



Change is Hard: Transitions and the Liminal Positionality of Postdoctoral Fellows in Engineering and Computer Science

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ABSTRACT

Postdoctoral fellows experience isolation and mixed messages about their position and purpose. Little research defines the positionality of postdoctoral fellows, leaving faculty and postdoctoral fellows to make assumptions based on their own experiences. This research describes the socioecological context of the postdoctoral position in engineering and computer science from the perspective of postdoctoral supervisors and postdoctoral fellows. Qualitative semi-structured interviews were conducted with 19 postdoctoral fellow supervisors and 30 postdoctoral (postdocs) fellows about mentoring and their expectations for postdoctoral positions. Open coding and thematic analysis identified supervisors' and postdocs' perceptions and assumptions about the postdoctoral position. The results make explicit the ambiguity of the postdoc position in engineering and computer science while highlighting distinctions in role definitions between supervisors and postdocs that contribute to liminality and potential for conflict. Supervisors and postdocs describe the postdoc position as one of transition, often relying on comparisons to other academic positions to define the role. The lack of clear role definitions contributes to ambiguity in postdoc development expectations. Assumptions and perceptions of the postdoc position further define the position as liminal. The ingrained instability of the position inevitably contributes to postdoc confusion and concern about their position within a lab specifically and academia generally. Based on our findings, we provide recommendations centered around defining and communicating expectations for a postdoc's role with structure for transition into and out of the role may improve the fellowship experience for both supervisor and postdoc.

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The postdoctoral (postdoc) fellowship often functions as a transitional position between being a doctoral student and professional work in industry or academia. The postdoc functions as a space for trainees to develop and broaden professional skills, improve research performance, and increase publication rates. However, unclear expectations and ambiguous goals for the postdoc contribute to murky conceptions of what a postdoc fellowship is, its purpose, and how postdocs should behave and be treated as they move from one position to another. Existing literature focuses on biological and biomedical sciences, where the vast majority of postdoc positions exist (National Center for Science and Engineering Statistics 2019). However, postdoc positions are increasingly required for professional careers in industry and academia in other fields, such as engineering (Main, Wang, & Tan 2021; NSB 2016). For example, the number of postdocs in engineering has increased year over year, more than doubling between 2004 and 2019, to 8,266 postdocs in the United States (National Center for Science and Engineering Statistics 2019). For this project, we interviewed 30 postdoctoral fellows (postdocs) and 19 postdoc supervisors in engineering and computer science about their expectations for postdocs to understand how postdocs conceptualize the purpose and position of postdoc training in engineering and computer science. While postdoc role definitions demonstrated ambiguity in an already liminal space, some commonalities point to opportunities to improve postdoc and supervisor experiences through clarification of career goals and postdoc role definitions.

LITERATURE REVIEW

Generally, existing postdoc literature focuses on disciplines outside engineering and computer science, particularly in biological and biomedical sciences that hold more history with postdoc training and therefore documentation and research investigating the postdoc experience (Nowell et al. 2018). In addition, some research investigates science, technology, engineering, and mathematics (STEM) postdoc training and includes some representation of engineering postdocs (e.g., Åkerlind 2005). While engineering and computer science have recently employed postdoctoral positions more frequently, literature on postdoctoral education and development from a disciplinary engineering lens has not yet emerged. As such, in this literature review, research from fields with more established postdoc expectations provides valuable background on postdoctoral education and expectations for postdoctoral positions.

Even in established literature, definitions of the postdoc position vary while focusing on training in preparation for a professional career, often assumed to be in academia. Postdoc positions are intended to help scholars develop deeper methodological and subject content competency, management, and other professional skills in preparation for the professoriate (Borrego et al. 2010; Mendez et al. 2022; Rybarczyk et al. 2016; Su 2011). Some descriptions specify the position as a scientific apprenticeship (Institute of Medicine 2000). Others focus on training in professional skills (National Postdoctoral Association 2019), yet these descriptions lack valuable specificity in developing individual expectations of engineering and computer science postdoc scholars. With the default assumption that postdoctoral scholars inherently are interested in academic careers, in engineering, postdocs may still be interested in industry careers, a continued misalignment between academic and industry goals. The uncertainty and multiple career paths for postdocs, in addition to wide variations in the definitions of the purpose of and roles of postdoctoral scholars, contributes to ambiguous expectations between postdoc supervisors, postdocs, and institutions, some of which may cause distress.

The transition from graduate student to postdoctoral fellow represents a “step onto a path that is less clear” than the doctoral expectations defined by institutions, accreditation agencies, research advisors, and doctoral dissertation committee members (Omary et al. 2019, p. 2317). Since administrative oversight of postdocs relies on the principal investigator, not a university, there is no consensus on what postdoctoral mentoring comprises, though most studies assume a modern manifestation of the apprenticeship model. Nerad (2011) notes the burden of apprenticeship on one supervisor and instead recommends a “global village” approach to the mentorship of postdocs,

where a professor serves as a research mentor, and the laboratory, department, university, and disciplinary environments also take a role in developing postdocs. The multiple mentorship approach and an associated supportive environment have been documented to be an effective strategy for postdoctoral training and development (Faupel-Badger et al. 2015), but assume that other committee members, stretched thin on time and resources, will be fully invested in a peripheral postdoctoral scholar's development without collaborative incentive. In its ideal form, centralized postdoc training can provide additional mentorship and support for postdocs to develop career skills with support from existing mentors despite conflict over obligations and uncertainties in application (Sun et al. 2023). However, with more mentors come more expectations and opportunities for conflict in the purpose of the postdoc position, and in general, Nerad's "global village" conceptualization is not typically realized in STEM higher education. Postdoc training can provide additional mentorship and support for postdocs to develop career skills with support from existing mentors.

Empirical and anecdotal evidence suggests there is wide variability in postdoc experiences: While some postdocs report productive and fulfilling relationships with their supervisors, others document intellectual property violations, neglect, and unhealthy or abusive expectations (Mendez et al. 2021; Scaffidi & Berman 2011; Yadav et al. 2020). Davis (2009) found that postdoctoral scholars who planned their professional experiences at the beginning of their appointments experience statistically significantly greater success, including increased publication rates, grant submission rates, and in subjective opinions of supervisor relationship satisfaction. Misalignment in expectations generates friction between postdoc supervisors and postdoc fellows when supervisor expectations and research productivity do not balance with postdoc's career aspirations, career development, and work-life balance (Omary et al. 2019).

To date, this work has not yet extended to focus on the disciplines of engineering and computer science. This is important because there are large disciplinary differences in career paths, earning potential, and training models between the life and biological sciences and engineering: For example, even the relative novelty of postdoctoral positions in engineering and computer science separates the disciplinary cultures. Postdoctoral positions in biological and life sciences are all but required—sometimes more than one—to be competitive for a tenure line professorship, whereas in some engineering domains, it is still possible to land a faculty position without having completed a postdoc. Some literature includes engineering within a broad STEM umbrella (e.g., Hudson et al. 2018), but postdoc experiences remain under-researched by the engineering and computer science education research community, resulting in few discipline-specific resources and best practices for the community to support postdoc development.

Recent research has begun to explore the factors supporting the development, learning, success, and satisfaction of postdocs in engineering and computer science postdoc fellowships. Physical sciences and engineering postdoctoral positions tended to be shorter, have higher salaries, and slightly more likely to be in industry than life sciences postdocs (Denton et al. 2022). Because of these factors, and the diversity of roles, postdoctoral positions are often marked with ambiguity and overly broad job descriptions and expectations for engineering and computer science postdocs reflect the unclear position of postdocs, contributing to a misalignment of expectations and career goals (Zerbe et al. 2021; Zhu et al. 2021). The ambiguity continues in the misalignment between expectations at the beginning of a postdoc appointment and postdoc development expectations from engineering and computer science postdoc supervisors (Bahnson et al. 2022). Then, in practice, the knowledge, skills, and attributes required of new engineering and computer science postdocs do not align with postdoc supervisors' development expectations, contributing to unclear goals, miscommunication, and friction between postdocs and supervisors (Bahnson et al. 2022). For these reasons, a focus on how postdoctoral scholars in computer science and engineering disciplines are experiencing their postdoctoral positions is required.

THEORETICAL FRAMING

In our research, we find multiple theories of academic education and mentoring helpful in conceptualizing the experiences of postdoc scholars. The most prominent theory is the leader-

member exchange (LMX) theory developed by Graen and colleagues (1973). LMX posits that member experiences are inherently connected to the leader's perspectives. We find this reflects the apprenticeship model and its power dynamics most often used in postdoc advising, supervision, and mentoring. A postdoc supervisor's essential role of mentorship and advocacy demonstrates the LMX leader-member relationship. Further, LMX requires multiple stakeholders to share priorities and goals: Ostensibly, postdoc supervisors and postdocs share research priorities, as well as training and career goals.

LMX relationship development is predominantly explained through *role definition* or *social exchange* (Sears & Hackett 2011). We find both explanations useful in investigating postdoc supervisors' descriptions of the postdoc position. Role definition refers to the development of work roles and tasks based on informal and successive exchanges as leaders assign tasks, and members complete them (Graen & Scandura 1987). Leader-member relationships strengthen through mutual agreement on the role definition, the role is clarified, and the role is successfully completed by the member (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). Power dynamics present in the leader-member relationship reflect those in the supervisor-postdoc relationship such that the leader/supervisor holds significantly more power and control over the social exchanges and role definition development than the member-postdoc. In this work, we find role definition and social exchange to be integral to the success of the postdoc traineeship. We contend that if faculty expectations and assumptions about the postdoc position are ambiguous, supervisors and their postdocs will have little chance to clarify role definitions or develop necessary social exchanges to align expectations to meet individual goals or needs. We find LMX provides an encompassing theory that motivates our research to investigate the ways postdocs' and supervisors' role definitions and social exchanges shape the postdoc experience. This theoretical lens also supported the formation of our participant recruitment survey and background data collection, the design of the interview protocol, and interpretation of the findings.

The unclear descriptions of the postdoc, particularly in engineering, and the tenets of LMX theory drive our research questions:

- 1) How do postdocs and postdoc supervisors describe the postdoc position (role definitions)?
- 2) How does postdoc role definition ambiguity contribute to mismatched expectations and experiences for postdocs and postdoc supervisors (social exchanges)?

METHODS

As part of a more extensive mixed-methods study on engineering postdoctoral training, this study draws on qualitative interview methods to generate data from current and recent postdocs and postdoc supervisors.

PARTICIPANTS, RECRUITMENT, AND DATA COLLECTION

Potential engineering and computer science faculty participants were identified from National Science Foundation (NSF) awardees in the engineering (ENG) and computer science (CISE) divisions in the year 2019. The NSF awardees were the primary sample for research. Additional participants were recruited with snowball sampling. A recruitment email invited potential faculty participants to complete a short survey on mentorship of postdocs and demographics. Participants with postdoc mentorship experience were asked to volunteer for individual qualitative interviews about their postdoc mentoring experiences. Faculty were also asked to forward the invitation to their current or recent postdoc trainees. Some faculty-postdoc pairs may be present in our dataset. Due to concerns around reidentification and power dynamics around current and future employment for the postdocs, we have chosen not to identify pairs in this analysis. Additional postdoc trainees were recruited by emailing postdoc listservs at the top US engineering institutions.

The recruitment survey asked participants about engineering discipline, years of experience, experience with and as postdocs, institution, nationality, race/ethnicity, gender, and a short mentorship competency assessment (MCA; Fleming et al. 2013). The MCA measures beliefs about mentorship ability for supervisors and postdocs perceptions of their supervisor's abilities. Selected volunteers who completed the recruitment survey were invited to participate in the semi-structured qualitative interview. Supervisors were selected to represent a range of engineering disciplines, years of experience, experience with postdocs, race/ethnicity, gender, and self-assessed mentorship ability based on MCA responses. Similarly, postdocs were selected to represent a range of engineering disciplines, number of postdocs, years in a postdoc, race/ethnicity, gender, and supervisor mentorship ability based on MCA responses. All Black, Latinx, and Indigenous postdocs were invited to participate due to their perspectives in a white-majority field. During interviews, additional postdocs with low MCA responses (poor mentorship ratings) were invited due to more positive-than-expected responses to interview questions. Recruitment continued until saturation, at which point we were not gaining new insights from additional participants.

The selected interview volunteers were invited to schedule a 60-minute semi-structured interview via Zoom videoconferencing software. The first author (a postdoc) and an advanced graduate student interviewed postdocs. The second and third authors, who hold engineering and computer science faculty appointments, interviewed postdoc supervisors. The peer-based interviews reduce power differentials while increasing the rapport based on shared positions. The semi-structured interview protocol encouraged follow-up questions and allowed the flow of conversation to guide the interview progression (Rubin & Rubin 1995). The interview focused on mentor relationships and expectations, engaging participants in discussing their expectations and relationships within the postdoc-supervisor relationship. Some interview prompts asked participants about their views on the purpose of a postdoc fellowship. In response to this prompt and throughout the interview, participants referred to the transitional nature of the postdoc position. The interviews were audio-recorded. Participants received a \$25 Amazon gift card after completing the interview. All procedures were approved by the authors' institutional review boards (IRBs).

Postdoc supervisors in engineering and computer science participated in the interviews representing a wide range of perspectives. Participants had advised between 1 and 10 postdocs and had been in faculty positions for at least one year, with some holding faculty positions for over 20 years in US high research institutions. Faculty represented multiple engineering disciplines: aerospace (n = 1), chemical (n = 2), civil and environmental (n = 5), computer science (n = 4), electrical (n = 3), engineering education (n = 3), and mechanical (n = 1). In addition, participants included women (n = 3) and men (n = 16); US-born participants (n = 13) and faculty born outside of the US (n = 6). The majority of the faculty were white (n = 15), with some Asian (n = 2), Middle Eastern (n = 1), and African American or Black (n = 1) participants. While we sought greater variation in demographic backgrounds, our sample reflects current faculty backgrounds (Yoder 2018). Most of our participants had experience advising postdocs from outside of the US, reflecting the large number of visa-holding postdoc trainees (NCSES 2019).

Similarly, postdoctoral fellows represented a wide range of perspectives in engineering and computer science at US high research institutions. The majority of postdocs were at new institutions and in new research labs distinct from their doctoral research labs (n = 27). Postdocs came from multiple engineering and computer science disciplines: aerospace (n = 1), biomedical (n = 2), chemical (n = 4), civil and environmental (n = 3), computer science (n = 7), electrical (n = 2), engineering education (n = 4), engineering physics (n = 1), materials (n = 2), and mechanical (n = 4). In addition, postdoc participants included women (n = 12) and men (n = 18); US-born participants (n = 12) and postdocs born outside of the US (n = 18). The majority of postdocs were white (n = 11) or Asian (n = 12), with some participants from other backgrounds: Middle Eastern (n = 1), African American or Black (n = 2), Hispanic/Latinx (n = 3) participants. The majority of Asian postdocs were also born outside of the US. While additional detail on the intersections of demographic categories may be informative, providing such information increases the risk of reidentification.

Interview recordings were professionally transcribed for analysis by a secure online service. The interview transcripts were cleaned to improve accuracy and deidentify data that could contribute to reidentification. The coding process followed an open or emergent coding method using NVIVO qualitative data analysis software to develop a codebook of themes (Creswell & Miller 2000; Creswell & Plano-Clark 2018). A postdoctoral fellow coded all of the interviews to identify descriptions of postdoc trainees and the postdoc position. Codes were developed and added based on new phenomena identified in the interviews throughout the coding process. Interviews were coded for discussions of mentorship, supervision, definitions, relationship quality, expectations, and outcomes of the postdoc position. All authors meet periodically during coding to discuss emergent codes, review transcripts, and develop themes based on coded interviews. The team developed themes based on the rereading transcripts to review and discuss codes and examples to represent perceptions of the postdoc position. Themes were developed by comparing interviews within groups (supervisors and postdocs) and then by comparing between the groups. Combined with our open coding process, this allowed us to identify new and unexpected similarities and differences between supervisors and postdocs in how they defined the role of postdoc and the (mis)match in expectations and experiences.

Throughout our research process we committed to quality and trustworthiness in qualitative research methods (Walther, Sochacka, & Kellam 2013). We engaged with theory, existing literature, returning to the interview text, reviewing coding, and extensive questioning of our interpretations of the finds. We sought examples of *role definition* and *social exchange* defined by Leader-Member Exchange Theory. Our approach supported management of our assumptions and biases in reading, coding, and interpreting participants' statements to ensure a strong contribution to the under researched area of postdoctoral training in engineering and computer science.

LIMITATIONS

Limitations within this, as in all studies, must be acknowledged. The participants in this research represent a diverse set of postdocs and postdoc supervisors in engineering and computer science with a range of experiences (e.g., career stage, past postdoc training) and perspectives (e.g., discipline, gender, race/ethnicity) on the postdoc position. Still, our participants represent a limited set of engineering and computer science postdocs and supervisors (e.g., high research institutions, primarily white institutions [PWIs]). In addition, some supervisor participants had limited experience supervising postdocs or had not had a postdoc for several years. However, qualitative research brings more profound meaning to questions of mentorship and performance expectations demonstrating significant value to understanding the postdoc position in engineering and computer science. While themes represent our participants, the generalizability of the results may be limited.

POSITIONALITY

The research team represents both sides of the postdoc position with a postdoc in engineering education and two faculty members with research programs in engineering and computer science education. Combined, the perspectives of the research team bring a more nuanced view of the postdoc fellowship position. As the primary analyst, the first author and postdoc holds expectations for the postdoc supervisor based on his background as a psychologist and as an engineering education postdoc. Similarly, as the interviewers and primary investigators, the faculty team members bring expectations based on their experiences with postdocs and faculty in engineering and computer science. The second and third authors hold tenured faculty positions at different research-intensive institutions with technical departments in mechanical engineering and computer science, with both holding technical degrees in their respective fields and PhDs in engineering education. In addition, the first and third authors recently completed hiring and goal setting as a new postdoc and new postdoc supervisor pair.

Together, our divergent backgrounds provide a well-rounded view of the postdoc trainee position and faculty expectations for postdoc trainees. As a team, we agree on fundamental tenets that inform how we approach this study and qualitative data. First, we accept and critique the gendered and raced history of engineering and computer science disciplines and that this history continues to systematically oppress people from traditionally underrepresented backgrounds (Pawley 2017). The system includes unstated expectations and norms that influence expectations, assumptions, and experiences across job positions, including faculty and postdocs. Further, we are committed to research and practice that increases the diversity, equity, and inclusion (DEI) of engineering and computer science disciplines, thereby supporting the future diversity of the professoriate. While this analysis is not explicitly focused on questions of DEI, our interest in postdoc mentorship stems from concern over the potential for the postdoc to be an additional gendered and raced hurdle to success for already oppressed and minoritized groups in engineering and computer science. However, we are also products of the same system: Good and bad experiences at multiple institutions shape the way we view and approach our research questions. With adherence to trustworthiness and commitment to high-quality qualitative research standards (Walther, Sochacka, & Kellam 2013), we present this work as a step forward to the empirical investigation of postdoctoral training in engineering and computer science.

FINDINGS

Postdocs exist in a liminal space between doctoral training and a professional career. We focus on liminal space as a situation in which participants must learn, perform, and conform to culturally specific expectations to move from one space to another (Dutta 2015; Dutta 2016; Turner 1969; vanGannep 1960). Within this space, itself defined by transition, postdocs face role definitions that place them in comparison to graduate students and to some extent, junior faculty. In addition, the social exchanges described by postdoc supervisors and postdoc trainees leave significant ambiguity for postdoc development trajectories. Our results are organized into explicit liminal postdoc role definitions, followed by direct and indirect comparisons to doctoral students and junior faculty that describe social exchanges that further defined the postdoc role. Table 1 provides a summary of role definition themes.

ROLE DEFINITION THEMES	POSTDOC THEMES	SUPERVISOR THEMES
Defining the Postdoc Position as Liminal	Training for the next steps	Space between lives
	Short-term development opportunity	Differences in capabilities for graduate students, postdocs, and faculty
	Transition, training, and preparation period for future roles	Make-up for past performance
	prepare and gain experience	
Doctoral Student (Plus)	Lab productivity	Lab responsibilities
	Career goal identification	Motivation differences
		Safety net job
Junior Faculty (Minus)	Career goal definitions	Growth and development of knowledge, skills, and abilities
	Exclusion from faculty roles and responsibilities	Assumption of faculty career goal

Table 1 Summary of Role Definition Themes.

DEFINING THE POSTDOC POSITION AS LIMINAL

Postdoc supervisors and postdocs defined the postdoc position as one of transition from doctoral student to professional. Many supervisors assumed an academic path for their trainees either explicitly or through word choice in their description of the postdoc. Eva, a mid-career faculty member in civil and environmental engineering with experience supervising several postdocs,

began by reflecting on the different types of postdocs she had supervised – those who stay temporarily following their PhD, Fulbright scholars, and more traditional postdocs. Eva began her description of a postdoc position as transitional.

In some ways, it's a transitional period for people. They have their PhD, but they're not quite in that academic role as an Assistant Professor. – Eva, Supervisor

Postdocs similarly described the position as transitional, temporary, and short-term. However, postdocs focused on liminality due to the need for training or preparation for the next step in their career without assuming that step would be along the academic track. Ethan continued in his doctoral lab as a postdoc to finish projects and develop independent projects in chemical engineering. He focuses on the need for additional training for career preparation.

Postdoc is a temporary position, so they should have some type of career training depending on what career track the postdoc is on. – Ethan, Postdoc

Similarly, Billy described the position as a short-term opportunity to develop. Billy worked as a software engineer before returning to his doctoral program. His work experience gave him a unique perspective on the career preparation needed after completing his doctorate in software engineering.

It's a really weird job because it's a short-term job that is explicitly preparation for something else, but the preparation aspects are maybe a matter of more personal responsibility, or at least they can be. – Billy, postdoc

Abel described his desire for a short postdoc in computer science by relating the postdoc to a student role rather than a faculty or research role. The postdoc provided the opportunity to improve his CV to be hired as faculty.

For me, I think I wanted it to just be two years, because I already didn't want to be in a student or student like role for a long time. Abel, postdoc

As an early-career researcher, Sean has mentored one postdoc trainee in engineering education. Sean thought about the postdoc position as a space between two different lives, with the demarcation of before the postdoc as one life and after the postdoc as a new life. While he hesitates to name the space “purgatory,” the word is apt as it focuses on the betweenness and undefined nature of the postdoc traineeship.

I don't wanna call it purgatory 'cause it's an exciting place to be... You don't have a permanent job yet, and so there's a lot of excitement with this particular opportunity because it allows you to do anything you want, it's a break from the rigors of having just completed a PhD, whether... For me, I kinda went straight through, for others, they're coming back to get their PhD, but it's a time to maybe think about what you wanna do next without having to immediately jump into it. – Sean, supervisor

Another early-career faculty member, Chris, described the differences between postdocs, doctoral students, and faculty in terms of capability in mechanical engineering. Chris described his experience working 88-hour workweeks to make-up for a lack of experience as he became established. The comparison between positions reflects his past gaining experience after his PhD while becoming faculty which in turn influences the relationships he experiences between groups.

The difference between a professor and a graduate student's pretty big, but with a postdoc, it's very small in terms of ideal intellectual capability and everything like that. So it's more of a collaboration. – Chris, supervisor

Isaiah contextualizes his description in relation to the employment opportunities available to computer scientists with doctoral training. As an early-career computer scientist with only one postdoc trainee, his description of the postdoc position is influenced by his perspectives on his field, where a postdoc is not necessary for industry or academic employment. His comment provides a

description of the postdoc position as a different kind of transition period—a time to make up for previous performance.

The people that I have seen do a postdoc in my field, do so primarily for a couple of reason. One reason, which is probably the most common reason, is that they may not have published enough in their PhD, they may not have done enough work in their PhD, and they feel like, “Okay, if only I could have an extra couple of years and beef up my profile, then I would be quite competitive for academic positions.” So I feel like that is the most common reason why I see postdocs exist. – Isaiah, supervisor

Colette, like many postdocs, comes from another country, where she studied a non-engineering field. Colette described her postdoc as an opportunity to prepare for and gain experience in academia in the US. Her postdoc in materials engineering allows her to address clinically relevant problems in her non-engineering field.

My postdoc, actually, it's just a bridge to get me more prepared for the academia, especially here in this new scenario in the United States, because I didn't know much about the... How to do the grant writing here, how it works with mentorship. – Colette, postdoc

Lillian addresses several issues of liminality in her experiences with lack of professional development. In her first postdoc, Lillian felt cutoff from potential mentors and did not find the support she needed from her supervisors. During her second engineering education postdoc, Lillian had experiences with multiple mentors, institutions, and expectations that helped her identify her needs for career development within the transitional context of the postdoc position.

Well, considering like a postdoc is temporary and it's supposed to be the steppingstone to something else, like a huge part of that should be the career development, it shouldn't be some small thing, push it aside, it should be like the main... At least half of your job. That was kind of a joke, is like your job is finding another job, right? But in my experience, there was very little of that, of actually helping you do that. – Lillian, postdoc

Across descriptions, participants defined the postdoc as a transition period with assumptions tied to preparation for future positions. Faculty focused these career and role expectations on an academic track expectation, while postdocs were less specific about their career trajectory. As such some faculty held postdoc role definitions that focused on a linear trajectory into academic careers. While commonly held by all faculty participants, a few recognized the assumption was likely to be inaccurate. Postdocs tended to have less linear role definitions using the postdoc as an opportunity to explore, develop, and prepare for undefined future career options. The unclear descriptions of the position and career expectations reflect the unclear role definitions of most postdocs reflecting a common ambiguous role definition for engineering postdocs.

The transitional nature and assumptions about postdocs define the postdoc position in relation to the doctoral student (*plus*) and junior faculty (*minus*), similar to both, but not the same. Therefore, the “in-between” role lacks clarity inviting miscommunication and conflict.

The remainder of our findings are organized around these two themes. Postdocs are more than (*plus*) a doctoral student; more responsibilities, expectations, independence, and experience. Simultaneously, postdocs are less than (*minus*) a junior faculty: fewer responsibilities, lower expectations, less independence, and in need of experience. Together, the themes demonstrate the ways role definition ambiguity contributes to the mismatch between expectations and experiences for postdocs and postdoc supervisors.

Doctoral Student (Plus)

Throughout descriptions and discussions of the postdoc position, all participants compared postdocs to advanced doctoral or graduate students even while recognizing there should be a distinction, but both groups struggled to find a firm definition in what a postdoctoral fellowship

was without comparison to another role. However, the topic of comparison tended to differ between supervisors and postdocs. Supervisors discussed comparisons to doctoral students in contributions to lab productivity, while postdocs focused on lab responsibilities. Hugo describes the difference as the postdoc contributing more intellectually to projects.

So, it's not much different than a PhD student, but the idea generation, proposal development, I would say, is unique. – Hugo, supervisor

Similarly, Fingon describes the postdoc position as a doctoral student with slightly different requirements and as “the lazy guy” who just tells people what to do. As a new postdoc in chemical engineering, he recognized that the additional responsibilities he had were similar to faculty responsibilities even though he still felt like a graduate student.

But for me, I still feel it's more like a graduate student for me, but you're basically a graduate student... It's like... It's kind of like you start to get that treatment at the end of the PhD when you are a senior member in the group, but still, it's not as heavy. ... But yeah, added to that, you have to handle this administrative stuff and bureaucratic things and facilities, and everything, yeah. – Fingon, postdoc

Nemo started his postdoc in a research institution after completing his PhD in Europe as a Southeast Asian native. The cultural differences and lack of students at the research institution provided a stark change when Nemo started the postdoc position. Nemo recognized and discussed the change in his responsibilities as a postdoc. He adjusted his approach to problem-solving due to his change in position even though it was similar research.

I found some differences in terms of responsibilities, because now I have a PhD, so I am more responsible to things. I cannot just go to my advisor and say, “Hey, this is not working,” I have to find the solutions and then go, “Okay, I tried this, this, this, still it is not working, do you have a suggestion?” But it comes from the experiences. – Nemo, postdoc

One supervisor, Leona, discussed the difference between mentorship and advising as an engineering education faculty member. She began to discuss her philosophical perspectives on the differences between being a supervisor and being a mentor. She stopped to specify that she thinks these are similar for students and postdocs. Later in the interview, she distinguishes between the contributions students and postdocs can make to research.

Right now, I'm conflating graduate student and postdoc when I think of advising. ... Oftentimes as a graduate student, you may just be receiving orders, that's not really the best way to say it, but you're just kinda on the receiving end of information. But I hope that postdocs begin to move to a place where they have some agency, and they begin to understand either why certain decisions are made or be able to influence a direction for a research project. – Leona, supervisor

Throughout these examples, the postdoc position remains defined only in opposition or comparison to the graduate student position, thus limiting the description and potential of what a postdoc can be, do, and achieve. The majority of postdoc supervisors saw postdocs as highly motivated. Arran discusses the difference between doctoral students' punctuality and commitment to long research hours compared to postdocs. In his description, Arran proposes that postdocs are more willing to work excessive hours and spend more time in the lab. He ties this to the difference in compensation:

But the postdocs, the good thing about them that they are very punctual, because they're getting paid here. See, again, the money plays a role here. – Arran, supervisor

However, Josiah saw a different comparison between doctoral students and postdocs due to the transitory nature of the postdoc position. He sees some students using the postdoc as a safety net rather than as an opportunity to develop. The difference then limits motivation to contribute to research progress.

One thing is that when you hire a PhD student then they're working towards their PhD. And so, there's a big drive for that, and they have to basically get their PhD. And at the same time, they have a longer period in which they get trained. Whereas sometimes we get a postdoc who is in your lab because they did not find an industry position or another position in which they would have preferred and so they're using this time to basically find another job. And in that case, maybe they are not super inclined to perform wonderfully well in your lab, and so that's why maybe there's a bigger failure rate. – Josiah, supervisor

Postdocs did not discuss their motivations in terms of productivity, but rather focusing on career goals and needs as in previous quotes. Colette's motivation is to prepare for an academic career: *It's just a bridge to get me more prepared for the academia, especially here in this new scenario in the United States.* Ethan specifies the need for career preparation in the postdoc: *They should have some type of career training.* Billy refers to the transitory nature of the postdoc: *That is explicitly preparation for something else.* The motivation for postdocs depends on the career path planned, the needs of the individual postdoc, and the reality that a postdoc is a temporary position.

Junior Faculty (Minus)

While supervisors defined postdocs as not graduate students, they often specified they were still not faculty members, as in Eva, Hugo, and Chris' quotes. In this way, postdocs are partially defined as junior faculty; however, postdocs are still less-than faculty and in need of additional training to be prepared for faculty careers. When discussing the purpose of the postdoctoral fellowship, supervisors discussed the importance of growth and development of knowledge, skills, and abilities, often in preparation for faculty careers. As an engineering education professor, Thomas has had several postdoc trainees. When he discussed the educational purpose of the postdoc, he reflected on his own experiences as a postdoc and the benefits he received from additional training.

I think a postdoctoral position is extremely useful because as a graduate student, you learn an awful lot about your particular little bin, and you don't tend to look outside that bin very much, and as a postdoc, you tend to be forced to look at it either at the same bin from a different angle or an entirely different bin, which is a broadening experience that is I think very valuable. You get different perspectives because you're in a different place, different ways of thinking about things, interacting with different people and having different kinds of conversations. – Thomas, supervisor

As a senior faculty member in a civil and environmental engineering department, Amir had extensive experience supervising postdoc trainees. Amir identifies often undeveloped skills doctoral engineers will need to become successful faculty members: interdisciplinary research and research grant writing. Within this need for additional education lies an assumption that postdoc trainees are preparing to be faculty and that they are not yet ready to be in junior faculty positions.

So he would learn how to participate in a research, in a group research, interdisciplinary research, in which he or she might take the leading role. ... they need to learn how to apply for grants. What is the meaning of writing a grant for, for instance, NSF? What are the criteria that they have to participate, or they have to bring into the proposal? What is the reviewing process? How do they need to... Well, they go through the process of... I'm introducing, for instance, and I'm like, "Okay, this is how they review the process. Now write it according to that review process. Write it to be able to answer those reviewer questions." – Amir, supervisor

At the same time, many faculty assumed an academic trajectory or even explicitly expected postdocs to continue into academia rather than industry. For instance, Henry, a senior faculty member in aerospace engineering with experience supervising several postdoc trainees, bemoaned his current postdoc going into industry. He sees her choice of the industry as a loss for her and academia and also seems almost offended that she should seek any career except academia.

Unfortunately, not all my postdocs became faculty members. Maybe 90% of them did. ... I'm really disappointed she went to a company. She was just a natural for a faculty position, but, her mom was a faculty member or something, I don't know. She had this deep prejudice about not becoming a faculty member. Maybe after a year in company she'll sort it out. So my goal is to get them into a faculty position, and this is done by helping them like by having them write proposals. – Henry, supervisor

A newer faculty member in chemical engineering, Josiah, described how he helped postdocs plan their training goals. He discusses developing mentorship plans for trainees based on their goals. He starts by focusing on preparation for academic careers for international students but adds a caveat that postdocs may be choosing other careers.

I talked to them about their long-term goals and they were basically planning to go back to their home country and find an academic position after the postdoc, or maybe also another option was to join industry. – Josiah, supervisor

Participants focused on career development for academic positions assuming or expecting the need for specific skills and development for trainees transitioning from graduate student to faculty. However, not all postdocs intend to take, and most will not be able to take, faculty positions resulting in misaligned or incomplete training experiences for those postdocs.

At the same time, some supervisors recognized the postdoc position as transitory in that postdocs are expected or encouraged to seek the next position as part of being a postdoc trainee. Other supervisors spoke about assisting postdocs in considering their next position and the accomplishments in the postdoc position necessary to achieve the trainee's goals. Discussing a postdoc's career goals may assist the supervisor and advisee better define expectations, training, and outcomes of the postdoc training. Edwin provided an example of how he used career goals to help define necessary outcomes for his computer science postdoc.

I think that kind of thinking about goals and the next step, what's the next job, was really helpful for both of us to set some expectations on what should be done. So I knew, "Okay, you wanna get a tenure-track job? You need to have a top tier publication that you own." – Edwin, supervisor

Postdoc participants discussed their position as less than faculty as a difference in responsibilities that still set them apart from faculty, rather than being unprepared for faculty responsibilities. Fingon saw differences in role expectations for postdocs remaining less than for faculty.

But one thing I noticed is that, at least for me, it's the experience of both worlds, of being a graduate student and being a postdoc, being an advisor, being like a faculty. And I was used to the part of being a graduate student, ... but there are serious issues on the other side when you become a faculty member that you have to deal with. ... So, when you're a postdoc, you're in between, you have to do both. And that wasn't something I was expecting. – Fingon, postdoc

Similarly, some postdocs discussed the exclusion they felt from faculty roles and responsibilities that left them in between and isolated. Billy discussed being excluded from faculty meetings despite his role as an instructor during his computer science postdoc.

Well, it's like I'm in Never Neverland, it's like I'm a faculty member, but I'm not. My guess, if there's a reservation [about letting postdocs attend faculty meetings], is that it's related to hiring, 'cause in the meetings they wanna talk about who's getting hired, and if I'm gonna be on the market soon, maybe they don't wanna do that, but the flip side is, I don't get exposure to what's going on in the department really at all in any way. So that's kind of challenging, but it's not an immediate problem per se. It doesn't make it so that I can't do my work. But it also makes me less of a member of the community. – Billy, postdoc

Lizzy had similar experiences being excluded from faculty spaces in her civil engineering department. She was treated as faculty in some ways, while not being allowed to participate as a full member of the faculty. She attributed the exclusion to a lack of consideration of postdocs.

And it's like, it's not anybody's fault that they didn't think about the postdocs, but why not include them? – Lizzy, postdoc

Throughout our participants' descriptions of the postdoc role, supervisors and postdocs alike struggled to define the postdoc role as independent of doctoral student and faculty status. The interpretations and assignments of meaning varied, and the ambiguity of the position descriptions imposes problematic ambiguity on inhabiting the member role within the leader-member relationship.

DISCUSSION

Postdocs and postdoc supervisors described the postdoc as a transitional and liminal space with comparisons to doctoral students and junior faculty with unclear role definitions. The dependence on comparison to existing, more well-defined groups to describe the postdoc position highlights the “not-ness” of the postdoc and the struggle experienced in attempting to define the role clearly. Nearly all supervisors and postdocs compared the postdoc to the doctoral experience, while a few of each directly compared the postdoc to faculty. Supervisors and postdocs focused on faculty careers more often used a faculty comparison. Supervisors' descriptions of the postdoc role increase the liminality of an already transitory position resulting in increased ambiguity in role definitions and potential for expectation misalignment within the leader-member relationship. Ambiguity and misaligned expectations leave opportunities for misunderstanding and conflict between postdocs and their supervisors. Throughout our results, we see the ways descriptions of the position contribute to an unclear role definition and ambiguous expectations. Leader-member exchange theory posits that the role definitions of both the leader and the member, and the social exchange occurring, are important in facilitating optimal development settings. In our case, finding that both faculty and postdoctoral scholars define the postdoc position with respect to what it's *not* rather than what it *is*, we propose a rift in the role definition that primarily affects the postdoctoral scholar.

When faculty assume academic careers and focus on comparisons with doctoral students or faculty, they are unable to assist postdocs in clearly articulating goals for their future careers. The lack of supervisor support for goal development contributes to a lack of direction, leading postdocs to feel aimless and stuck in their positions (Haley et al. 2018). Similarly, McAlpine (2018), while attempting to make postdocs visible as groups of scholars, identifies a disparity in postdoc roles and expectations based on funding, job duties, and career aspirations. McAlpine asserts that postdocs need to be understood as a set of scholars with a wide range of needs and expectations. Our participants' assumptions about the purpose and expectations of the postdoc position show how uncommon it is for supervisors to recognize the full range of needs and expectations in the postdoc.

Stark differences and conflicting descriptions demonstrate the murky role descriptions supervisors and postdocs hold for the purpose of their postdocs. Within our results, several instances of conflicting descriptions highlight the disparities that exist in supervisors' role definitions of the postdoc position. For instance, Arran and Josiah held opposing views on the motivation of postdocs to be productive. The expectation for postdocs to be highly motivated by money, training needs, or career goals sets follows from an expectation that a postdoc is a deliberate step in a career path. However, some postdocs take the position as a back-up option or “safety net” as Josiah called it, reflecting a different motivation for starting a postdoc that may contribute to differences in motivation to contribute to ongoing research and publication efforts unlike doctoral students who require research progress to complete the doctorate. The conflicting descriptions identified here reflect the ambiguity in expectations identified in recent research on engineering and computer science postdoc positions (Bahnson et al. 2022; Zerbe et al. 2021; Zhu et al. 2021). Assumptions

and expectations for the postdoc revolve around descriptions of the position as development in preparation for the professorate or other academic position (Borrego et al. 2010; Rybarczyk et al. 2016; Su 2011). We found these assumptions common among our faculty participants (e.g., Eva, Shaun, and Chris), even when participants had conflicting experiences, such as Henry, whose “natural for a faculty position” postdoctoral scholar was entering industry. Others recognized industry as an option for career goals, like Josiah, while still giving precedence to academic pathways. Similarly, some postdocs held ambiguous career trajectory plans in relation to their postdoc position, while the majority saw the postdoc as a step along an academic career path.

We also note some discrepancies within the social exchange component of LMX theory in this context. Some participants, such as Billy and Abel, expected engineering and computer science postdoc positions to be short. The short time frame fosters a lack of opportunities for social exchange beyond the leader-member relationship necessary to develop important research connections and networks, as well as limiting social support and personal connections. Further, postdocs often work in isolation in new places, without adequate support, which can lead to feelings of isolation (Åkerlind, 2005; Scaffidi & Berman 2011). For instance, Chris’ reference to a collaborative relationship with postdocs or Thomas’ statement about the importance of discussions to broaden postdocs’ experiences and background. The lack of time for social exchange limits supervisor and postdoc communication and the ability to collaboratively construct and align expectations and goals for the postdoc position.

The limited and liminal postdoc position fosters misalignment in expectations contributing to discomfort for postdocs and their supervisors as they transition into the role. Poor alignment of expectations leads to conflict, unmet training and research goals, and ineffective preparation for future careers (Layton et al. 2020; Vanderford et al. 2018). In recent work in engineering and computer science, expectations for postdocs when they begin the position do not match supervisors’ expectations for development during the postdoc training period (Bahnson, Berdanier, & Ross 2022). The power dynamics inherent in a supervisor/employee pair are exacerbated in the supervisor/postdoc pair due to the heightened influence supervisors exert over future employment opportunities for postdocs. Ambiguous role definitions complicate postdocs’ ability to navigate the power dynamics as they seek to socially construct clearer understandings of their positions. Postdocs may feel concerned that direct requests for role clarity may signal a lack of knowledge or skill to their supervisor leading postdocs to struggle to perform their responsibilities. Further, intellectual property violations or abusive expectations reported in existing literature (Mendez et al. 2021; Scaffidi & Berman 2011; Yadav et al. 2020) demonstrates the potentially harmful effects of the power dynamics in supervisor/postdoc relationships. Clearer descriptions of the position, expectations, and goal alignment at the beginning of the postdoc appointment will help ground postdocs their own space rather than simply in comparison to graduate students and faculty.

While the focus of this paper was not to compare differences in perspectives of US-born postdoctoral scholars with those of international scholars, we do note from other literature in the postgraduate space that there are additional pressures and power dynamics that exist for foreign scholars, leading to the potential for abuse (Cantwell & Taylor 2013; Huang et al. 2016; Miller & Feldman 2015). Because of the liminality of the postdoctoral position, and the increasing “requirements” (whether formal or informal) to have completed a postdoc to be competitive for faculty positions (Main et al. 2021; Mendez et al. 2022; Roach & Sauermann 2017), postdoctoral students are highly disenfranchised. Because postdocs have limited time in new locations, the lack of social exchange with other mentors and postdocs at the new location further isolates and disenfranchises postdoctoral scholars. Future work could be focused on exploring power differentials and the way that liminality manifests as potential disenfranchisement in postdoctoral scholars from a variety of nationalities.

Our findings and much of our discussion focus on the downside to liminality in postdoc definitions; further, our implications emphasize reducing liminality. However, we will point out that the postdoc position is inherently liminal—its purpose is to transition from “education” to “career” in a position that shares characteristics of both (Borrego et al. 2010; Mendez, et al. 2022; Rybarczyk et al. 2016; Su 2011). Liminality cannot and should not be eliminated from postdoc positions.

To be effective, in individual training programs, the position must remain open to a dynamic role definition that evolves with the postdoc. Our implication is not that liminality be removed, but rather that unfocused, fuzzy, ambiguous, liminality sets postdocs and their supervisors up for conflict, misunderstanding, and unsatisfactory experiences. Improving shared definitions of the postdoc as liminal—an intentional transition from one space to the next—will benefit postdocs and supervisors while preserving the open, flexible, exploratory potential of postdoctoral positions.

FUTURE WORK

Given the increasing importance of postdoc positions for faculty positions, future work should further explore the sources of postdoc role definitions and how definitions vary between disciplines and institutions. The high percentage of postdocs in the US who were born outside of the US requires further exploration of the nuances around being a postdoc from outside of the US. Similarly, investigation of differences in expectations for the postdoc in those who hold doctoral degrees from US institutions and institutions outside of the US could expand our understanding of conflicts around role definitions. Future research would benefit from investigating how liminality shapes postdoc outcomes and how that could be used to provide implications for future programmatic changes. Similarly, a direct comparison to the biological and life science fields that have a more extended history or more developed description of the postdoc position could provide valuable insights to be implemented in engineering and computer science.

IMPLICATIONS

Eliminating the liminality present in the postdoc position role definition remains unlikely given the transitory nature of the position itself. Intentionally engaging in a mutual construction of the role definition through a social exchange will assist in clarifying the postdoc role and my increased expectation alignments. Several possibilities may better improve the experience and outcome of postdoctoral collaboration for the postdocs and supervisors. A common thread in our recommendations is improved communication to eliminate assumptions from supervisors and postdocs about the role definitions of a postdoc position. The implications outlined below intentionally focus on individual role definitions rather than policy or prescribed practice. The intention is not to prescribe communication, documentation, or expectations for what a postdoc and supervisor need to do to be successful. We eschew a prescriptive policy in favor of highlighting areas for postdocs and supervisors to intentionally consider due to the individual nature of postdoc positions and to avoid the appearance of a checklist for successful role definition. Policy and prescribed practice will not replace the individual role definition work required to improve postdoc and supervisor experiences. While these implications have been developed based on interviews in engineering, other fields may find clarification of the postdoc role equally useful in improving the postdoctoral training experience.

1. A clear, common description of the purpose and content of the postdoc position needs to be established between supervisor and postdoc as an initial step at the beginning of the collaboration. Ongoing evaluation and revision of this description will help accommodate the changing needs and expectations as postdoc and supervisor develop over the course of the collaboration.
2. Given the individual nature and specific expectations for postdocs based on specific research questions, funding, career goals, and existing skills, the description of the position may take on highly unique characteristics distinguishing it from any other postdoc position. Due to the individualized nature of role definition and identity, any description or agreement about the postdoc position will require time and effort from supervisors and postdocs and cannot be wholly copied from other similar descriptions.
3. Clear, early, and often communication around individual expectations, evolving needs, and changing goals are necessary to maintain a common description of the postdoc. Only through open and honest communication can realignments happen as the position progresses and faces new or unexpected challenges.

4. High-quality mentorship cannot be replaced by a common understanding or clear communication. Supervisors need to engage in mentorship best practices with their postdocs to ensure the quality of the collaboration for both parties. To do this successfully, supervisors and postdocs may need to discuss what good mentorship looks like to them. Institutions providing training and evaluation of mentorship practices could be one opportunity to increase the quality of postdoctoral mentorship.
5. Individual development plans, mentorship plans, or similar goal-setting worksheets are only as good as the time and effort that all parties put into completing, referring to, revisiting, and updating the plan. Further, these cannot be “one and done” plans; rather, they need to evolve and develop just as much as a standard description of the purpose and outcomes of the postdoc.
6. Increasing peer communication may help postdocs provide social support, exchange, and additional role opportunities. Universities have begun or are improving their offices of postdoctoral services. Expanding the role of these offices to provide and engage postdocs may provide needed support and mentoring beyond the supervisor by providing social and professional networking opportunities.

CONCLUSIONS

Faculty and postdoc descriptions of the postdoc role increase the liminality of the position rather than decrease ambiguity and misalignment. Clear role definitions developed through interactions and open communication about career goals and performance expectations can improve postdoc and supervisor experiences of the postdoc experience. Simultaneously, descriptions, definitions, and expectations that depend upon reference to other groups limit the ability of supervisors and postdocs to clearly define their positions and align their expectations during the transition while attempting to complete meaningful goals as part of their career trajectory. Developing postdoc-specific expectations and role definitions independent of other academic positions can support communication, goal development, and achievement. Postdocs depend on high-quality mentorship to meet their development and career preparation goals. Without clear and consistent communication about the postdoc position, postdocs and supervisors cannot expect to develop and maintain a successful collaboration.

DATA ACCESSIBILITY STATEMENT

Deidentified data used in this research is available upon request to Dr. Catherine Berdanier at the termination of the sponsored research.

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The authors have no competing interests to declare.

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REFERENCES

- Åkerlind, G. S. (2005). Postdoctoral researchers: roles, functions and career prospects. *Higher Education Research & Development*, 24(1), 21–40. DOI: <https://doi.org/10.1080/0729436052000318550>
- Bahnson, Berdanier, & Ross. (2022). Postdoctoral supervisors' expectations of the knowledge, skills, and attributes required for and developed during postdoctoral training. *International Journal of Engineering Education*, 38(5A), 1274–1290.
- Borrego, Á., Barrios, M., Villarroya, A., & Ollé, C. (2010). Scientific output and impact of postdoctoral scientists: A gender perspective. *Scientometrics*, 83(1), 93–101. DOI: <https://doi.org/10.1007/s11192-009-0025-y>
- Cantwell, B., & Taylor, B. J. (2013). Internationalization of the postdoctorate in the United States: Analyzing the demand for international postdoc labor. *Higher Education*, 66(5), 551–567. DOI: <https://doi.org/10.1007/s10734-013-9621-0>
- Creswell, J. W., & Miller, D. (2000). Determining validity in qualitative inquiry, *Theory and Practice*, 39(3), 124–130. DOI: https://doi.org/10.1207/s15430421tip3903_2
- Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research*. (Third ed.) Thousand Oaks, California: SAGE.
- Davis, G. (2009). Improving the postdoctoral experience an empirical approach. In R. B. Freeman & D. L. Boroff (Eds.), *Science and engineering careers in the United States: an analysis of markets and employment* (Issue June, pp. 99–127). University of Chicago Press. <http://www.nber.org/books/free09-1>. DOI: <https://doi.org/10.7208/chicago/9780226261904.003.0004>
- Denton, M., Borrego M., & Knight D. B. (2022). U.S. postdoctoral careers in life sciences, physical sciences, and engineering: government, industry, and academia. *PLoS ONE*, 17(2): e0263185. DOI: <https://doi.org/10.1371/journal.pone.0263185>
- Dutta, D. (2015). Sustaining the pipeline: experiences of international female engineers in U.S. graduate programs. *Journal of Engineering Education*, 104(3), 326–344. DOI: <https://doi.org/10.1002/jee.20077>
- Dutta, D. (2016). Negotiations of cultural identities by Indian women engineering students in US engineering programmes. *Journal of Intercultural Communication Research*, 45(3), 177–195. DOI: <https://doi.org/10.1080/17475759.2016.1165727>
- Faupel-Badger, J. M., Raue, K., Nelson, D. E., & Tsakraklides, S. (2015). Alumni perspectives on career preparation during a postdoctoral training program: a qualitative study. *CBE Life Sciences Education*, 14(1), 1–8. DOI: <https://doi.org/10.1187/cbe.14-06-0102>
- Fleming, M., House, S., Hanson, V. S., Yu, L., Garbutt, J., McGee, R., Kroenke, K., Abedin, Z., & Rubio, D. M. (2013). The mentoring competency assessment: validation of a new instrument to evaluate skills of research mentors. *Academic Medicine*, 88(7), 1002–1008. DOI: <https://doi.org/10.1097/ACM.0b013e318295e298>
- Graen, G., Dansereau, F., Minami, T., & Cashman, J. (1973). Leadership behaviors as cues to performance evaluation. *Academy of Management Journal*, 16(4), 611–623. DOI: <https://doi.org/10.5465/254694>
- Graen, G. B., & Scandura, T. (1987). Toward a psychology of dyadic organizing. In B. Staw & L. L. Cumming (Eds.), *Research in organizational behavior* (Vol. 9, pp. 175–208). Greenwich, CT: JAI Press.

- Haley, K. J., Hudson, T. D., & Jaeger, A. J.** (2018). Career coherence, agency, and the postdoctoral scholar. In A. Jaeger & A. J. Dinin (Eds.), *The postdoc landscape: the invisible scholars*. DOI: <https://doi.org/10.1016/B978-0-12-813169-5.00006-9>
- Huang, Y., Cantwell, B., & Taylor, B.** (2016). Reasons for becoming a postdoc: differences by race and foreign-born status. *Teachers College Record*, 118(11), 1–29. DOI: <https://doi.org/10.1177/016146811611801106>
- Hudson, T. D., Haley, K. J., Jaeger, A. J., Mitchall, A., Dinin, A., & Dunstan, S. B.** (2018). Becoming a legitimate scientist: science identity of postdocs in STEM fields. *Review of Higher Education*, 41(4), 607–639. DOI: <https://doi.org/10.1353/rhe.2018.0027>
- Institute of Medicine.** (2000). *Enhancing the postdoctoral experience for scientists and engineers: a guide for postdoctoral scholars, advisers, institutions, funding organizations, and disciplinary societies*. Washington, DC: The National Academies Press. DOI: <https://doi.org/10.17226/9831>
- Layton, R. L., Micoli, K. J., Vanderford, N. L., Solberg, V. S. H., Jahangir, A. E., Hall, J. D., & Ponder, C. A.** (2020). Career planning courses increase career readiness of graduate and postdoctoral trainees. *F1000Research*, 9(1230), 1–51. DOI: <https://doi.org/10.12688/f1000research.26025.1>
- Liden, R. C., & Maslyn, J. M.** (1998). Multidimensionality of leader-member exchange: An empirical assessment through scale development. *Journal of Management*, 24(1), 43–72. DOI: <https://doi.org/10.1177/014920639802400105>
- Main, J. B., Wang, Y., & Tan, L.** (2021). The career outlook of engineering PhDs: influence of postdoctoral research positions on early career salaries and the attainment of tenure-track faculty positions. *Journal of Engineering Education*, 110(4), 977–1002. DOI: <https://doi.org/10.1002/jee.20416>
- McAlpine, L.** (2018). Postdoc trajectories: making visible the invisible. In A. Jaeger & A. J. Dinin (Eds.), *The postdoc landscape: the invisible scholars*. DOI: <https://doi.org/10.1016/B978-0-12-813169-5.00008-2>
- Mendez, S. L., Cooksey, S. E., Starkey, K. E., & Conley, V. M.** (2022). Professorial fit: perceptions of engineering postdoctoral scholars. *Studies in Graduate and Postdoctoral Education*, 13(3), 266–280. DOI: <https://doi.org/10.1108/SGPE-07-2021-0052>
- Mendez, S. L., Starkey, K. E., Cooksey, S. E., & Conley, V. M.** (2021). Environmental influences on the STEM identity and career intentions of Latinx STEM postdoctoral scholars. *Journal of Hispanic Higher Education* 0(0), 1–19. DOI: <https://doi.org/10.1177/1538192721992436>
- Miller, J. M., & Feldman, M. P.** (2015). Isolated in the lab: examining dissatisfaction with postdoctoral appointments. *The Journal of Higher Education*, 86(5), 697–724. DOI: <https://doi.org/10.1080/00221546.2015.11777380>
- National Center for Science and Engineering Statistics (NCSES).** (2019). *Survey of graduate students and postdoctorates in science and engineering: Fall 2019*. NSF 21–318. Alexandria, VA: NSF. Retrieved January 20, 2022. [Report]. <https://ncses.nsf.gov/pubs/nsf21318/>
- National Postdoctoral Association.** (2019). *What is a postdoc?* Retrieved March 1, 2022. https://cdn.ymaws.com/www.nationalpostdoc.org/resource/resmgr/2019_launch/resources/whatsapd/whats_a_postdoc.pdf
- National Science Board.** (2016). *Science and engineering indicators*. Arlington, VA: National Science Foundation. Retrieved April 19, 2023. <http://www.nsf.gov/statistics/2016/nsb20161/#/downloads/report>
- Nerad, M.** (2011). It takes a global village to develop the next generation of PhDs and postdoctoral fellows. *Acta Academica, Supplement*, 2, 198–216. <http://www.ufs.ac.za/ActaAcademica>
- Nowell, L., Ovie, G., Berenson, C., Kenny, N., & Hayden, K. A.** (2018). Professional learning and development of postdoctoral scholars: a systematic review of the literature. *Education Research International*, 2018(1), 1–16. DOI: <https://doi.org/10.1155/2018/5950739>
- Omary, M. B., Shah, Y. M., Schnell, S., Subramanian, S., Swanson, M. S., & O’Riordan, M. X.** (2019). Enhancing career development of postdoctoral trainees: act locally and beyond. *Journal of Physiology*, 597(9), 2317–2322. DOI: <https://doi.org/10.1113/JP277684>
- Pawley, A. L.** (2017). Shifting the “default”: the case for making diversity the expected condition for engineering education and making whiteness and maleness visible. *Journal of Engineering Education*, 106(4), 531–533. DOI: <https://doi.org/10.1002/jee.20181>
- Roach, M., & Sauermann, H.** (2017). The declining interest in an academic career. *PLoS ONE*, 12(9), 1–24. DOI: <https://doi.org/10.1371/journal.pone.0184130>
- Rubin, H. J., & Rubin, I. S.** (1995). *Qualitative interviewing: The art of hearing data*. Thousand Oaks, CA: Sage.
- Rybarczyk, B. J., Lerea, L., Whittington, D., & Dykstra, L.** (2016). Analysis of postdoctoral training outcomes that broaden participation in science careers. *CBE Life Sciences Education*, 15(Fall), 1–11. DOI: <https://doi.org/10.1187/cbe.16-01-0032>
- Scaffidi, A. K., & Berman, J. E.** (2011). A positive postdoctoral experience is related to quality supervision and career mentoring, collaborations, networking and a nurturing research environment. *Higher Education*, 62(6), 685–698. DOI: <https://doi.org/10.1007/s10734-01>

- Sears, G. J., & Hackett, R. D. (2011). The influence of role definition and affect in LMX: A process perspective on the personality – LMX relationship. *Journal of Occupational and Organizational Psychology*, 84(3), 544–564. DOI: <https://doi.org/10.1348/096317910X492081>
- Su, X. (2011). Postdoctoral training, departmental prestige and scientists' research productivity. *Journal of Technology Transfer*, 36(3), 275–291. DOI: <https://doi.org/10.1007/s10961-009-9133-3>
- Sun, T., Drane, D., McGee, R., Campa, H., III, Goldberg, B. B., & Hokanson, S. C. (2023). A national professional development program fills mentoring gaps for postdoctoral researchers. *PLoS ONE*, 18(6): e0275767. DOI: <https://doi.org/10.1371/journal.pone.0275767>
- Turner, V. (1969). *The ritual process: structure and anti-structure*. New York, NY: Aldine de Gruyter.
- Vanderford, N. L., Evans, T. M., Weiss, L. T., Bira, L., & Beltran-Gastelum, J. (2018). Use and effectiveness of the individual development plan among postdoctoral researchers: findings from a cross-sectional study. *F1000Research*, 7(1132), 1–28. DOI: <https://doi.org/10.12688/f1000research.15610.2>
- vanGannep, A. (1960). *The rites of passage*. London: Routledge.
- Walther, J., Sochacka, N. W., & Kellam, N. N. (2013). Quality in interpretive engineering education research: reflections on an example study. *Journal of Engineering Education*, 102(4). DOI: <https://doi.org/10.1002/jee.20029>
- Yadav, A., Seals, C. D., Sullivan, C. M. S., Lachney, M., Clark, Q., Dixon, K. G., & Smith, M. J. T. (2020). The forgotten scholar: underrepresented minority postdoc experiences in STEM fields. *Educational Studies – AESA*, 56(2), 160–185. DOI: <https://doi.org/10.1080/00131946.2019.1702552>
- Yoder, B. (2018). Engineering by the Numbers. *American Society for Engineering Education*, 13–49. <https://www.asee.org/documents/papers-and-publications/publications/college-profiles/2017-Engineering-by-Numbers-Engineering-Statistics.pdf>
- Zerbe, E., Zhu, J., Ross, M., & Berdanier, C. G. P. (2021). Highlighting the Barren Landscape of Postdoctoral Resources: A Content Analysis of University Websites. *Proceedings - Frontiers in Education Conference, FIE, 2021-October*. DOI: <https://doi.org/10.1109/FIE49875.2021.9637276>
- Zhu, J., Zerbe, E., Ross, M., & Berdanier, C. G. P. (2021). *The stated and hidden expectations: applying natural language processing techniques to understand postdoctoral job postings*. Conference: 2021 ASEE Annual Conference. https://www.researchgate.net/publication/354010430_The_Stated_and_Hidden_Expectations_Applying_Natural_Language_Processing_Techniques_to_Understand_Postdoctoral_Job_Postings

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