA scale in ECS for postdoctoral scholars (MCA-ECS.P) and postdoctoral supervisors (MCA-ECS.S; Bahnson et al., 2023). The final

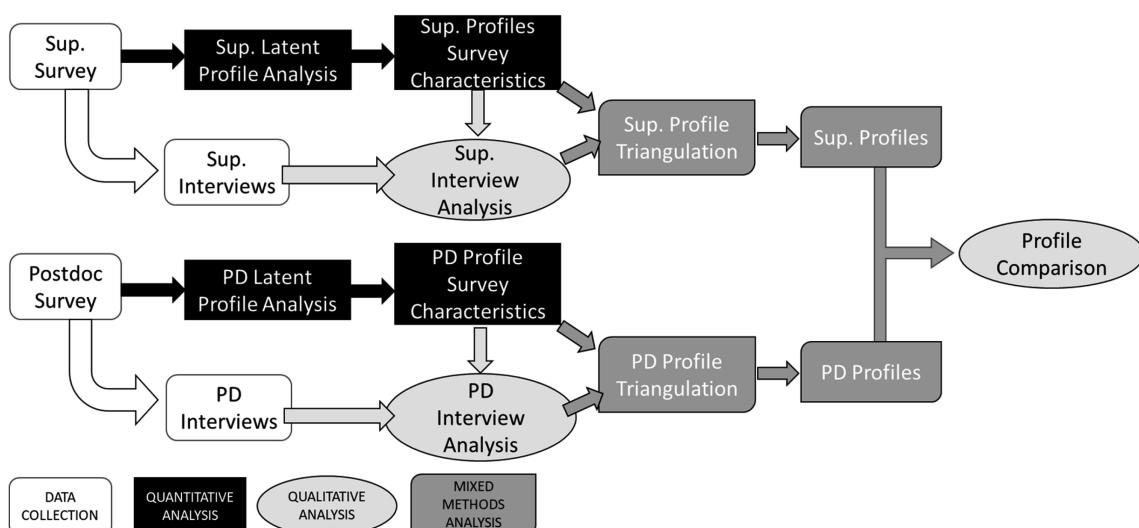


FIGURE 1 Data collection, analysis, and profile characterization for supervisor (Sup.) and postdoc (PD) data flow.

question on the survey asked if participants would participate in a semi-structured qualitative interview. Participants were asked to forward the study to other eligible postdoctoral or faculty participants.

Participants indicated their gender and race/ethnicity by selecting from listed options, including write-in options, and indicated their field of study in a write-in item. Individuals not in ECS disciplines and those who did not fully complete the survey were removed. The final analytical sample included 113 current or recent postdoctoral scholars and 165 faculty members with experience in supervising postdoctoral scholars in ECS. Faculty were not informed whether their postdocs completed the survey or the follow-up qualitative interview.

4.3 | Faculty demographics

The faculty survey participants had a wide range of experiences, including holding faculty appointments for 0–5 years (16%), 5–10 years (33%), 10–15 years (20%), 15–20 years (9%), or >20 years (22%). They mentored a range of postdocs, that is, 1–2 (48%), 3–5 (29%), 5–10 (16%), or ≥10 postdocs (7%). The faculty sample included women (30%) and men (70%) and represented a range of race and ethnicity identities, including 20% Asian, 3% Black or African American, 1% Hispanic or Latinx, 73% White, and 3% another race or ethnicity. Most faculty participants were raised in the United States (57%), while the remainder were from outside the country (43%). The faculty sample represented a range of ECS disciplines (e.g., civil, chemical, mechanical). Overall, the sample represents ECS faculty well with the sample slightly overrepresenting women and White faculty and underrepresenting Asian faculty (American Society for Engineering Education, 2020).

4.4 | Postdoctoral scholar demographics

Similarly, postdoctoral participants had diverse experiences, including holding positions between 1 and 4 years (1 year, 36%; 2 years, 26%; 3 years, 28%; 4 years, 10%). The majority were in their first postdoc position (74%), with some in their second (23%) and very few in a third postdoc position (3%). Some postdocs held positions in the same lab where they completed their Ph.D. (12%), while the majority had entered a new lab working with a new supervisor (82%), and a few had another arrangement (6%; e.g., new supervisor within the same lab). The postdoc participants represented a range of disciplines (e.g., civil, electrical, mechanical). Postdocs reflected current levels of representation of gender, race/ethnicity, and nationality in engineering (NCSES, 2023).

4.5 | Selection of interview participants

Interview participants were selected from the volunteers in the survey to represent the full range of survey participants. A total of 20 postdoctoral supervisors and 29 postdoctoral scholars were recruited to participate. Postdoc participants were selected to represent a variety of ECS disciplines, gender, race/ethnicity, nationality, MCA.ECS.P scores, and the number of postdoc positions. Similarly, supervisors were selected to represent a variety of disciplines, gender identities, race/ethnicity, nationality, and MCA.ECS.S scores, number of supervised postdocs, and years as a faculty member. Descriptive data for the qualitative interviews is available in Table A1. In the qualitative phase, we intentionally sampled women (Supervisor $n=4$; Postdoc $n=12$) and those from marginalized race and ethnicity groups (Supervisor $n=4$; Postdoc $n=18$) in ECS to ensure we heard issues from voices typically overwhelmed by dominant narratives, especially given our priority in considering postdoctoral mentorship as a critical link in broadening participation in the future professoriate. We include Asian and Middle Eastern participants in the marginalized race and ethnicity groups due to societal marginalization and discrimination (E. McGee, 2018; Park et al., 2017; Sue et al., 2007; Trytten et al., 2012), even though Asian and Middle Eastern people are not underrepresented in engineering spaces (American Society for Engineering Education, 2020; NCSES, 2023). However, we did not use a quota system for representation; rather, we sampled participants to ensure some diversity in gender, race/ethnicity, nationality, and MCA score representation. Participants were allowed to select a pseudonym for use in published work and were told that a pseudonym would be assigned to them if they did not want to select one. All participant names used are pseudonyms.

4.6 | Quantitative measures: Mentorship competency assessment scale

The original MCA scale was developed to assess six areas of research mentorship competency from the point of view of mentors and mentees and has demonstrated strong reliability and validity (Fleming et al., 2013). However, the MCA measures mentor and mentee beliefs on the same scale and the areas of mentorship were not identified based on factor analysis, rather focusing on groups of important mentorship areas supervisors should be competent in following a mentorship training (Fleming et al., 2013). That is, the original scale was not intended to measure postdoc and supervisor beliefs specific to each group or to measure mentorship factors; rather, it was intended to measure targeted mentorship issues (e.g., diversity) related to mentorship training. In previous work, we detailed the issues with the use of the MCA and our development of two scales based on scale development best practices (Bahnson et al., 2023). The resulting scales (MCA.ECS.P and MCA.ECS.S) include items from the original MCA and represent mentorship competency factors identified in the survey data (Bahnson et al., 2023). Items were removed from the original MCA on the basis of multicollinearity and exploratory factor analysis (EFA). EFA was conducted in SPSS with principal axis factor and oblique rotation (promax). The Kaiser criterion and parallel analysis were used to identify an appropriate factor solution (Gaskin & Happell, 2014). EFA indicated one overall factor for each scale (postdocs and supervisors). MCA.ECS.P includes 14 items with a prompt to assess their supervisor (“Please rate how skilled your postdoctoral mentor is in the following areas related to postdoctoral mentorship”). MCA.ECS.P demonstrated strong internal validity (Cronbach's $\alpha = .941$; Bahnson et al., 2023). MCA.ECS.S includes 17 items on which they rated themselves (“Please rate how skilled you feel you are in the following areas related to postdoctoral mentorship”) and held strong internal reliability for one factor (Cronbach's $\alpha = .939$; Bahnson et al., 2023). For each scale item, participants rated the item from “Not at all skilled” (1) to “Highly Skilled” (7) or selected “not observed.”

MCA.ECS.P and MCA.ECS.S hold a high level of face validity representing clear concepts important for postdoctoral mentorship. In addition, the adapted scales remain similar in content to the original MCA (Fleming et al., 2013) and to other assessment adaptations (MCA-21; Hyun et al., 2022). Evidence of convergent validity includes similarity to leadership skills as measured by LMX (Graen & Uhl-Bien, 1995). We considered correlation coefficients $>|.30|$ with significance levels (p) $<.001$ as evidence of convergent validity (Swank & Mullen, 2017) and $<|.70|$ as evidence of divergent validity (Bahnson et al., 2023).

4.7 | Qualitative methods: Semi-structured interview procedures

Participants selected for the semi-structured interview received an invitation to schedule a 75-min interview. All interviews were conducted via Zoom videoconferencing software and were recorded and professionally transcribed for analysis. Two ECS faculty interviewed the faculty supervisors, and two engineering education postdocs interviewed the postdoctoral participants to reduce power differentials and maximize rapport. The interview protocols were developed using best practices to generate broad engagement and responses from participants, framed through theory, existing literature, and in alignment with the research questions including the semi-structured nature of the interview. Theory informed the protocol to specifically ask questions about the social exchanges between postdocs and supervisors and the role of a postdoc. The semi-structured interview asked postdocs about their social exchange experiences as a mentee in a postdoctoral fellowship (e.g., *Can you describe the personality and working style of your postdoctoral advisor? What do you like and not like?*) and their beliefs about mentorship (e.g., *Do you expect your postdoc advisor to also be a mentor? Are those roles different in your mind?*). Postdocs and faculty were asked about their expectations of a postdoc (e.g., for postdocs, *How is your postdoctoral appointment structured? What are you responsible for? Were the expectations for your postdoctoral position clear to you at first? How have these expectations evolved over time?*) Similarly, interviewers asked faculty about their educational experiences (e.g., *Tell me about your trajectory to and through engineering/computer science?*) and perspectives on mentorship and supervision of postdocs (e.g., *To you, what is the educational purpose of a postdoctoral position?*). Protocols were piloted and refined through multiple passes of refinement with the research team. Interviewers used qualitative probes extensively to gain more detailed descriptions and to allow a flexible conversation about mentorship at the postdoc level. All participants who completed the interview received an Amazon gift card for \$25 in compensation for their time.

5 | DATA ANALYSIS

Data analysis was conducted in three phases: (i) LPA (quantitative), (ii) thematic analysis (qualitative), and (iii) triangulation (mixed methods). Each phase of analysis seeks to identify mentorship competency beliefs that shape the social and material exchanges in the postdoc-supervisor relationship with an emphasis on identifying key differences in how supervisors and postdocs negotiate postdoc roles through social exchanges that define the postdoc role and supervisor expectations. Social exchange theory and leader-member exchange theory provide a framework to conceptualize how social exchanges between a postdoc and supervisor shape the experience and perception of the postdoc role, expectations, and experiences of postdoc and supervisor. The theoretical framework assisted in identifying and interpreting the social and material exchanges and role definitions discussed by participants.

5.1 | Latent profile analysis of survey data

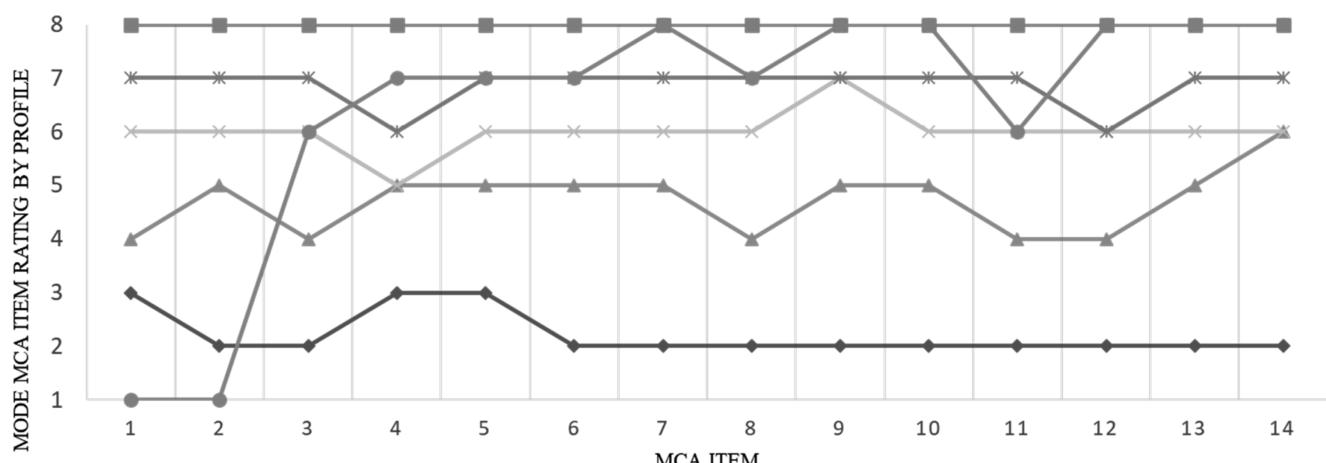
LPA is an appropriate analysis method when theoretical constructs underlie connections between indicators that combine in distinct ways to identify distinct profiles among participants (Spurk et al., 2020). In our case, the multiple skills required for postdoctoral mentorship combine to generate disparate mentorship beliefs and experiences for mentors and mentees. Supervisors and postdocs hold beliefs about mentorship that inform how they engage in social exchanges with each other. Supervisors' beliefs in mentorship competency provide an opportunity to identify different ways in which supervisors believe they should interact with postdocs. Similarly, postdoc mentorship competency assessments of their mentors provide an opportunity to identify the beliefs that have shaped their social exchanges with their supervisors. LPA was used to identify potential profiles of mentorship competencies. As a method, LPA can answer several questions for the research team in terms of how many profiles are appropriate; it can assign individuals to a profile and then identify the prevalence of profiles (Spurk et al., 2020). This is helpful to answer our first set of research questions (*How many and what profiles exist in the mentorship style for postdoc mentors based on self-assessment and mentee assessment? What is the frequency of each profile?*).

STATA was used to compare models with the different potential numbers of latent profiles. LPA analysis used the Gaussian family, log link measurement type to represent the continuous, non-normal nature of the survey data. We compared models based on relative fit information criteria based on the Akaike's information criterion (AIC), sample-adjusted Bayesian information criterion (SABIC), corrected Akaike's information criterion (AICc), consistent Akaike's information criterion (CAIC), and entropy. The lowest AIC, SABIC, AICc, and CAIC, with a higher entropy, indicate the best fitting models (Spurk et al., 2020; Tofghi & Enders, 2007). As part of the mixed-methods analysis, it was necessary to interpret and judge from these criteria a selected number of profiles that can usefully provide sufficient granularity to explore the mentorship beliefs of postdocs and supervisors and reflected the qualitative data. A thorough description of the model fit selection process is part of the Results section, as is conventional in LPA studies.

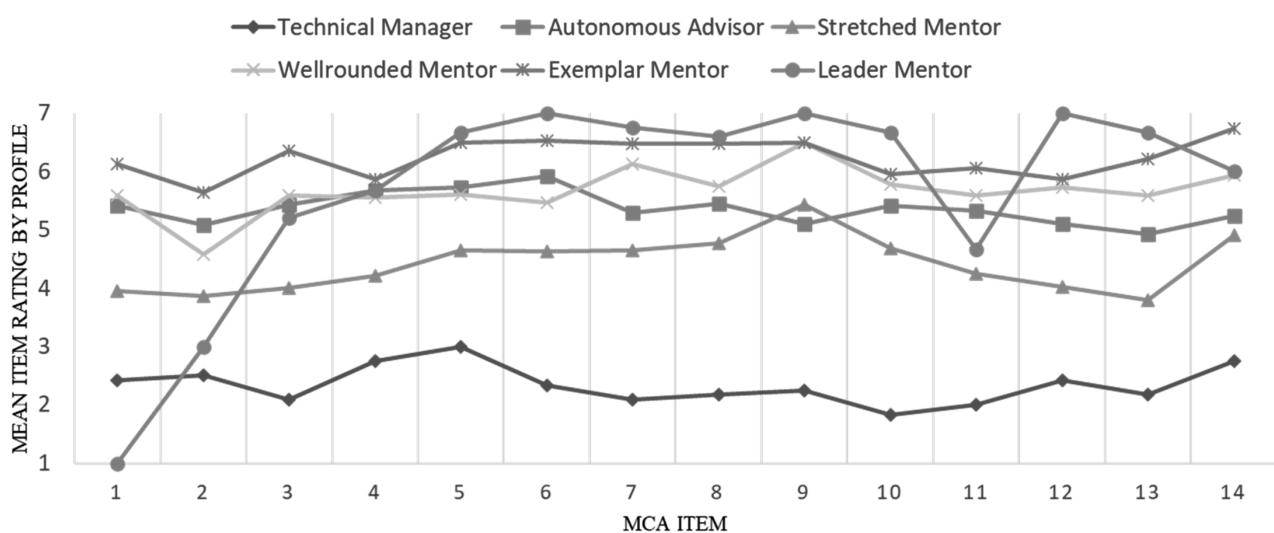
After LPA, we assigned each participant in the survey sample to their profile. The item-level means, standard deviations, skewness, kurtosis, and the number of participants were calculated for each profile. The mean indicators can assist in interpreting the content of profiles (Dahling et al., 2017; Moeller et al., 2018). In addition, we identified the mode for each indicator to provide another comparison between profiles. Graphed item-level means and modes (refer to Figures 2 and 3) were then used as we interpreted the meaning, characteristics, and comparisons for each profile, combined with analysis and interpretation of the qualitative interview findings from participants who represented each profile.

5.2 | Interview analysis

A secure online professional service was employed to transcribe the qualitative interviews before analysis. The research team cleaned the transcripts for accuracy and to de-identify the data. The qualitative interview data analysis improved our understanding of how the quantitative differences between the profiles manifest. Qualitative analyses facilitate a clearer individual-level picture of mentorship beliefs and how those beliefs shape postdoc and supervisor social exchanges, experiences, and role definitions. Some of the descriptors from the quantitative profiles were used as initial sensitizing codes (e.g., "lack of mentorship"), and each interview was coded based on the participant's quantitatively identified LPA. The coding process allowed for emergent codes and sensitizing codes based on the quantitative data



Panel 2a. Mode for each MCA postdoc item with lines for each latent profile



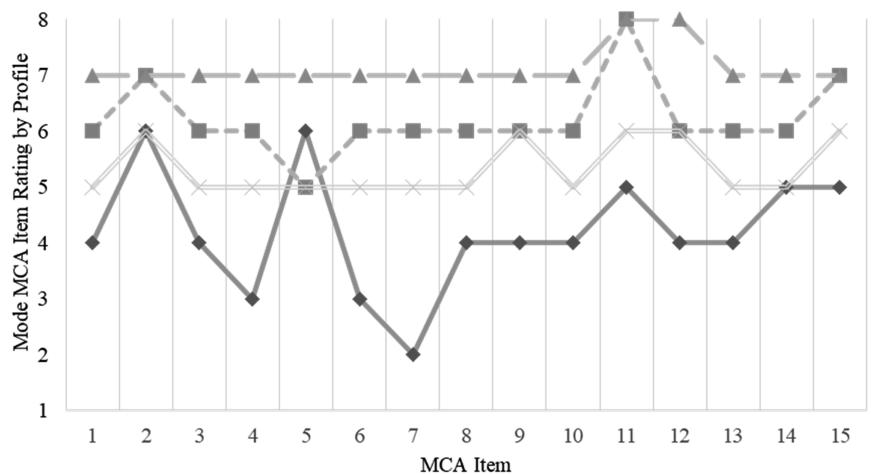
Panel 2b. Mean for each MCA postdoc item with lines for each latent profile

Panel 2c. MCA postdoc item key

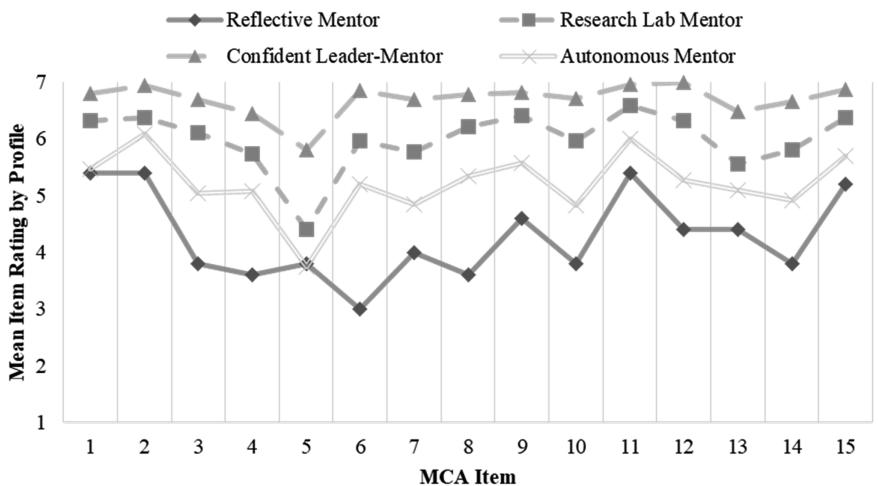
1. Pursuing strategies to improve communication
2. Coordinating with other mentors
3. Aligning expectations
4. Considering mentor–mentee differences
5. Developing strategies to meet goals
6. Assessing mentee knowledge
7. Building confidence
8. Stimulating creativity
9. Acknowledging mentee's professional contributions
10. Negotiating path to independence
11. Accounting for different backgrounds of mentors and mentees
12. Setting career goals
13. Understanding impact as a role model
14. Helping mentees acquire resources

FIGURE 2 Mode and mean rating for MCA postdoctoral latent profiles.

(Creswell & Miller, 2000; Creswell & Plano Clark, 2011). Interviews were coded in the NVIVO qualitative data analysis software by the first author, a postdoctoral fellow. Coded data were then developed into profile-based themes using thematic analysis (Creswell & Miller, 2000; Creswell & Plano Clark, 2011). Codes were used to generate qualitative themes for each profile to determine how those profile characteristics were represented in each participant's interview.



Panel 3a. Mode for each MCA supervisor item with lines for each latent profile



Panel 3b. Mean for each MCA supervisor item with lines for each latent profile

Panel 3c. MCA supervisor item key

1. Providing constructive feedback
2. Developing a trusting relationship
3. Accommodating communication styles
4. Pursuing strategies to improve communication
5. Coordinating with other mentors
6. Aligning expectations
7. Considering mentor–mentee differences
8. Enhancing mentee skills
9. Building confidence
10. Stimulating creativity
11. Acknowledging mentee’s professional contributions
12. Negotiating path to independence
13. Accounting for biases and prejudices
14. Accounting for different backgrounds of mentors and mentees
15. Setting career goals
16. Understanding impact as a role model
17. Helping mentees acquire resources

FIGURE 3 Mode and mean ratings for MCA supervisors by latent profile.

Themes were developed based on common codes within each profile. The final code list is presented later in the qualitative Results section.

5.3 | Triangulation

The latent profile triangulation method is based on best practices for mixed-methods research. The method is novel in that it uses qualitative data to describe latent profiles, unlike standard LPA analysis that focuses on the shape or quantitative distinctions in the profile data (Spurk et al., 2020). The profile-based qualitative codes provided insight into the differences between the quantitative profiles, allowing a more accurate characterization of the profiles through triangulation of the data streams (Creswell & Plano Clark, 2011). Here we use qualitative methods as an essential step in appropriately analyzing quantitative data—that is, we seek to elaborate and enhance the quantitative profiles through qualitative data (Flick, 2019; Greene et al., 1989). In our triangulation, we use the qualitative themes identified to explain the quantitative differences between LPA profiles (Creswell & Plano Clark, 2011). The analysis framework used qualitative themes to uncover the meaning behind quantitative differences in the LPA profiles. The triangulation analysis enables a connection between quantitative ratings and qualitative descriptions of social exchanges and role development in postdoc-supervisor relationships. Using themes allows a deeper and more complex characterization of the profiles while integrating the qualitative and quantitative data to gain new insights into the identified mentorship profiles.

5.4 | Positionality of the researchers

Two faculty members led the research team and hold technical engineering or computer science degrees, engineering education teaching and research experience with tenured positions at different nationally recognized colleges of engineering. Two engineering education postdocs contributed to the project through interviews, analysis, and writing, including the first author of this article. In addition, a computer science graduate student contributed to data collection logistics and analyses. The combined technical and practical backgrounds provide a nuanced view of postdoctoral mentorship. The primary analyst and first author holds mentorship expectations based upon training as a psychologist and engineering education researcher and developed during the postdoctoral position in which this research was the primary project and the third author served as mentor and supervisor.

As a team, we agree on the need for evidence-based education practice to improve ECS experiences. In particular, we share a critical view of the gendered and raced history of ECS from which we have developed as researchers and educators. Evidence-based education practice provides key opportunities to critique existing practices, norms, and institutions that continue to systematically oppress people from marginalized backgrounds (Pawley, 2017). Access and opportunity provided through postdoctoral study require critical and evidence-based practice to continue to increase diversity, equity, inclusion, and justice as a resource to work toward a more representative future professoriate. Our experiences in ECS as a White man, a Black woman, and a White woman invariably shape our perspectives and interests in improving training experiences for future postdocs. We adhere to trustworthiness and high-quality research standards (Walther et al., 2013) as essential to this work becoming a step forward in improving mentorship practice for ECS postdoctoral fellows and their supervisors.

5.5 | Limitations

As with all research, some limitations to the design and outcomes inform future research directions. The low representation in the qualitative interviews of the less frequent profiles represents a limitation in the generalizability of the qualitative descriptions of the profiles. Future research that can increase the representation of the less frequent profiles in quantitative and qualitative data may identify additional key aspects of these profiles.

The original intention of the multi-methods research did not include LPA identification and description. Instead, the need for LPA analyses was identified through qualitative thematic analysis, highlighting the often contradictory views on the postdoctoral position (Bahnson et al., 2022a). Future research designed to measure and describe postdoctoral mentorship LPAs may identify additional nuance or context necessary to understanding postdoctoral mentorship

competency in ECS. Similarly, future research could assess the significance and implications of profiles in predicting postdoc outcomes such as career success, choice, and satisfaction.

A key limitation of our research is not engaging postdoc-supervisor pairs. Initially, we considered this an opportunity to explore specific sets of mismatched expectations. However, postdoctoral supervisors hold an extremely high level of influence over postdocs' future employment, career development, research, and publication opportunities. As such, with qualitative data, we did not feel we could adequately protect anonymity for postdoc participants. Any paired quote would result in the participants identifying with each other. At the same time, postdoc supervisors depend on the productivity and abilities of postdocs, some of whom were still active in the lab. We were concerned that supervisors may be less forthcoming about their postdocs as well. The potential for severe and lasting harm to a postdoc-supervisor relationship outweighed our interest in matching postdoc and supervisor experiences.

Finally, the reported research applies only to ECS, which may have unique disciplinary characteristics from other science, technology, or math disciplines. In this field, postdoctoral funding often comes from NSF; however, other funding sources are also common. Our recruiting focus on NSF awardees may create unintended limits on generalizability within ECS postdoc supervisors. The faculty participants described their experiences that reflect their backgrounds and training, highlighting the need for additional research to investigate potential differences between faculty. Future research should seek to identify the funding mechanism for postdoc scholars to identify potential differences influenced by funding sources and requirements. In addition, future research with science and mathematics postdocs may find similar or distinct postdoctoral mentorship profiles. This research provides a template for such research to expand our understanding of the differences and similarities in STEM postdoctoral mentorship.

6 | RESULTS

The latent profiles for postdocs and supervisors are presented first, with the quantitative descriptions of each profile. The qualitative characterization follows the quantitative descriptions. The last Results section directly compares postdocs' and supervisors' quantitative and qualitative profiles. In the following sections, we have labeled profile names (P) for postdoc and (S) for supervisor to clarify which group the profile belongs in—especially in the Comparison and Discussion sections, the distinction becomes important. In addition, we have italicized items to distinguish them from other text and profile names. As a note, some of the profile names are *purposefully similar* between the postdoc and supervisor themes as a way of showing the commonalities in the profiles of the two stakeholder groups.

6.1 | Latent profiles identified

Table 1 indicates the model fit estimations. These estimations do not identify the number of profiles appropriate without additional interpretation. For postdocs, the lowest AICc is for three profiles and SABIC is for four profiles, with both models exhibiting acceptable entropy ($>.90$). However, the six-profile model has the lowest AIC and CAIC with a higher entropy than the three- or four-profile models. As part of mixed-methods analysis, a three-profile model does not provide useful information for understanding postdoc mentorship experiences. Reviewing the item-level means by profile for the three-profile model showed profiles of high, moderate-high, and moderate across all items. Similarly, a four-profile model produces very high, high, moderate-high, and moderate profiles on survey items. However, previous qualitative analyses of postdoc and supervisor interview data (Bahnson et al., 2022a; Bahnson et al., 2022b; Bahnson et al., 2023) have shown a much more complicated picture of mentorship experiences, with positive and negative experiences in different aspects of mentorship (refer to Discussion). For these reasons, we continued our analysis with the six-profile model for postdocs.

For supervisors, the fit indicators provide a somewhat more direct solution (Table 2). The lowest fit indicators are split between a three-profile (AICc and CAIC) and a four-profile (AIC and SABIC) model. The four-profile model had the higher entropy value. Again, reviewing the item-level means for each profile, the three-profile model produces a simple set of very high, high, and moderate-high supervisor mentorship profiles. Based on previous qualitative analyses, we knew this three-profile solution did not adequately represent the kinds of varied narratives supervisors had given us. We continued analysis with the four-profile model for supervisors. The models with six postdoc and four supervisor latent profiles were selected based on the review of all fit measures, the utility of profiles, and fit with qualitative data.

TABLE 1 Number of profiles with fit statistic scores for postdoctoral and supervisor profiles.

Number of profiles	LL	FP	AIC	SABIC	AICc	CAIC	Entropy
Postdoctoral participants							
2	-2143.58	43	4373.15	4490.05	4428.80	4533.05	0.96
3	-2085.83	58	4287.67	4444.30	4421.86	4502.30	0.93
4	-2041.11	73	4228.22	4426.68	4512.54	4499.68	0.93
5	-2043.56	88	4263.11	4500.75	5009.01	4588.75	0.95
6	-1996.65	103	4199.30	4477.45	7769.97	4580.45	0.96
7	-1983.24	118	4202.48	4521.13	1082.03	4639.13	0.97
Supervisor participants							
2	-4212.62	52	6972.07	7143.22	7028.07	7198.22	0.97
3	-3256.38	74	6660.75	6891.04	6782.73	6965.04	0.94
4	-3205.91	93	6597.82	6887.23	6840.65	6980.23	0.97
5	-3204.20	111	6630.39	6975.82	7090.84	7086.82	0.97

Note: Bold numbers show the lowest value and italics show the highest value.

Abbreviations: AIC, Akaike's information criterion; AICc, corrected AIC; CAIC, consistent AIC; FP, free parameters; SABIC, sample-adjusted Bayesian information criterion.

6.2 | Postdoc profiles

In the following subsections, the results for the postdoc data are reported and summarized. First, the quantitative ratings of supervisors by postdocs are discussed by the LPA profile. Second, the qualitative data are provided by the LPA profile. Finally, the triangulation of meaning between quantitative and qualitative data streams is used to describe the postdoc profiles.

6.2.1 | Postdoc quantitative profiles

LPA indicated six profiles for postdocs' ratings of their mentors. Figure 2 (Panels 2a and 2b) is line graphs depicting each postdoc profile's (a) mean and (b) mode response to each MCA.ECS.P item. The points on the graph indicate the mean or mode for each item based on a single profile, which allows comparison between the quantitative differences in the LPA-identified profiles. In the first, Technical Manager(P), postdocs rated mentors low across items (Figure 2) and was the second least common profile ($n = 13$). The mode (Panel 2a) and mean (Panel 2b) of all items were ≤ 3 on the 7-point scale, indicating a generally poor assessment of mentorship competency by these postdocs of their supervisors. Two items had the lowest means for any profile: *Negotiating path to independence* (Item 10) and *Accounting for backgrounds* (Item 11). For the second and most common profile ($n = 78$), Autonomy Focused Advisor(P), postdocs most commonly selected the "unobserved" response on all MCA items (Figure 2, Panel 2a). However, the means for all MCA items in this profile remain moderately high, between 5 and 6 (Figure 2, Panel 2b), indicating tension between the modes emphasizing unobserved skills and moderately high means on other mentorship skills. The Stretched Mentor(P), the third profile ($n = 60$), postdocs rated their supervisors in the middle with mode and mean of all MCA items hovering around or just above 4 (Figure 2, Panels 2a and 2b). The exceptions are *helping mentees acquire resources* (Item 14) with a mode of 6 and *acknowledging mentee's professional contributions* (Item 9) with a mean above 5.

The fourth and fifth profiles, Well-Rounded Mentor(P) ($n = 51$) and Exemplar Mentor(P) ($n = 61$), held high and very high, respectively, modes and means for all MCA items (Figure 2, Panels 2a and 2b). However, the means for both profiles dip for the item *coordinating with other mentors* (Item 2). The sixth and least common ($n = 7$) postdoc mentor profile is the Leader-Mentor(P), which had high mode and mean for MCA items except for two: *pursuing strategies to improve communication* (Item 1) and *coordinating with other mentors* (Item 2; Figure 2, Panels 2a and 2b).

TABLE 2 Postdoctoral rating of supervisor profiles: Survey and qualitative characteristics of postdoctoral profiles with qualitative examples from interviews.

Profile number	Profile name	MCA-scale characteristics	Profile-specific codes	Qualitative characteristics	Interview examples
1	Technical Manager(P)	Postdocs rated mentors below average across items with items 10 and 11 particularly low.	<ul style="list-style-type: none"> Lack of mentorship Independence Future planning DEIJ Discrimination Background 	Research-focused at the expense of other mentorship.	<p>Our research meetings have just a research focus, we're just talking about what does the data mean. I have another professor who we talk about career and that side of things. (Rosie)</p> <p>I think he's not really a hands-on researcher and he's getting more and more not hands-on over the years. I would describe him more as a manager and, as a manager, he's not very, very involved, so you have a lot of freedom. However, in some sense, he was involved, and, in some sense, he wasn't. (David)</p>
2	Autonomy Focused Advisor(P)	“Unobserved” response was most common rating on all MCA items.	<ul style="list-style-type: none"> Time Positive mentorship experiences Negative mentorship experiences 	Low or unstructured engagement with both positive and negative mentorship experiences.	<p>[Meetings happened] if my advisor is around in the department, when we're chatting over Slack, he would just say that, let's quickly have a personal meeting, he would drop by to my office. (Amir)</p> <p>They're very supportive. So I think the idea is always to work towards something that would help me. So, let's say if we are just discussing a project, they would take up the role of a mean reviewer and ask me tough questions. (Amir)</p> <p>In the beginning it was kind of intimidating to me, but then they clarified that that's what we mean ...</p> <p>Well, they were not supportive, but they were understanding of the situation. (Amir)</p>
3	Stretched Mentor(P)	Middle ratings across items in mean and mode.	Impact on mentee from mentor	All mentors were junior faculty or from marginalized groups.	<p>I feel like my advisor is, like, she's respected and respected in a fine way, you know? But I wonder if she would be more respected and more revered if she were a man? (Lea)</p> <p>Because we are Asian and our way of communication is a little bit different with American, and also maybe because of my English is not really good and sometimes the other members in the lab do not want to speak much with me like they speak together. (Hun)</p>

(Continues)

TABLE 2 (Continued)

Profile number	Profile name	MCA-scale characteristics	Profile-specific codes	Qualitative characteristics	Interview examples
4	Well-Rounded Mentor(P)	High mode and mean across MCA items.	<ul style="list-style-type: none"> Positive mentorship experiences DEIJ Discrimination Background Other mentors 	Generally positive mentorship experiences.	He'll ask me about my career goals, ask me if I need help with anything, he offers to read proposals I'm working on. And he checks in on me with life outside of the lab. (Ethan)
5	Exemplar Mentor(P)	Very high mode and mean across MCA items—except coordinating with other mentors.	<ul style="list-style-type: none"> Positive mentorship experiences Engagement 	Generally positive mentorship experiences with something which makes the relationship especially valuable.	If I'm struggling with something, he would literally sit next to me on my desk and certainly help me figure it out. ... he doesn't mind getting his hands dirty. (TomBrady)
6	Leader-Mentor(P)	Low mean and mode for communication and coordinating mentors.	<ul style="list-style-type: none"> Communication Other mentors 	Positive mentorship with postdocs conforming to PI communication styles.	<p>I don't get a lot of his time, but I get enough that I get good guidance. He has kind of an interesting set up where he has bi-weekly stand-up meetings. (BIB2B3)</p> <p>I actually went out of my way to ask people that I admire about what their advice. (Abel)</p>

Note: Item 10 = Negotiating path to independence; Item 11 = Accounting for backgrounds.

Abbreviation: DEIJ, diversity, equity, inclusion, and justice.

6.2.2 | Postdoc qualitative profiles

Profile-specific a priori codes were developed based on the quantitative data for each profile (Table 2). Distinguishing characteristics (i.e., mean or mode differences in profiles) were identified by taking the essence of the item as a code. For instance, for the Technical Manager(P) profile, the low mean for *negotiating path to independence* (Item 10) led to a code of *independence* for the qualitative interviews in the Technical Manager(P) profile (Table 2). Qualitative analysis of interviews with postdocs identified unique meanings for similar concepts. Thematic analysis identified several common themes for postdocs that aligned with several mentorship competency categories as well as the social and material exchanges and experiences of postdocs. For example, communication and independence were common mentorship competency themes for postdocs. Broad themes of positive and negative experiences with supervisors represented the two most common themes in postdoc interviews.

Interview data provides a much more robust demonstration of the differences between postdoc profiles. The Technical Manager(P) profile generally exhibited low MCA ratings, leading to multiple qualitative codes such as lack of mentorship (Profile-Specific Codes, Table 2). In the qualitative data, the lack of mentorship is tied directly to the qualitative characteristic of research-focused at the expense of other forms of mentorship (Table 2). In addition to the qualitative examples in Table 2, Greta discussed the supervisor relationship as focused on completing research “My primary responsibilities are, I am doing my own research” which is then reported to the principal investigator on the project who “doesn’t have time to build the community and interactions for sustainable collaboration.”

The Autonomy Focused Advisor(P), Well-Rounded Mentor(P), and Exemplar Mentor(P) profiles generally held positive MCA scores leading to “positive mentorship” as a profile-specific code for each (Table 2). However, despite the similarity between profiles in LPA-based codes, interview data clarified the distinctions between profiles, illustrating nuances between similar codes. For example, in Autonomy Focused Advisor(P), low or unstructured supervisor engagement dampens positive mentorship and is further hindered by negative mentorship within the same relationships (Table 2). Here and in Table 2, qualitative quotes are intentionally from two participants who demonstrate all three features of the Autonomy Focused Advisor(P) profile. For example, Wesley discussed his supervisor as disengaged from the research process characterizing the relationship as unstructured (Table 2) and as “It’s just unofficial, ‘You need help, I’ll help you. Come to me if you need help. I’ll check in with you every couple of weeks’, but that’s sort of about it.” This approach gave Wesley both a sense of independence and as being unsupported, contributing to an agitated and stressful work environment: “He is a very intense man and runs a very intense and stress-filled lab.” Wesley’s supervisor also provided specific and positive mentorship related to his career goals, even though Wesley was surprised by the comment:

He actually took the time to say, “No, you are doing very well. You could get an R1 tenure track position, and I think you would be selling yourself short if you took this position.” So that ... It’s surprising, but that reduced my stress level by a ton knowing that he is approving of the work I’m doing and will write me a really good letter of rec, and I’m in no danger at all right at the moment.

However, Wesley felt unable to approach his supervisor, generating conflict between independence and the need for positive mentorship for fear of negative mentorship interactions.

In Well-Rounded Mentor(P) and Exemplar Mentor(P) profiles, positive mentorship represents a standard expectation for mentorship, with Exemplar Mentor(P) taking on an unexpected element of positive mentorship. For both, positive mentorship was described as an interest in the research, career, and success of the postdoc. Ethan described his Well-Rounded Mentor(P) as “very involved” available to discuss career goals, read proposals, and “he checks in on me with life outside of the lab.” The Exemplar Mentor(P) has similar positive mentorship descriptions with an added or unexpected element demonstrating special attention to mentor-mentee relationships identified in qualitative descriptions of these supervisors (Table 2). Some described the supervisor in positive social terms, such as Catherine who said “she’s awesome, she’s very cool” and Colette “she is really such an open person” or recognized the extra effort required of mentors: Chuck said “she *actually* tries, really!” as if to say that even the act of trying to be a good mentor was unexpected.

The last postdoc profile, Leader-Mentor(P), focuses on the low mean and mode for “communication” and “coordinating with other mentors” MCA items. Again, the meaning of the low items gains clarity from the qualitative data. Communication issues in the profile more clearly revolve around the need for postdocs to adapt to the supervisor’s communication style—rather than negative or no communication (Table 2). In addition, the participant who chose the

pseudonym BIB2B3 said that in a research group setting, his supervisor is “very focused on the project, we have these deadlines” while one-on-one meeting communication can be more “mentory,” comprising identifying individual research objectives, how to reach them, and the support needed. In addition, postdocs who characterized their supervisors as Leader-Mentor(P) discussed having additional independently identified mentors. Abel described several mentors besides his supervisor: “I had my UG advisors, mentors in industry, … a friend who was a professor” in addition to his postdoc mentor.

6.2.3 | Postdoc profiles summary

Briefly, we will summarize the main characteristics and differences between the postdoc profiles. The Technical Manager(P) focuses on the research productivity of the postdoc while not engaging other areas of mentorship such as preparing the postdoc for independent research or adjusting expectations or mentorship to account for differences in the postdoc’s background.

The Autonomy Focused Advisor(P) focuses on the independence of the postdoc, allowing freedom for postdocs to develop; however, positive and negative mentorship experiences add nuance to individual relationships in this profile. The Stretched Mentor(P) provides as much mentorship as possible given the competing demands of pre-tenured faculty time and attention while facing additional challenges as members of marginalized groups. The Well-Rounded Mentor(P) and Exemplar Mentor(P) exhibited generally positive mentorship characteristics. However, the Exemplar Mentor(P) included some special experiences that positively surprised postdocs in the relationship. The Leader-Mentor(P) profile had positive mentorship for research and independence but required postdocs to conform to the communication styles and preferences of the supervisor. In addition, Leader-Mentor(P) supervisors expected postdocs to identify other mentors independently.

6.3 | Supervisor profiles

As with the postdoc profiles, the following subsections present the summarized results for the supervisor data. The supervisors’ quantitative ratings are discussed by the LPA profile, and qualitative data by the LPA profile, with the triangulation of meaning between quantitative and qualitative data streams as the final section.

6.3.1 | Supervisor quantitative profiles

LPA indicated four profiles for supervisors’ ratings of their mentorship competency. The first and rarest ($n = 6$) category of supervisors, who comprised the profile called Reflective Mentor(S) supervisors, gave themselves moderate ratings across all MCA.ECSS items (Figure 3). The mode fluctuated between relatively high 6 and relatively low 2 (Panel 3a), and the means more consistently centered around 4 (Panel 3b). The second most common profile ($n = 68$), Research Lab Mentor(S), held high modes for most items except *coordinating other mentors* (mode = 5), and the modal value was 8, “unobserved” for *acknowledging the mentee’s professional contributions* (Panel 3a). The mean for items remained high, with a dip to near 4 on the *coordinating other mentors* item (Panel 3b). The most common profile ($n = 87$), Confident Leader-Mentor(S), had item modes at the highest point (7) except for two modal values of 8, unobserved, for *acknowledging the mentee’s professional contributions* and *negotiating a path to independence* (Panel 3a). The mean values for this profile were consistently higher on all MCA items; however, a dip in the mean for *coordinating other mentors* is present (Panel 3b). The last profile, Autonomous Mentor(S), was less common ($n = 26$) and had moderate modes for all items (Panel 3a). The means fluctuated between 4 and 6, except for a similar dip in the mean for *coordinating other mentors* (Panel 3b).

6.3.2 | Supervisor qualitative profiles

Supervisor interview themes focused on the role of the postdoc within the lab, the purpose of the postdoc, the qualities of a productive postdoc, and the focus of the supervisor on research, productivity, or people. While useful in describing

the profiles, thematic analysis was most useful in distinguishing the nuances in emphasis for supervisor profiles around people and productivity. Qualitative profile-specific codes (Table 3) assisted in distinguishing supervisor interviews that had similar quantitative profiles. The Research Lab Mentor(S) and Confident Leader-Mentor(S) profiles had similar MCA scale item ratings, with the qualitative data clarifying the differences between the profiles. For instance, both had modal values of 8, unobserved, for *recognizing mentees' contributions*. Qualitative data indicate that the supervisors in the profile Confident Leader-Mentor(S) focus on results for existing projects: the supervisor sends them off, and the postdoc returns with results. At the same time, the profile Confident Leader-Mentor (S) members' approach to research limits the postdoc's ability to develop independence, reflecting the "unobserved" mode for *promoting postdoc independence*. For example, Carmen described the postdoc onboarding process and the direct supervision from a permanent staff member who coordinates the projects, subprojects, and specific analyses with the postdoc.

We have a Google Drive that has relevant papers and PowerPoints, and other things to get them up to speed on the general project, and then we also have documentation for using the computational resources ... And then my project specialist, she knows all of the projects in the lab really well, so she'll work with them when they get started. And then they'll usually let me know what type of data analysis they wanna start with, what's subproject that they wanna work on, and then they'll get started on that, and we'll go from there. (Carmen)

This provides a strong background for postdocs, support in the beginning, and structure while separating the supervisor/mentor from direct observations of the postdoc's development in independent research.

However, the "unobserved" mode for *recognizing the mentee's contributions* in Research Lab Mentor(S) holds two meanings (Table 3). Research Lab Mentor(S) profile supervisors use a hands-off approach to their postdocs supervising lab research, indicating that "unobserved" is literal: supervisors do not see postdocs working in the lab. For example, Kevin uses a supportive framework while expecting the postdoc to develop research plans:

I do very little. So, I try to treat my postdocs more collegially than I would with a student, where I'm not trying to cut your food for you, I want to see how you construct a plan. And I'm not ... I'm trying to not put myself in the position of, "I'm here to approve or disapprove of your plan." I'm a resource for strategizing, I want to see how you think about research, but I want to lean in only if I think something is horribly, horribly wrong. (Kevin)

Other Research Lab Mentor(S) profile supervisors' "unobserved" ratings were reflected in supervisors identifying a lack of specific skills in their postdocs (Table 3). For example, Edwin discussed problems that arise when the postdoc supervises graduate students who stop producing results: "She didn't really have much experience with that and didn't realize when there is a real problem that requires an intervention."

Another difference between Research Lab Mentor(S) and Confident Leader-Mentor(S) profiles is the supervisor's approach to other mentors. Supervisors exhibiting the Research Lab Mentor(S) profile did not focus on coordinating other mentors, but instead focused on postdocs becoming "other mentors" for the students within the research lab. Again, Edwin provided a framework for postdocs to manage students, which he intended to support mentorship within the lab supervision structure: "I give the framework and the tools to her [the postdoc] to sort of supervise and collaborate with students, so we use task management software." While the Research Lab Mentor(S) held an internal "other mentor" approach, Confident Leader-Mentor(S) profile participants intentionally encouraged postdocs to identify and develop additional mentor relationships (Table 3). For example, Hugo discussed a postdoc who needed expert information on a topic less familiar to the supervisor and said, "I connected them [external expert and postdoc], and then she [postdoc] had communications with the person, but it was with some objective in mind. So, I definitely introduced them [the postdoc] to other colleagues." The external and internal focus of "other mentors" can be beneficial depending on the postdoc's development needs.

Profile Reflective Mentor(S) had fewer and less apparent defining features based on the MCA scale item ratings. However, the qualitative analysis identified distinctions in line with the MCA descriptions (Table 3). The least common profile, Reflective Mentor(S), with moderate self-ratings across items, we thought the MCA ratings might indicate increased self-awareness in how they mentored postdocs. The single qualitative interview for Reflective Mentor(S) demonstrated this self-reflective perspective on postdoc mentorship. Erin reflected on her experience saying, "I didn't know

TABLE 3 Supervisor self-rating profiles: Scale and qualitative characteristics of postdoctoral profiles with qualitative examples.

Profile number	Profile name	MCA-scale characteristics	Profile-specific codes	Qualitative characteristics	Interview examples
1	Reflective Mentor(S)	Moderate self-ratings across items	Self-reflection	Self-reflective concern for efficacy of postdoctoral mentorship	I have really lost sleep over it, that's partly just growing as a faculty member I think. When you have someone that you try your best support and it just doesn't work. (Erin)
2	Research Lab Mentor(S)	High ratings except coordinating other mentors and "unobserved" mode for recognizing mentee's contributions	<ul style="list-style-type: none"> • Other mentors • Mentee contributions 	<p>Mentorship focused on students, rather than building other mentorship relationships</p> <p>Hands-off approach to postdoc research</p> <p>Postdoc lack research skills</p>	<p>[Lab structure] It's definitely PI postdoc graduate students and undergrads, because the postdoc just has the knowledge in the lab, I can't be in the lab enough to help the graduate students, but the postdoc can, so then the postdoc kinda gets to be in-charge of, here's what we're trying to get accomplished today, that type of thing. (Louis)</p> <p>I found that some analytical skills were missing in my postdoc. (Josiah)</p>
3	Confident Leader-Mentor(S)	Mode at 7 except: "unobserved" mode for recognizing mentee's contributions and promoting independence	<ul style="list-style-type: none"> • Research focus • Mentee independence • Mentee contributions 	<p>Focused on postdocs contributing to existing projects</p> <p>Involvement of other mentors</p>	<p>We have to have a kick-off meeting and we sit down and I will tell them the job, this is what we need, and this is the short-term goal and the long-term goal, and how many papers we want, how many experimental work we should do in the lab, what machines we have, how to deal with people in the lab, the timing, their office, how many conferences we're gonna attend, all of this, we set them. We set those goals and they have to give me a progress report every week. (Arran)</p> <p>And so making sure that she has people who are advising her, providing various different feedback from different perspectives, so it's not just the perspective that I have and learning from others, both internally at the institution, but also externally. (Sean)</p>
4	Autonomous Mentor(S)	Strong belief in skill set; Not all high ratings	<ul style="list-style-type: none"> • Relationship • Coordinating mentors • Mentee contributions 	<p>Person focus</p> <p>Product focus</p>	<p>Self-motivation is the biggest thing I'm looking for [in a postdoc]. (Chris)</p> <p>I'll give them [the postdoc] a copy of the funded proposal on white paper first because that's our deliverables. So, they're responsible for making sure we hit the deliverables. (Chris)</p>

what I was doing; I felt so insecure.” Our participant had an all-around negative experience mentoring a postdoc and spent significant time during and after the postdoc reflecting on her role in the failure of the postdoc (Table 3).

Autonomous Mentor(S) held a similar challenge with few distinguishing MCA features. However, using the Profile-Specific Codes (Table 3) allowed us to identify two distinctive features of the Autonomous Mentor(S). Participants in the Autonomous Mentor(S) profile focus on two aspects of mentorship: (i) the person or personality and (ii) the research product. Autonomous Mentor(S) supervisors sought postdocs with the right qualities, such as self-motivation, that could be used and molded in any research field (Table 3). For example, Zachary discussed the importance of personal qualities and group dynamics over specific research abilities:

I believe that the quality of the person is more important than the [research] area [expertise/knowledge]. I can teach somebody the area. If they're not good, then there's not a whole lot I can do. ... I worry a lot about my group dynamics. ... A really good postdoc, they really can help everybody else in their group, I found that to be really important. (Zachary)

At the same time, Autonomous Mentor(S) supervisors focused on the output of postdocs regarding project deliverables or research papers (Table 3). Again, even for Zachary, who holds a person-focus on who should be in the lab, holds a strong research product focus: “At the end of the day, what I care about is papers. That's it. That's what you're here for, that's what I care about, I want papers.” Here and in Table 3, we use person and product-focus quotes from the same two mentors to demonstrate that these expectations coexist in Autonomous Mentor(S).

6.3.3 | Supervisor profiles summary

Briefly, we will summarize the main characteristics and differences between the supervisor profiles. The Reflective Mentor(S) highlighted self-reflection on mentorship ability and rated themselves moderately demonstrating the recognition that improvement in mentorship skills is possible and necessary. Research Lab Mentor(S) expected research productivity from postdocs and focused mentorship on graduate students. This allowed for independence and the opportunity for missed mentorship opportunities. Confident Leader-Mentor(S) profile supervisors believed in their competency as mentors and focused on postdocs contributing to existing research projects with little emphasis on postdocs developing independence or the involvement of other mentors. Similarly, Autonomous Mentor(S) supervisors believed in their skills and held a dual focus on postdocs as a person who needed motivation and development compared to the expectation that a postdoc could independently contribute to research progress with clear deliverables.

6.4 | Profile comparison

Postdoc and supervisor profiles share some similarities based on postdoc ratings of their supervisors and supervisor self-ratings. Technical Manager(P) profile was typified by low mean ratings across items and is interpreted as focusing on research at the expense of mentorship. No supervisor profile held similarly low self-ratings as these postdocs rated their supervisors. Other supervisor profiles held a similar focus on research in which supervisors rated themselves as performing other forms of mentorship.

Autonomy Focused Advisor(P) and Autonomous Mentor(S) profiles share medium-high ratings with means hovering around 5 across items with a dip at the item *coordinating other mentors*. However, the Autonomous Mentor(S) profile does not share the same mode of unobserved items across items found in Autonomy Focused Advisor(P). The postdoc profile Stretched Mentor(P) and supervisor profile Reflective Mentor(S) share moderate ratings on most items, with the mean fluctuating around 4 with a peek at the item assessing supervisor's ability in *acknowledging mentee's professional contributions*. The postdoc profile Well-Rounded Mentor(P) and supervisor profile Research Lab Mentor(S) align around generally positive mentorship experiences with a research focus and a lack of other mentor coordination. Exemplar Mentor(P) and Confident Leader-Mentor(S) also mirror each other closely, with postdoc rating averages slightly under supervisors' average self-ratings representing an overall positive mentorship experience. Similarly, Leader-Mentor(P) aligns with Confident Leader-Mentor(S) except for the postdocs' mean rating ($M = 1$) for the item measuring *pursuing strategies to improve communication* well below the supervisor's average rating ($M = 6.44$).

Figure 4 shows how the postdoctoral profiles align (dotted lines), misalign (question marks), or do not align (X) with supervisor profiles, offering an illustration for how “misaligned expectations” between faculty supervisors and postdoctoral scholars manifest in terms of mentorship philosophy (which will be further interpreted concerning theory and literature in the Discussion section).

6.5 | Results summary

Briefly, we answered our first research question by identifying six postdoc profiles and four supervisor profiles, summarized with the number of participants per profile in Figure 4. Similarities exist between profiles; however, with our mixed-methods approach we were able to identify quantitative and qualitative differences between profiles. Tables 2 and 3 provide detailed information on each profile with a brief description in Figure 4. Differences in postdoc profiles tended to identify the emphasis on the supervisor's relationship with the postdoc, research, mentorship, relationship, or the lack of a necessary aspect of leadership such as communication. As depicted in Figure 4, profile alignment between postdoc and supervisor profiles is not clear-cut. Initially, similarities based on the quantitative data seem to connect profiles fairly well, while the qualitative data tended to demonstrate the importance of the quantitative differences.

7 | DISCUSSION

This is the first study that specifically works to characterize different mentorship profiles within the context of postdoctoral education, and the first to also assess how conceptualizations of mentorship are different from the points of view of postdoc and postdoc supervisors within ECS. Identification of mentorship profiles from the perspective of mentors and mentees demonstrates why misalignments occur in postdoctoral education: mentors and mentees hold some similar yet distinct perspectives on postdoctoral mentorship. In sum, the takeaway from this work, viewed through the framework of LMX theory, shows specifically how easy it is for misalignments to occur rooted in differences in mentorship beliefs, and begins to disentangle what those specific misalignments are in the mentoring relationship.

In response to our first research question to identify the number and frequency of mentorship profiles, we identified six postdoc profiles from their assessments of a mentor's competency and four mentor profiles of supervisors from their self-assessments of mentorship competency. Most postdoc participants fell within four of the profiles: Autonomy Focused Advisor ($n = 78$), Exemplar Mentor ($n = 61$), Stretched Mentor ($n = 60$), and Well-Rounded Mentor ($n = 51$), with far fewer in the other two profiles, namely Technical Manager ($n = 13$) and Leader-Mentor ($n = 7$). The four supervisor profiles identified included Confident Leader-Mentor ($n = 87$), Research Lab Mentor ($n = 68$), Autonomous Mentor ($n = 26$), and Reflective mentor ($n = 6$).

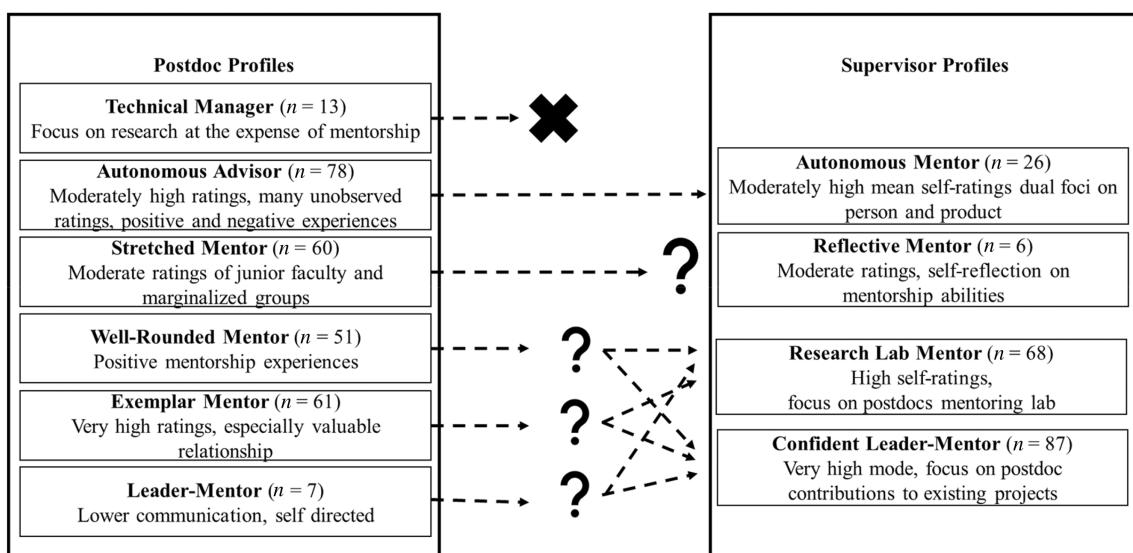


FIGURE 4 Alignment between postdoctoral and supervisor profiles.

Our quantitative and qualitative analyses provided detailed descriptions of the characteristics of mentors within each profile. The profiles based on postdocs' assessments demonstrate the wide range of experiences in mentorship from their supervisors. Postdocs' positive and negative ratings of their supervisor's mentorship reflect that some postdocs have very positive experiences while others have very negative experiences with their supervisor (Camacho & Rhoads, 2015; Mendez et al., 2021; Omary et al., 2019; Scaffidi & Berman, 2011; Yadav et al., 2020). Postdocs in the Technical Manager(P) profile described their supervisors' focus on research at the expense of other forms of mentorship. The focus on one aspect of the social exchange, namely the research product, limits the social resources postdocs gain from the relationship. Research focus driven by fast-paced and competitive research fields pushes postdocs and supervisors to publish, leaving little time for other priorities (Igami et al., 2015; Nerad & Cerny, 1999). While evident in the Technical Manager(P) profile, the pressures of publication and research productivity likely form the basis for some of the more moderate ratings as in the Stretched Mentor(P) and the dual foci of the Autonomous Mentor(S) profile. The positive and negative mentorship ratings across postdoc profiles highlight the positive impact of high-quality and intentional mentorship (Scaffidi & Berman, 2011) on developing research independence (Yadav & Seals, 2019), productivity (Miller & Feldman, 2015; Ross et al., 2016; Su, 2011), and publication and career (Kahn & Ginther, 2017; Main et al., 2021; Yang & Webber, 2015). At the same time, poor mentorship, reflected in lower ratings, can lead qualified individuals to leave STEM and academia (Karaklis Noel et al., 2022; Yadav et al., 2020; Ysseldyk et al., 2019). Faculty lack the training and experience to be high-quality mentors for postdocs, often relying on general mentorship ability or experience in mentoring doctoral students (Bahnson et al., 2022b). Postdocs require individualized development and mentoring to reach individual goals beyond the structure, checkpoints, and the degree offered by doctoral programs and mentoring. The lack of training may contribute to the issues around mentorship and communication seen even when postdocs experienced generally positive mentorship, as represented in Well-Rounded Mentor(P), Exemplar Mentor(P), and Leader-Mentor(P).

At the same time, the characteristics of the supervisor profiles provide insight into how postdoctoral supervisors view their mentorship roles. Postdoctoral supervisors exhibit a smaller range of self-ratings that cluster at the *top* of the scale items, potentially indicating self-bias and lack of reflection. Only the Reflective Mentor(S) profile departs from the pattern by ranking themselves moderate or lower on different aspects of mentorship. Self-reflective postdoctoral mentorship strategies may assist supervisors in identifying and implementing areas of needed attention (Cavanaugh, 2018; Hokanson & Goldberg, 2018), leading to more effective mentorship relationships; however, based on the relatively high self-rankings from faculty on the other items, supervisors may not be aware that they may need improvement in their ability to be reflective.

Research Lab Mentor(S) and Confident Leader-Mentor(S) differ in focus on mentorship within the lab and engaging with external mentors. Both approaches provide opportunities and benefits to postdocs. Mentoring between doctoral students and postdocs provides opportunities for postdocs to gain experience in leading a research team and practice effective mentorship techniques in a supportive environment (Bahnson et al., 2022a; Blaney et al., 2020). Often, a multi-mentor approach is recommended to ensure that the needs of postdocs are met without overwhelming an individual supervisor (Nerad, 2011) and positively contribute to practical postdoctoral training and professional development (Faupel-Badger et al., 2015; Risner et al., 2020; Sun et al., 2023). However, with more mentors come more expectations and opportunities for conflict in the purpose of the postdoc position. An issue that plagues postdocs is the lack of clarity around the postdoc's role (Åkerlind, 2009; Bahnson et al., 2024), with multiple mentors with different expectations and goals for the postdoc exacerbate. The focus on personal attributes and research productivity in the Autonomous Mentor(S) profile contributes to negative experiences for postdocs and supervisors when postdocs do not have the personal attributes or research output supervisors expected from initial interactions (Bahnson et al., 2022a; Borrego et al., 2010; Su, 2011).

Postdocs' and supervisors' expectations misalign in the postdoc role, career expectations, productivity and publication, and professional development needs (Åkerlind, 2009; Su & Alexander, 2018; van der Weijden et al., 2016; Zhu et al., 2021), complicating the relationship. The marginal alignment between some postdoc and supervisor profiles highlighted postdocs' and mentors' different perceptions of postdoctoral mentorship while demonstrating the misunderstanding and missed opportunities in ECS postdoctoral mentorship.

The profiles identified largely focus on behavioral aspects of mentorship that reflect the behaviors measured in the MCA. A notable exception is the Stretched Mentor(P) who shared traits of junior faculty or marginalized individuals. Additional traits may influence profile membership; however, we did not identify any patterns in academic title, race/ethnicity, gender, institution, or nation of origin. The social exchanges and role definitions identified through quantitative and qualitative analyses highlight the disparate nature of the interaction between mentorship beliefs,

postdocs, and supervisors. As such, this should not be seen to replace existing leadership types or styles, but rather as an identification and description of the unique set of profiles in ECS postdoctoral training.

Revelo and Loui (2016) identified student and mentor roles in undergraduate and graduate student mentorship during a summer research experience. The roles they identified through grounded theory approach named pairs of researchers such as novice (student) and director (mentor) that would match skills and expertise well while other pairs would constitute a mismatch. For instance, a novice (student) and consultant (mentor) would not start the relationship with shared expectations for who holds the primary responsibility for the research relationship. Our mentorship profiles and descriptions complicate this kind of mis/match in a relationship. For example, postdocs are necessarily not novices in their doctoral specialty, but may very well be joining a lab for experience in areas in which they are novices. The postdoc and supervisor must navigate an individual and complex set of knowledge, skills, and abilities to develop functional roles in the service of a particular set of postdoc and supervisor goals. While every mentorship relationship must be developed individually, other mentorship relationships often begin with more clear expectations for content, context, and duration of the relationship, such as the completion of one summer research project.

7.1 | Qualification of application

Generalizability is often not the goal of qualitative or mixed-methods research. However, given the importance of LPA in this project, a brief discussion of generalizability may be appropriate. The boundary conditions for the analyses presented here must start with ECS. The unique social, practical, and applied nature of much of engineering research at the postdoctoral level differentiates the participants in this research from other science and mathematics postdocs. The profiles identified are generalizable within this boundary. Fields beyond engineering and computer science interested in identifying mentorship practices for postdocs could use this work to develop similar mixed-methods approaches to identify similar or distinct patterns in mentorship beliefs and how those inform role definitions for postdocs and supervisors.

Our samples do presuppose some interest in postdoc mentorship. Participants who are not interested in postdocs would not have responded to survey invitations. However, given the requirement for supervisors to have or have had a postdoc, we are relatively unconcerned about this potential bias in the sample. While increasingly common, relatively few faculty members in ECS complete a postdoc or have postdocs in their research labs. Supervisors who do have postdocs seem highly likely to be interested and engaged in mentoring their postdoc scholars. A possible result of a selection bias is that supervisors who do not care about postdoc mentorship would not have completed the survey. The potential is for a fifth supervisor profile of supervisors with lower self-ratings. A more likely bias, as seen in our supervisor data, is that supervisors overestimate their mentorship competencies. As stated previously, supervisors are unlikely to excel at every aspect of mentorship. However, two of the four supervisor profiles rated themselves consistently at the top of the scale and represented a supermajority of supervisors (83%). Even so, many supervisors were willing to mark “unobserved” for items—a recognition that they do not perform a specific mentorship competency—not even that they are not good at it, but that they do not do it. With the combination of these, we feel the supervisor profiles well represent ECS postdoc supervisors.

7.2 | Recommendations and implications

Our main recommendation for postdocs is to seek positions in which the mentorship needed is available and recognize that every supervisor will not be excellent at every aspect of mentorship. Supervisors need to be self-reflective enough to know what mentorship they offer postdocs and what mentorship should be sought elsewhere. Together, openly discussing mentorship practices and needs will allow postdocs and supervisors who hold disparate mentorship beliefs and competencies to identify strategies to meet postdocs' needs through other mentors, programs, or intentional mentorship competency development.

Postdocs and supervisors may find their negative (and positive) experiences of postdoctoral mentorship present in these analyses. We suggest recognition of differences in mentorship competencies and expectations presents the first step in altering the social exchanges and role definitions that lead to misalignments and negative experiences. Postdoc supervisors want their postdocs to be successful, and discussion of mentorship opportunities should be encouraged and frequent—not reserved for annual appraisal—but integrated into the regular social exchanges between postdocs

and supervisors. One option is to specify a portion of time during regular meetings as mentorship. This practice opens the floor for questions and discussion beyond the practical week-to-week discussion of research, findings, lab function, and publications.

7.3 | Methodological contribution

This work also offers strong methodological contributions to mixed-methods research. Existing practice suggests that theory be used to identify the meaning differences in identified profiles or rely on quantitatively distinguishing profiles (Spurk et al., 2020). Defining LPA profiles often relies on the researchers' ability to readily identify differences in profiles, thereby generating "qualitatively distinct profiles" that do not involve qualitative data (Meyer & Morin, 2016; Spurk et al., 2020). Qualitatively distinct profiles are recognized as superior in that they are easily distinguishable and meaningful differences are apparent (Meyer et al., 2015; Meyer & Morin, 2016; Spurk et al., 2020). Åkerblad et al. (2021) discuss two mixed-methods projects from Finland that used latent profile analysis and qualitative data as examples of integrative strategy design while not detailing how qualitative data informed profile definition. Similarly, other research describes the use of LPA and qualitative data to answer research questions without triangulation to reach profile definitions (e.g., Cimpian, 2017; Xu & Recker, 2012).

The research presented here demonstrates the importance of qualitative data in explaining quantitative differences in profile. The profile definitions would lack clarity and distinctiveness without the qualitative analysis and triangulation of the definition. The method of combining LPA with thematic analysis of qualitative interviews demonstrates an alternative method that may clarify the quantitative and theoretical ambiguity of profiles or explain why two profiles are meaningfully distinct when quantitative difference does not readily provide meaning to the profile. The method overcomes a significant shortcoming in LPA research while offering new directions for education and organizational research.

8 | CONCLUSION

Identifying the underlying profiles of mentorship competency assessments by postdocs and supervisors provides insight into the various mentorship styles used in ECS. Postdocs and supervisors may make more informed decisions when beginning postdoctoral relationships when they have more aligned expectations for mentorship behavior. MCA is a useful tool for postdocs and supervisors to discuss mentorship expectations throughout the postdoctoral relationship. The profiles identified show the range of mentorship, the discrepancy in postdoc mentor experiences, and the misalignment of postdoc profiles and supervisor profiles. Supervisors may find self-identification with one of the profiles useful in self-evaluation of their mentorship beliefs and practices. Similarly, postdocs may find the profiles useful in identifying differences in expectation and experience to address concerns which may be hard to identify or define in other terms. While similarities between the two sets of profiles exist, the differences highlight the misalignment in expectations that lead to poor postdoctoral mentorship experiences for postdocs and supervisors. Improved communication around mentorship expectations, needs, and abilities allows one to address misalignments early in a mentee-mentor relationship that can improve postdoc-supervisor relationships.

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APPENDIX

TABLE A1 Qualitative interview participant demographics and LPA profile.

Pseudonym	Discipline	Gender	Native country	Racial or ethnicity	LPA profile number
Supervisor interview participants					
Erin	Engineering education	Woman	USA	White	1
Henry	Mechanical, aerospace	Man	USA	White	2
Thomas	Physics, engineering	Man	USA	White	2
Phillip	Computer science, electrical	Man	USA	White	2
Edwin	Computer science	Man	USA	White	2
Marco	Electrical engineering	Man	USA	White	2
Leona	Engineering education, industrial	Woman	USA	African American	2
Kevin	Computer science	Man	USA	White	2
Hugh	Computer science	Man	Iran	White	2
Eva	Environmental engineering	Woman	USA	White	2
Josiah	Chemical engineering	Man	India	Asian	2
Louis	Environmental engineering	Man	USA	White	2
Sean	Engineering education	Man	USA	White	3
Hugo	Civil engineering	Man	Iran	White	3
Carmen	Electrical engineering	Woman	USA	White	3
Amir	Structural, computational design	Man	Iran	Middle Eastern/White	3
Arran	Civil engineering	Man	Egypt	White	3
Isaiah	Computer science	Man	India	Asian	3
Zachary	Chemical engineering	Man	USA	White	4
Chris	Materials science, mechanical	Man	USA	White	4
Postdoc interview participants					
Greta	Environmental engineering	Woman	USA	White	1
David	Computer science	Man	Israel	White	1
Amir	Aerospace engineering	Man	India	Asian	2
Arjun	Electrical engineering	Man	USA	Asian	2
Hassan	Electrical engineering	Man	India	Asian	2
Vihaan	Computer science	Woman	India	Asian	2
Sergio	Civil engineering	Man	Columbia	Latino	2
Lillian	Engineering education	Woman	USA	White	2
Wesley	Chemical engineering	Man	USA	White	2
Clyde	Mechanical engineering	Man	China	Asian	3
Emma	Engineering education	Woman	France	Asian	3
Hun	Mechanical engineering	Man	Vietnam	Asian	3
BruceWayne	Mechanical engineering	Man	India	Asian	3
Lea	Computer science	Woman	USA	Black	3
Darcy	Engineering education	Woman	USA	White	3
Romeo	Biomedical engineering	Man	Italy	White	3
Nemo	Engineering physics	Man	India	Asian	4
Amy	Computational physiology, medicine	Woman	China	Asian	4

TABLE A1 (Continued)

Pseudonym	Discipline	Gender	Native country	Racial or ethnicity	LPA profile number
Ethan	Chemical and biomedical	Man	USA	Black	4
Rosie	Mechanical engineering	Woman	USA	White	4
Tom Brady	Civil engineering	Man	India	Asian	5
Pineapple	Computer science	Woman	USA	Hispanic	5
Colette	Material engineering	Woman	Brazil	Latino	5
Fingon	Chemical engineering	Man	Iran	Middle Eastern	5
Chuck	Mechanical engineering	Man	USA	White	5
Catherine	Biomedical engineering	Woman	Turkey	White	5
Lizzy	Civil engineering	Woman	USA	White	5
BIB2B3	Computer science	Man	USA	White	6
Abel	Computer science	Man	Egypt	Asian	6