International Journal of Engineering Education Vol. 38, No. 5(A), pp. 1274–1290, 2022
Printed in Great Britain

0949-149X/91 $3.00+0.00

Postdoctoral Supervisors' Expectations of the Knowledge, Skills, and Attributes Required for and Developed During Postdoctoral Training*

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Postdoctoral fellows report experiencing misalignment between their expectations and their experiences in postdoctoral training. Little research explores their experiences with less still attempting to identify advisors' expectations of postdoctoral fellows. This research aims to describe the knowledge, skills, and attributes (KSA) advisors/principal investigators expect when postdoctoral fellows begin and the expectations for developing postdoc KSA during the fellowship. Qualitative semi-structured interviews with postdoctoral advisors provide data about the hiring, starting, and development expectations advisors have for postdocs. Axial coding with KSA and abductive analysis identify advisors' KSA expectations. Postdoctoral advisors describe hiring requirements and development expectations that do not clearly align. This misalignment starts postdocs and advisors in a new relationship with already misaligned expectations. Clarified language in hiring requirements and development expectations can help advisors and postdocs begin the fellowship with better-aligned expectations. The research reported here provides language to advisors and postdocs to assist and guide KSA expectations.

Keywords: postdoctoral; mentorship; qualitative; KSA; professional development

1. Introduction

Postdoctoral fellowships are important for academic and high-level industry careers [1] in science and engineering fields to broaden expertise, develop new skills, and focus on publications. The effects of a productive postdoc are measurable: Su [2] found that individuals with postdoctoral training produced more publications and were more likely to earn positions in prestigious departments in the three years following the completion of their dissertations, whereby continuing the trajectory of publication success. Postdoctoral positions are also useful for individuals considering careers at national laboratories or industries, aiding newly-minted doctorates in building networks, honing skill sets, and mapping their future career trajectories. Despite the postdoctoral position being a relatively common trajectory, there is very little literature that examines the postdoctoral position as an educational stage.

By design, postdoctoral experiences are individualized, funded to meet the needs of specific projects that require advanced skill sets, and are intended to be conducted through a close relationship with a more senior faculty member. This flexibility means that there is often little oversight or governance over formal postdoctoral training or mentorship. Some universities have offices for postdoctoral affairs, but levels of resources to aid in competency development vary broadly [3]. Further, postdoctoral hiring processes are often influenced by personal connections, with nearly total leeway given to the hiring advisor, increasing the chances of biased hiring that perpetuates disparities in access for individuals from marginalized racial and gender groups [4]. Literature also demonstrates that the unstructured nature of postdoctoral positions leads to irregular and potentially incomplete access to mentorship [5, 6] and resources [1, 7, 8], begetting discrepancies. There are tangible effects of the *laissez-faire* approach to postdoctoral hiring and mentorship demonstrated by national numbers: Of the 8,266 postdoctoral scholars in computer science and engineering, only 24% identify as women, and of U.S. citizens and permanent residents, 3% identify as being from a racially marginalized group [9]. Once in a postdoctoral position,

* Accepted 14 May 2022.

research suggests that postdoctoral scholars are often dissatisfied with the support they receive from institutions and supervisors [10], often feeling "invisible" [11] or feeling like they are on a "postdoctoral treadmill" [12]. Therefore, a specific focus on postdoctoral experiences and education is necessary to unpack the system of postdoctoral education.

To disentangle a murky system of postdoctoral experiences, we must systematically investigate smaller pieces of the puzzle. Because of the wide variation in both hiring processes and postdoctoral experiences documented in the literature, we first seek to understand from a faculty advisor's point of view the qualities and characteristics they look for when hiring postdocs, outside of the domain knowledge that is typically in postdoctoral position ads (if there are even formal position ads released) [3]. By understanding the types of knowledge, skills, attributes, and competencies that postdoctoral advisors are seeking from postdoctoral applicants, and those that should be developed through the duration of the postdoctoral position, we will demystify the process for future postdoctoral researchers with the end goal of promoting equity and justice in higher education and the future professoriate.

2. Literature Review

Postdoctoral experiences are common in science and engineering disciplines, though the prevalence varies by sub-discipline. In some fields, at least two postdoctoral experiences are expected before obtaining a faculty position. Though some disciplines of computer science and engineering emphasize postdoc experience less, each year there are approximately 8,266 postdocs in these fields in the U.S. [9]. Postdoc positions are intended to help scholars develop deeper methodological and subject content competency, management, and other professional skills in preparation for the professoriate [2, 13, 14] or specialized industry or government research careers. While educational gains are likely significant, postdocs remain largely forgotten by the engineering education research community: In fact, in the last ten years, no rigorous studies of the postdoctoral educational experience have been published in the Journal of Engineering Education, International Journal of Engineering Education, or European Journal of Engineering Education, though a few conference papers [15, 16] focused on programmatic interventions or the development of specific skills.

Some research on postdoctoral scholars across STEM disciplines (particularly biological sciences) has been conducted in Higher Education, though many articles group postdocs with graduate students in discussing professional development and mentorship [e.g., 17]. However, grouping postdoctoral scholars as a research subject population with graduate students limits the impact of findings: While literature agrees that postdoctoral scholars (as do graduate students) benefit from "good advising and mentorship" [12, 18–21], it is likely that the characterization of good postdoctoral mentorship is different than for graduate students. The research community must aim to study postdoctoral scholars separately from either graduate student or early faculty populations.

A few research articles highlight broad competencies that postdoctoral scholars should learn through their time as postdocs that are not learned as a graduate student, such as those related to publication productivity and overseeing small groups of students [14]. Most literature points to the utility of individual development plans (IDPs) in clarifying competencies and goals as a conversation between advisors and postdocs, though not all postdoctoral advisors use formalized mechanisms. IDPs are a formalized and written set of plans and milestones intended to assist in connecting trainees' current and future professional goals with their intended funded research project while identifying available and needed resources. Postdoc-driven IDPs assist scholars in aligning individual goals and plans with development opportunities and appropriate career expectations under the guidance of an experienced advisor [22, 23]. Some funding agencies, such as NSF, require a postdoctoral mentorship plan in the grant application, however, there is limited empirical knowledge on how or to what extent these plans are followed by postdocs, though IDPs have been proven to be effective [24]. Funding from the NIH requires postdocs to engage in professional development opportunities, with more oversight on the types of professional development opportunities that must be afforded to the supported postdoctoral scholar to promote competency development.

Some universities support postdoc competency development with additional professional development training, typically in the form of workshop series. University programming and workshops can effectively boost postdoctoral productivity, especially with clear milestones for written manuscripts [7] and career readiness [22]. However, reliance on centralized programming loses important disciplinary nuances essential for success [8]. Other literature documents that many postdoctoral scholars feel that these professional development opportunities, specifically for skills that are not immediately practical for their current research, are not a good use of time. Indeed, Nowell et al. [8] found that even when postdocs had access to and were aware of

robust professional development opportunities, they still did not participate in professional development opportunities until the end of their postdoc position, when those non-research activities became more urgent. Omary et al. [12] note that the tension between immediate research productivity and long-term professional growth can impede necessary competency development that inhibits future success.

Even though there is some research capturing postdoctoral experiences (often capturing the hardships, discrimination, and isolation of a liminal and transient stage of education), and literature on the importance of competency development (embedded within the professional development and IDP conversation), there have been no studies to date that clarify specifically what advisors are expecting from incoming postdoctoral scholars when they are hired, and what the advisors expect will be learned through the postdoc. In essence, literature shows us the result (feelings of disenfranchisement from the point of view of the postdoc), and the value of growth opportunities, but without a clear understanding or articulation of specific knowledge, skills, and attributes. Especially because the few studies that have been accomplished are not discipline-specific, we argue that a disciplinary lens on computer science and engineering postdocs will be highly valuable to the community, both for future postdocs and for current and future postdoctoral advisors.

Our research on postdoctoral education subscribes to multiple theories of academic and adult education, one of the most poignant being leader-member exchange (LMX) theory, originally proposed by Graen and colleagues [25]. In this theoretical perspective, the experiences of a member are intrinsically connected by the leader's perspectives, calling into account the power dynamics often displayed in academic settings and the role that strong mentorship, championship, and advocacy can have in preparing postdoctoral scholars for their future careers. One of the tenets of LMX is the necessity for multiple stakeholders to share the same priorities and goals. In this work, we argue that if faculty goals are opaque or assumed, it is highly improbable that postdoctoral scholars will feel supported or be able to thrive. Given that other literature shows that academia tends to replicate itself as a gendered and raced workplace due to the unspoken expectations, norms, rules, and "old boys club," we argue that LMX as an overarching theory motivates research investigating the perceptions of multiple stakeholders in mentorship, advising, or supervisory relationships.

In this research, we subscribe to the "Knowledge, Skills, and Attributes (KSA)" conceptual framework to capture competency development. Magana [26], citing Rocco and Plakhotnik [27], notes that conceptual frameworks are useful to describe concepts relevant to a study and the relationships between them, helping to shape both the research questions and the data analysis procedures. While the origins of the KSA framework are murky, it has been documented as a way of describing competency development in the military from the 1960s [28]. In past studies, a KSA framework has guided the evaluation of requirements and expectations within engineering and computer science. For example, Ahn and Cox [29] used a KSA framework to develop a survey for graduate students and postdocs to examine their undergraduate mentoring abilities and needs, and other studies have identified KSAs required for engineering Ph.D. holders in industry [30] and academia (and those who migrate between sectors) [31]. Given that literature has not articulated competencies expected of beginning postdocs or those that should be developed during a postdoctoral position, the KSA framework will elicit a clear understanding of how postdoctoral advisors envision competencies and competency development for their postdocs. Therefore, the specific research questions for this study are as follows:

1. What knowledge, skills, and attributes do principal investigators expect when hiring a postdoctoral fellow?
2. What knowledge, skills, and attributes do principal investigators expect postdoctoral fellows to develop during the appointment?

3. Methods

As part of a larger funded, IRB-approved, mixed methods study on engineering and computer science postdoctoral education, this study employs qualitative interview methods to elicit interview data from current and recent postdoctoral advisors.

3.1 Participants, Recruitment, and Data Collection

Faculty participants were identified by compiling a list of recent National Science Foundation (NSF) funding awardees publicly available on the NSF website. Initial invitations emailed to NSF engineering (ENG) and computer science (CISE) directorate grant recipients included a study description and a link to a postdoctoral mentoring survey. If participants had mentored postdocs, the final question in the survey asked participants to volunteer for individual qualitative interviews about their postdoc mentoring experiences. From the survey responses, interview participants were selected for

Table 1. Summary of Participant Demographics

Years as faculty	n	Postdocs mentored	n	Discipline	n	Race/ Ethnicity	n	Gender	n	Country of Origin	n
0 to 5 years	3	1 to 2	9	Aerospace	1	White	15	Women	3	U.S.	13
5 to 10 years	6	3 to 5	7	Chemical	2	Asian	2	Men	16	Outside U.S.	6
10 to 15 years	4	5 to 10	3	Civil & Environ.	5	Middle Eastern	1				
15 to 20 years	2	10+	0	Comp. Sci.	4	African American or Black	1				
20 years+	4	Electrical	3								
		Eng. Edu.	3								
		Mechanical	1								

maximum variation of engineering and computer science departments, gender, and race.

Participants in this project represent engineering and computer science from a variety of perspectives (Table 1). Participants had been faculty in the following ranges: 0 to 5 years (n = 3), 5 to 10 years (n = 6), 10 to 15 years (n = 4), 15 to 20 years (n = 2), or more than 20 years (n = 4). Similarly, faculty advised a wide range of postdocs during their career: 1 to 2 postdocs (n = 9), 3 to 5 postdocs (n = 7) or 5 to 10 postdocs (n = 3). Faculty held positions in a range of engineering and computer science 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). Self-identified demographic representation included three women and 16 men; 13 born in the U.S. and six born outside of the U.S.; 15 white, 2 Asian, 1 Middle Eastern, and 1 African American or Black participants in the research. While we sought to select participants for maximum variation in background, the resulting interview participant pool reflects current trends in engineering and computer science faculty in the United States, which sits at 18% women and 2.5% Black/African American faculty; 3.7% Hispanic/Latinx faculty; and 28.7% Asian [32]. Many of the faculty had experience advising postdocs who were not from the United States, with ten specifically discussing additional challenges faced by international postdocs. This is an important factor for an international scholarly audience to consider, given that 67% of current postdoctoral scholars in engineering and computer science in the United States are not U.S. citizens or permanent residents [9].

The selected participants received an invitation to schedule a 60-minute semi-structured via Zoom videoconferencing software. The interviews were conducted by the two engineering and computer science faculty on this project in order to reduce power differentials with faculty interview subjects and to establish rapport given shared disciplinary backgrounds. The semi-structured nature of the interview allowed the interviewers to ask follow-up questions or probe deeper into answers to elicit a more precise understanding [33]. As part of the semi-structured interview protocol, faculty were asked about their own educational experiences and then their perspectives of mentorship and supervision of postdoctoral scholars in their experiences, including through the hiring, onboarding, and training phases. Throughout the interviews, participants referenced expectations for their postdocs in terms of what they expected from their incoming postdoctoral scholars, things they expected them to develop, and in some cases, discussed adverse experiences related to unfulfilled expectations. Two interview prompts asked participants specifically about their expectations for the knowledge, skills, and attributes of incoming new postdocs and those that they expected the postdoc to learn through their time as a scholar. The audio from these interviews was recorded, and participants who completed the interview received a $25 Amazon gift card for their time.

3.2 Data Analysis

The audio files from the interview were professionally transcribed for analysis by a secure online transcription service. The resulting text files were cleaned for accuracy and to deidentify specific data such as names. The qualitative coding process for these data followed a deductive approach using the broad framework of Knowledge, Skills, and Attributes to categorize expectations for postdocs that were either explicitly given in response to the specific questions, or that emerged in other parts of the interview. We defined *Knowledge* as the organized factual information necessary for or that must be applied to perform a job. *Skills* refers to the ability to perform those tasks necessary to successfully complete for a job function. *Attributes* describes observable attitudes and psychoso-

cial characteristics of the individual within a job context. After the KSAs were identified deductively, the data were analyzed with axial coding methods using NVIVO qualitative data analysis software to develop a codebook of themes [32, 33] characterizing postdoc advisor hiring requirements and development expectations for their postdoc advisees. A postdoctoral scholar on the project was responsible for the data analysis and interpretation parts of this project.

3.3 Positionality

As researchers, we approach this project from different academic positions. The first author is currently a postdoctoral fellow studying engineering education with a background in psychology. The second and third authors hold tenured positions at two different research-intensive institutions in computer science and mechanical engineering, both holding degrees in their technical fields and PhDs in engineering education research. As the primary analyst, the postdoctoral scholar brought his own expectations and assumptions about what postdoc advisors expect, while the faculty authors brought assumptions based on their own experiences with postdocs and graduate students. In addition, the first and third authors had recently gone through a hiring and goal-setting process as a new postdoc and new postdoc advisor. Together, our divergent perspectives provide a well-rounded view of the KSAs identified in this research, though we, as a team, agree on several tenets that influence the way we view this study and qualitative data. First, we agree that engineering and computer science disciplines are historically gendered and raced, and that there are systemic issues that continue to oppress people from non-normative backgrounds. These include unstated expectations and norms and is enforced by bias in hiring processes. As researchers and practitioners, we are invested in increasing the diversity, equity, and inclusion of engineering and computer science disciplines and supporting the diversity of the future professoriate. We are also products of the system: Our good and bad experiences at our own institutional contexts have shaped the way we view this problem and our data: Through high-quality qualitative work and adherence to the tenets of trustworthiness in qualitative data [34], we present this work as a useful step forward in the rigorous empirical investigation of postdoctoral education in engineering and computer science.

3.4 Limitations

As with all studies, there are limitations that must be acknowledged. Our participants represent a wide range of experiences mentoring postdoctoral trainees, still they are a limited set of engineering and computer science postdoctoral advisors. In addition, some participants had only had one postdoc or had not had a postdoc for several years. However, the robust nature of their narratives does support the use of the data to add to the postdoc research literature. Because literature shows that mentorship experiences as a mentee affect how one mentors [12], we expect that each individual's experience flavors their own view of postdoctoral education, but we also find value in capturing both well-conceived and ill-structured thoughts on expectations for postdocs given that many engineering and computer science faculty may not have explicitly thought about these issues. This is the value of qualitative research in providing information directly from the participants necessary to answer our research questions. Similarly, axial coding used to group experiences together may limit the identification of advisor expectations outside the KSA framework. However, this work provides ample evidence to support the use of qualitative methods and the KSA framework as useful in investigating advisors' expectations for postdocs.

4. Findings

The categories of knowledge, skills, and attributes and the themes within these characteristics are summarized in Fig. 1, separated by "Incoming Expectations," or the expectations of what KSAs an incoming postdoctoral scholar will bring with them into a new position, and the "Development Expectations" or the KSAs that the advisor has determined will be developed through the course of the postdoctoral position tenure.

Our findings revolve around a central theme: the misalignment of "Incoming Expectations," or the expectations of what KSAs an incoming postdoc will bring with them into a new position, with the "Development Expectations," or the KSAs that the advisor has determined will be developed through the course of the postdoctoral position tenure. While there are some themes that emerged in both columns (indicating alignment), there are many themes that are misaligned. In these cases, either the incoming expectation for the postdoc does not "go anywhere" or is not discussed as something to be further developed, or there is a KSA that is expected to be developed that has no origin, such that it was not a criterion on which potential for development was considered upon hiring. There are other "quasi-alignments" indicated by dashed lines, noting areas where faculty participants had trouble articulating the difference between the Incoming Expectations and Development Expectations. We posit that these misalignments and potential mis-

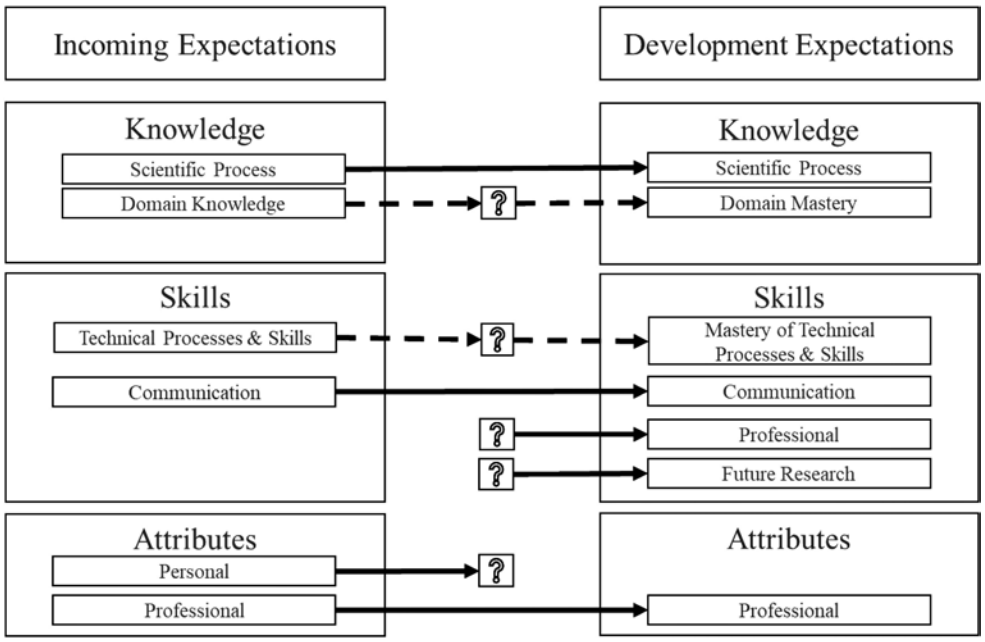

Fig. 1. Alignments and Misalignments between Incoming Expectations and Development Expectations of Knowledge, Skills, and Attributes (KSAs) for Postdoctoral Scholars in Computer Science and Engineering.

alignments can start the advisor-postdoc relationship on a path that will generate confusion and frustration for both parties in terms of evolving or hidden expectations for the postdoctoral scholar.

Using the schematic from Fig. 1 as a guide, we move systematically through the Knowledge components of both the Incoming Expectations and the Development Expectations of the Knowledge component, before moving to the same arrangement in the Skills and Attributes categories. Throughout the findings, we present quotes that contextualize the themes and show how they manifest in the computer science and engineering disciplines. We follow the discussion on the (mis)alignments of the KSAs with data noting tensions in the articulating and assessing these KSAs during hiring process that potentially can exacerbate the opportunity for miscommunication.

4.1 Knowledge: Incoming Expectations and Development Expectations

Advisors expected postdocs to enter their labs with sets of knowledge acquired during doctoral training. Knowledge sets centered around the scientific process, subject-based expertise, method-based expertise, and specific knowledge developed from doctoral research projects. In general, we saw strong alignment and quasi-alignment within this theme, showing that advisors conceptualized knowledge as something both required and to be developed, though the participant quotes demonstrate how faculty may conceptualize the role of specific domain knowledge differently.

4.1.1 Scientific Process

In a strong example of alignment between Incoming Expectations and Development Expectations, advisors spoke about the need for postdocs to be knowledgeable about the scientific process as a new postdoctoral scholar, as a methodology that deepens and becomes more robust and independent through a postdoc's tenure. In fact, as Louis and Zachary noted, this is really the purpose of a postdoctoral position:

> "In learning how to do research is something that happens when you're a graduate student, you better know how to do. . . And I will tell you there are some postdocs that don't, but they ought to know how to do research when they walk into a lab as a postdoc." – Zachary, Chemical Engineering

> "I think the primary focus, in my opinion, of a postdoc, is just to help further mature the individual in the whole scientific process, as well as start to really expand leadership opportunities, to start to take charge of things." – Louis, Civil & Environmental

The alignment of engineering knowledge in the scientific process provides one of the clearest connections between hiring requirements and development expectations. Advisors stated the importance of having a foundation in the scientific process at the beginning of a postdoc with the expectation that the postdoc would improve their understanding and application of the scientific process to engineering and computer science research during the postdoc.

4.1.2 Domain Knowledge to Domain Mastery

Advisors expected postdocs to begin with engineer-

ing or computer science and expertise in domain knowledge, which we use to describe the topic-, theory-, and methods-based knowledge necessary to contribute to engineering or computer science research. Though there was slight alignment between Incoming Expectations of domain knowledge, faculty participants struggled to discern between what is expected initially and what is developed over time. In the model shown in Fig. 1, this tension is denoted with a dashed line showing incomplete alignment. Isaiah's quote shows his expectations for incoming postdocs to be "very proficient" in one area with "fundamental competency" across a broad range of areas.

> "I expect an incoming postdoc to be [v]ery proficient in a particular methodological area, but I expect them to have a fundamental competency in all methodological areas, because I'll try to 'sit in the middle' as far as methods are concerned" – Isaiah, Computer Science

While most advisors did expect the postdoctoral scholars to also develop their mastery of domain knowledge through the postdoc, in many interviews, our participants had a difficult time delineating the skills that they expected their incoming postdocs to come in with versus those that were to be developed. Often, participants indicated a "more/plus" attitude toward the development expectations: While they expected postdocs to come in as full experts in an area, denoted by the conferral of a doctorate and prior experience, they also expected the postdoc to develop further mastery. Edwin, in particular, noted the importance of the postdoc position in developing technical mastery, especially for scholars who worked perhaps more superficially on a variety of projects in their doctoral program but had not had the opportunity to hone a research focus and methods specialty in their doctoral program, perhaps as a function of their doctoral funding.

> "One thing that I realized after quite a while, is that for [this postdoc], and probably for most postdocs, getting a really deep technical mastery of the specific research of one specific research area that is her intended area, is really vital. I found that there was not enough technical depth in any particular area we were working on, the technical depth was elsewhere." – Edwin, Computer Science

However, advisors also conceptualized the postdoctoral as likely (and designed) to stretch the postdoctoral scholar into new domains or to use new methods to study the same domain. Carmen also noted that there are other aspects of hiring that to her are as important, if not more important than incoming with the exact set knowledge to conduct the project, alluding to the importance of the Attributes category in her expectations for knowledge that an incoming postdoctoral scholar should have, referring to some of the other skills and attributes, alluding to the fact that highly specific domain knowledge is potentially a baseline competency, but other skills and attributes set highly qualified postdocs apart:

> "So technical, specific knowledge relating to the project is one thing, but I think there are other sets of competencies that I'm really interested in." – Carmen, Electrical Engineering

Through the quotes presented here, although there were general areas of alignment between knowledge that was expected for incoming postdocs and those that should be developed, in the participants quoted in this section, we note that faculty members do have different conceptions as to how that knowledge will either be applied or (perhaps) developed. Although the Knowledge theme is one that has the highest alignment between faculty discussing both desired Incoming Expectations and Development Expectations related to the same types of themes, there are still areas in which faculty cannot articulate clearly the differences between the two. We posit that these areas of ambiguity open potential for miscommunication with postdoctoral expectations, especially with postdocs who are coming immediately from a doctoral program.

4.2 Skills: Incoming Expectations and Development Expectations

Similar to knowledge, advisors held incoming expectations for their postdocs technical processes and skills particularly pertaining to specialized methodologies, analysis techniques, use of instruments, and other similar skill sets. However, faculty held often misaligned development expectations or did not have clear scaffolding to support skill development over the course of the postdoctoral position. Particularly, professional skills and future research planning were not clearly connected to incoming expectations. In addition, postdocs were expected to hold a set of communication skills developed in their doctoral training.

4.2.1 Technical Processes and Skills to Mastery of Technical Processes and Skills

Advisors expected postdocs to come to their postdoctoral positions armed with skills developed from their doctoral training in engineering or computer science. Given that most advisors noted that postdocs would be working on different technical problems than they did for their doctoral degree, these Incoming Expectations typically involved the translation of skills into a new laboratory, research, or experimental setup inn the advisor's research, as noted by Zachary:

> "I always say the best postdocs are the ones where you bring in a skill set that helps the group, and then [the

> postdoc] learn about something that helps [them] progress [their] career, so it's more about a skill set." – Zachary, Chemical Engineering

While there was strong alignment in the ways in which faculty discussed the importance of specific technical skills as both expected for incoming postdocs and as they are to continue to be developed, the particular thresholds for the depth of technical prowess expected for incoming postdocs varies, potentially dependent on contextual factors such as the type of funding that supported the postdoc. For example, Louis had a very high-pressure project which funded a postdoc to do a very specialized part of the project, and this expertise was required upon entry into the position, not expected to be developed through the experience:

> "We have a very specific role that we needed filled, so that was the bare bone minimum, 'you have to know how to do this.' . . . There was kind of like the baseline was there had to be this technical expertise level. If that wasn't there, it didn't make that candidate very competitive." – Louis, Civil and Environmental Engineering

Other advisors, based on their conceptualization of what a postdoctoral position is for and the bounds of the projects for which they had hired postdocs, noted their intentionality in selecting postdoctoral scholars with skills to complement existing lab competencies to explore future areas of promising research. Of note, these faculty indicate that they expect their postdoctoral scholars to already come in with "confidence and competence," (in the words of Kevin) to be able to contribute as a professional to the group, as noted by both Kevin and Amir.

> "So, I wanted somebody that actually had grounded technical skills, but I didn't need them to have my overlapping skills. So, I needed somebody that was very confident and competent in the data science, AI part." – Kevin, Computer Science

> "You get to work with people with different skills that I don't even have. I have some postdocs that they literally know more than me in software development. So, I'm being very honest, so I literally don't have time to go and learn all the techniques and tricks of software development that's why I'm working with them." – Amir, Structural Engineering

The difficulty that many of the faculty participants had in articulating the type and mastery of technical skills mimicked the difficulty they had in articulating differences in domain knowledge developed over the course of the position. Edwin continued in his interview to offer one interpretation of this split given the expectations and research economy of computer science:

> "Technical skills, technical mastery in one very focused area [is important], potentially continuing to build off of whatever their dissertation technical area was, or branching into something. I think learning how to pivot is also important. We have to pivot every couple of years or else we will lose touch with the field." – Edwin, Computer Science

The potential for misalignments in the way postdoctoral scholars envision the incoming skills compared with the skills that are to be developed is perhaps evidence of another underlying area that can cause tension and miscommunication between postdoctoral scholars and their supervisors.

4.2.2 Communication Skills

Communication skills were, without prompting, emphasized in the interviews by our participants. While in general, our faculty noted the importance of incoming technical knowledge and skills first, most participants spent more of the interview time discussing their expectations and needs for oral and written communication, and the development of specialized disciplinary discourse required for a postdoc's future career. The communication competency theme was one area where there was strong alignment and a clear understanding of the difference between what was expected for incoming postdocs (e.g., the demonstrated ability to lead publication efforts and present research verbally) based on the full acknowledgement a postdoctoral scholar can be responsible for learning new forms of scholarly communication requirements, such as grant writing and collaborative writing across research groups.

Many faculty noted that in developing these competencies, they tried to keep both a short- and long-term perspective, asking the postdoc to carry out the publications and other writing tasks required for a specific project while also trying to best position the postdoc to be competitive for their desired career trajectory, especially in academia which is heavily focused on grant writing and publications.

> "[The postdocs are] also involved with our external collaborators and dealing with them, dealing with stuff like making data use agreements with data providers from other universities. . . . I definitely push them to publish and then also work on grant proposals. But publishing is very big, and so I think it does help that we have some large collaborative projects, and so they don't feel like they need to do all of the work for one paper." – Carmen, Electrical Engineering

> "Our current postdoc is very much dedicated towards academia, and so we've been working with her a lot on increasing communication skills, lots of conferences and presentations, and of course, getting on papers." – Louis, Civil and Environmental Engineering

A specific communication skillset necessary for postdoc development identified by advisors included grant proposal writing. Faculty participants fully acknowledged that this aspect of coach-

ing communication was very difficult, especially because of the high-stakes nature of grant writing: An important proposal with several million dollars at stake is perhaps not a time for a postdoc to take a leadership role on a grant; however, the faculty participants acknowledge what an important skill grant writing it is for postdocs to be exposed to before they attempt a faculty position. Thomas notes his struggle with mentoring his postdocs in grant writing:

> "One thing I regret actually is I have not yet successfully involved most of my postdocs in proposal writing, which is another skill that no one tells you, you need to know until you already have the job in which it is required. And I feel like that's something that would really, really benefit a postdoc is to have had some experience with that, and I've never figured out how to do that well." – Thomas, General Engineering

Henry discussed the importance of not just teaching the mechanics of grant or paper writing, but coaching postdoctoral scholars in the grantspersonship required to convince various audiences, including program (funding) managers of the value of research:

> "You need to figure out how to convince, how to adjust your 'I want' to fit 'the program manager's wants.' And it's not an 'I'm gonna do this' If you keep saying 'I'm gonna do this,' program managers are gonna just slowly dissipate, and not have anything to do with you. But if you approach it from a point of view of, 'I'm gonna do stuff that makes you happy.' [chuckle] So trying to convince them of that. And it's same with reviewers and in papers. You have to talk to your audience." – Henry, Aerospace Engineering

Eva notes the time and effort it takes to develop this skill set with postdoctoral scholars, discussing her success over time at slowly introducing and involving them in various parts of the grant-writing process:

> "They've been able to help write proposals, really take a much more of a leadership role in proposal writing, but also with me mentoring and guiding them on that." – Eva, Civil and Environmental Engineering

4.2.3 Professional Skills

Advisors expected postdocs to develop a wide range of professional skills beyond engineering and computer science specific skills, but several of these skills did not map to any Incoming Expectations for professional skills. Many faculty discussed that the Development Expectations for professional skills involved navigating the disciplinary ecosystem and academic expectations, including the unspoken disciplinary expectations and norms required for achieving a faculty position and earning tenure in a specific sub-discipline. For example, Hugo discussed the unspoken norms in his discipline in terms of the number of papers required to be a competitive faculty applicant:

> "To be successful when you apply for an academic position, just a rule of thumb, something that's not written, something if you ask people, they'll give you different numbers, is just like you publish three papers, three, four papers a year after your graduation. That is how they evaluate your research involvement, that you didn't kind of drop the ball." – Hugo, Civil and Environmental Engineering

Professional skills often focused on outcomes in recognition of the postdoc as a transitory and a position to prepare future faculty. Some advisors worked with their postdocs to specifically plan to be competitive on the academic job market, such as Louis, who carefully thought about his postdoctoral scholar's evolution from just being competitive for an academic job to being able to thrive in an academic job:

> "We've focused a lot more heavily on, 'Alright, how do you continue to make yourself more competitive in the academic market?' But that evolves, but as far as their early expectations, it's in the job description and when we interview, we're like, 'Here are the bare bones that we need to have covered.' But then it's like, 'Well, what do you want on top of that?' " – Louis, Civil and Environmental Engineering

This strategic and methodological long-term career planning was one of the aspects that many faculty felt was an important part of the postdoc. Kevin, as an example, tries to model for his postdoc how to think about career vision, offering this advice to his postdoc:

> "Don't just think of the next paper or the next year, but how are you laying the groundwork more for a long-term successful career? How do you select a department that you wanna be in? 'Cause it's often much more your colleagues [that are important], than the stature of the organization. . . . Or if I can offer a more tactical or strategic view where I'm building on what they're doing, it's sort of a yes/and, versus, 'Oh my god, don't do that.' " – Kevin, Computer Science

While some advisors engaged their postdoctoral scholars more regularly in reflective practice and the inner workings of the discipline, many did note they tried to highlight for postdocs pathways to optimize their professional experience or perhaps revealing alternate career paths than the coveted tenure-line position that may be more in line with a postdoctoral scholar's interests. This conversation is particularly important in engineering and computer science, where most PhD-holders pursue industry careers, even those that do hold postdoctoral positions. Leona outlined how she thinks about this conversation with respect to mentoring her own postdoc:

> "I was just having a conversation yesterday with the postdoc that's working with me now, and we were

> talking about, you know, how tenure track positions are oftentimes presented as the Holy Grail in some institutions, but realizing based on her interest, I was like, 'But you said you don't like these things, like you told me that you would do service for free, and I need you to eat, so we need you to not do service for free. We need to find a way that. . .' I said, 'If you are satisfied or enjoy working in an academic context, there are a lot of people that make an institution go round, so there are a lot of roles that align with the things that you would do for free. And the things that make you grit your teeth, those don't have to be the core of your work.' And so my hope is that, with every postdoc, they leave with clarified career goals." – Leona, Engineering Education

Another specific skill set to be developed for postdoctoral scholars included mentoring and advising undergraduate or graduate students in the lab. Advisors used postdoctoral scholars to help shoulder the load of leading a large research group, while also providing the postdoc an avenue to develop and practice advising and mentoring skills, including conflict resolution when overseeing multiple undergraduate or graduate students.

> "Oftentimes, they are taking much more of a leadership role. And I think that where I look at the [postdocs] who've been really successful with me, they have been able to lead a team with graduate students and undergraduates and really take that leadership role in my research group, being able to make decisions and play a large role in mentoring." – Eva, Civil and Environmental Engineering

> "The leadership is really important, the leadership role. They learn how to delegate tasks. Not only delegating tasks, but also knowing the ins and outs of the tasks that they assign to different students, including graduate, undergraduate, and PhD. . . . They have to be trained for participating in conferences and giving feedback to the PhDs or advising PhDs and Master's students." – Amir, Structural Engineering

In sum, Professional Skills were one of the areas where there was a strong misalignment between Incoming Expectations and Development Expectations. While there was a strong emphasis on the importance of these skills to be developed over the course of a postdoctoral scholar's tenure in their position before their next step, there were no discussion of what professional competencies were expected from incoming postdocs. Indeed, as noted in Leona's quote, some postdocs may come in with misunderstandings about the nature of an academic career. In the interviews, faculty did not mention seeking postdocs who already have had smaller mentorship experiences, for example, or demonstrated evidence of reflection on future career goals. These are examples of potential misalignments that may also cause confusion or miscommunication between advisors and postdoctoral scholars.

4.3 Attributes: Incoming Expectations and Development Expectations

The attributes described by participants represent ideal, positive attributes for professionals, and were conceptualized much differently from either Knowledge or the Skills. We split this category into Personal Attributes and Professional Attributes. While the professional attributes were clearly seen as both Incoming Expectations and Development Expectations, personal attributes were expected at the onset and were not expected to develop further, indicating an understanding of these traits to be innate, or already honed to the extent that they would not develop further.

4.3.1 Personal Attributes

Personal attributes included honesty, motivation, and commitment. These attributes emerged typically as participants discussed adverse experiences with postdocs such as those involving data fabrication, issues with plagiarism, or untruthfulness in everyday conversations. Faculty discussed these attributes to both be essential to the success of any postdoctoral scholar, but things that should not have to be developed during the postdoc because they should already be in place. As noted by Arran and Hugo:

> "Beside knowledge, you have to have people who are honest, because you are gonna leave them in the lab, as you said that I'll... You are gonna trust them with the results. And we have seen lots of people making up results unfortunately." – Arran, Civil and Environmental Engineering

> "Transparency, truthfulness, I would say these are very important for many reasons. One is my flawed personality that I can't work well with those that they're not transparent with me, it's just like my weakness." – Hugo, Civil and Environmental

Faculty participants also valued the intrinsic motivation of incoming postdoctoral scholars in terms of demonstrated interest and investment in the project. As Leona notes, this motivation cannot be "manufactured" and she tries to discern that motivation based on past work:

> "They don't have to know my research in and out, . . . I look at things that they've worked on in the past, and if there's something related to [my work], then that gives me some sense of their intrinsic motivation to want to solve another problem related to this topic. [They have to have] intrinsic commitment to whatever problem that I'm focused on. And I don't want it [motivation] to be manufactured." – Leona, Engineering Education

This intrinsic motivation encourages persistence through difficult research challenges, an attribute noted by the participants as essential for a research career.

> "Most important attribute for any researcher is being passionately motivated to go into work every day and

> spend 10 hours banging your head on a wall trying to figure out the answer to the question. . . . because if you're just motivated to do that, even when it's hard, you're gonna get great stuff done." –Thomas, Engineering Education

Without this intrinsic motivation, faculty have been "burned" by postdocs who were not loyal to or committed to fulfilling their contract as a postdoctoral scholar, looking for new opportunities behind their advisors' back and sometimes leaving the lab without completing agreed upon deliverables: Josiah reflected on a past postdoc's hidden dissatisfaction that manifested with an abrupt departure to a higher-ranking university:

> "My postdoc was looking for a better position, and so they left me after eight months and found position in a much more established PI and in a much higher-ranking university." – Josiah, Chemical Engineering

Many faculty expressed dissatisfaction with postdoctoral scholars who did not view their postdoctoral positions as a professional commitment or a long-term process, and instead made choices that resulted in metaphorical "burned bridges." Each of these personal attributes was discussed by our faculty participants as baseline requirements that cannot further be developed: From the lens of the faculty participants, honesty, motivation, and commitment perhaps be reinforced during a postdoctoral position, but they cannot and should not be developed.

4.3.2 Professional Attributes

Professional attributes required for new postdocs represented individual characteristics necessary for productive working relationships including independence, being a team player, and communicating in a courteous or respectful manner. In addition, professional attributes, similar to professional skills, were expected to be developed as part of the fellowship. One of the most important professional attributes was independence, the development of which separates end-stage graduate students with postdoctoral scholars. Postdocs should be prepared for independent research with less supervision from the advisor while also developing independence during the fellowship. As an incoming expectation, advisors highly valued early demonstration of independence:

> "The other thing that I really think is important in terms of an attribute is someone who can self-manage. It's really important to me, for postdocs to feel some latitude and some independence. And so, it's nice if they know how to manage their own time and/or how to manage their workflow." – Leona, Engineering Education

While during the fellowship, postdocs should develop and engage in more independence than doctoral students.

> "Yeah, I think just practice gaining independence, so becoming more of an independent researcher instead of in grad school, it's. . . You're directed a little bit more by the PhD advisor. So yeah, I think that would be the main thing." – Carmen, Electrical Engineering

> "[A previous postdoc] . . . every single morning, he was outside my office, and he would ask me what he needs to do today, and it just drove me crazy and after four months, I was like, you're not getting renewed. I have spent way too much money to be telling you what to do every day. So, they need to be self-driven, that's important." – Marco, Electrical Engineering

At the same time, postdocs need to be team players using their knowledge and skills to support the lab and advisor beyond one research project. The ability to collaborate tended to be assumed as an Incoming Expectation while also a target for development. Advisors expected postdocs to develop or mature as independent research while developing their ability and confidence to take a stance on a research question and defend that stance scientifically.

> "I think it may go without saying, but some sense of feeling like a team player . . . And just realizing that there may be times when there are ebbs and flows and times of when we may need to help one another, or there are times when you might need help. Realizing that you're not an island to yourself, but that we're all trying to contribute to some larger goal. So those are probably some of the biggest things that I look for." – Leona, Engineering Education

In addition, advisors expect postdocs to be able to work in diverse research groups showing respect for other cultures and beliefs while maintaining a professional relationship.

> "I expect them to be extremely courteous and professional. We're not a family in our group, but we're always there to support each other. So, I expect people to treat everybody with respect and understanding that we all have different backgrounds." – Chris, Mechanical Engineering

Given that most of the faculty participants ran moderate- to large-research groups, increasing competence in managing interpersonal dynamics, delegating tasks and leading groups while establishing a culture of respect was a particularly important attribute for many of our participants to help their postdoctoral scholars achieve.

4.3.3 A Potential Cause for Misalignment: Difficulty Articulating and Assessing Knowledge, Skills, and Attributes Before and Through the Postdoc Experience

After articulating the themes within the categories of Knowledge, Skills, and Attributes and discussing alignments, quasi-alignments, and misalignments

between the Incoming Expectations and Development Expectations of these KSAs, it is valuable to present some data from our participants as they worked to articulate how they define and assess whether a potential postdoctoral scholar has the knowledge, skills, or attributes to be a strong contributing member of a research group. This is a tense conversation given the liminality of a postdoctoral position, which is typically for only one year, and perhaps longer if there is funding maintained. It also is a tense conversation because of the financial investment required to bring a postdoctoral student onto a research team. Further expectations from particular funding agencies requiring fast results can also impact whether a faculty member can hire someone who has potential but perhaps not specific experience versus someone who has highly specific experience but other issues.

Faculty noted a tension in how varied and unstructured hiring processes are, especially with respect to diversity, equity, and inclusion initiatives. Most faculty described their hiring processes that are informed by their own professional networks, hiring students from their colleagues or those who they have been watching develop as graduate students over the years from reputable research groups. Advisors found assessment of KSAs to be difficult when hiring a postdoc without direct personal recommendations. Even with a personal reference, advisors did not always find their postdoctoral scholars prepared with sufficient knowledge, skills, and attributes, even though they had tried to screen for competencies.

> "And I've definitely learned from getting some postdocs that were just terrible, terrible match. They just didn't have the skills. They're on a project, they're way over their head, just like, 'Oh.' [. . .] I brought a postdoc [. . .] who had been recommended by a former PhD student to do some work on human-AI interaction, and from their dissertation I had this sense that they really understood the capabilities of AI, and that they had a great command of English. They had neither of those two things." – Kevin, Computer Science

Some advisors attributed this to doctoral lab groups with high levels of collaboration – students may have worked peripherally on a project requiring a specific knowledge or skill set but may not have expertise: In addition, some advisors experienced difficulty assessing written and oral language proficiency before hiring, even with personal recommendations. Some found applicants from non-native English speakers to be less competent than expected in written and verbal communication abilities, perhaps because of the use of editing services. Therefore, we note here a tension between hiring a postdoctoral scholar that is known to the faculty member, understanding that the incoming postdoctoral student is more of a "known quantity" while at the same time ensuring inclusive hiring practices that do not simply reinforce the status quo.

Further, only a few of our faculty members discussed employing Individual Development Plans (IDPs) or other personalized development structures with their postdoctoral scholars, although many noted that their funding agencies required them to submit one prior to being granted funding to support a postdoctoral scholar. Isaiah noted the almost-flippant use of a "stock" postdoctoral mentoring plan required for funding from the National Science Foundation, rather than thinking critically about the needs of the particular postdoctoral scholar that would work on a given project.

> "Every time we used to submit a grant, for NSF, we copy-pasted whatever postdoc mentoring plan was given to us by our research lab." – Isaiah, Computer Science

A few of our participants leaned heavily on IDPs and postdoctoral mentoring plans as jumping-off points for ensuring effective communication and alignment of goals between the faculty members and the postdoctoral researchers, as demonstrated by Sean and Carmen: Sean discussed revising a postdoc mentoring plan to start a postdoc relationship with a shared set of expectations. He and his postdoc were able to come together on an agreement that helped align their expectations.

> "We had written a postdoc mentoring plan for an NSF award, I shared that document with her 'cause I had already written it before we identified her coming on. And I said, this is what we wrote, but I want you to tell me what you want from this experience. Tell me what you're thinking about in terms of your career aspirations and where you wanna go next. And let's rewrite this, so that at least we have a general understanding of what it is that I'm gonna try to provide to you and what you're gonna hopefully provide to me so that we have this relationship that is mutually beneficial to one another." – Sean, Engineering Education

Carmen discussed the use of an IDP at a tool for annual review and continuing to keep expectations aligned as the postdoctoral scholar progressed.

> "One thing that they have to do is the individual development plan, and we talk about all the things involved with that. We have an annual review type of thing where we go through a lot of those bullet points from the postdoctoral mentoring plan, and make sure that both sides are happy with progress and plans for the future." – Carmen, Electrical Engineering

In these quotes, we see a spectrum of attitudes pertaining to resistance of and embracement of formalized and individualized plans for mentorship of postdoctoral scholars, which are linked with

whether or not the postdoctoral scholar and the faculty members have shared understandings of the knowledge, skills, and attributes to be developed through the duration of the position. As Carmen's quote indicates, these are also useful to her in conducting annual reviews.

5. Discussion

The data reported here provide detailed responses to our research questions pertaining to articulating the KSAs that are (1) Incoming Expectations and (2) Development Expectations for postdoc scholars. However, the misalignment of requirements and expectations demonstrates an underlying cause of miscommunication and unmet expectations experienced by postdocs and advisors. The specific sets of knowledge, skills, and attributes described here provide specific language to advisors and postdocs to avoid misaligned expectations. Postdocs and advisors need clarity to enable more successful and positive experiences. From the point of view of Leader Member Exchange theory, this work offers a valuable perspective on how faculty members conceptualize the roles, knowledge, skills, and attributes that they expect an incoming postdoctoral scholar to have versus what they anticipate should be developed. The present research adds considerable value to the empirical conversation on postdoctoral advisorship and mentorship in engineering and computer science disciplines, given that literature shows that misaligned expectations create an opportunity for conflict, unmet goals, and poor preparation for future careers [22, 23]. As one stakeholder group in a postdoctoral dyad, it is essential to understand the perspectives of faculty advisors.

We did not explicitly ask the participants in this study to rank any of the KSAs in their hiring processes, and cannot assume prioritization of anyone. However, the myriad answers received from faculty with respect to their expectations for incoming postdocs and what they expected should be developed show that faculty themselves have very broad conceptualizations of a postdoc. One potential reason for this might be the type of funding that is being used to support a postdoctoral scholar: For example, a high-stakes project limits opportunities for learning and growth and requires higher levels of baseline technical competence in a very specialized domain (recalling Louis' quotes). We posit that without clear articulation of the incoming expectations and the development expectations for postdocs, there is a strong chance that a postdoc may be assuming different expectations: The limited literature on postdoctoral scholars confirms that within a single postdoctoral experience, expectations for prioritization during the postdoc remain unclear, with a tension between research and career development [12]. As demonstrated in several quotes in our work, advisors assumed ("I think it may go without saying") or expected ("I expect them to be") different things of postdocs, potentially contributing to unclear expectations. Further, many of our faculty participants themselves had difficulty articulating their own expectations, predicting potential misconceptions between the faculty and a new postdoctoral scholar.

We also note that past mentorship affects how incoming postdocs may be conceptualizing or assuming expectations: If a past mentor of a postdoc described the purpose of the postdoc position in a way that conflicts with the unarticulated priorities of the postdoc advisor, postdocs might not be performing as expected. Advisors should question their assumptions and articulate them both in hiring and development expectations to ensure clarity for postdocs. Past work has shown that postdoctoral position announcements offer broad or overly general requirements that can introduce miscommunication about qualifications and job duties [3]. Further, the hiring process remains murky, allowing biased review of application materials [4]. Clarity around KSA hiring requirements and advisors' KSA development expectations during the postdoc could remove potential misalignments caused by overly general and murky hiring practices.

Building and planning postdoc KSAs requires clear definitions of what KSAs the postdoc needs and how those will be developed during the fellowship as led by the postdoc advisor. The Individual Development Plan (IDP) is one of the most oft-used formats to structure postdoc professional development, asking postdoc scholars to work backwards from their long-term career goals, to identify KSAs they need and resources by which to obtain those skills. Although some funding agencies require postdoctoral mentorship plans, few of our participants discussed actively using them to guide postdoctoral achievement. Further, one drawback of postdoc-driven IDPs is that they require an intimate knowledge of obscure and ambiguous competencies for future careers. Postdocs may need assistance at multiple levels in developing an IDP. Postdocs must also clearly define a long-term career goal, which is one of the development expectations identified by some participants.

In addition, postdocs may have an expectation misalignment for their future careers. In academia, approximately 15% of postdocs across disciplines gain a tenure-track career [35]. An ever-evolving job market and academic research enterprise further complicates the issue of postdoc formation of

relevant KSAs. Many of our participants assumed or advocated for an academic trajectory for their postdocs, likely because of their own trajectory. However, postdocs may not be able to actively envision or develop transferrable skills or critically evaluate what competencies they may need in a non-academic environment [36], calling attention to the importance of mentorship.

In our study, the KSAs articulated may start the conversation for the knowledge, skills, and attributes that could be included on an IDP or some similar coaching strategy. However, we also demonstrated quasi-alignments and areas where there was significant tension between incoming and development expectations, which indicate that these skill sets remain open to interpretation and seemingly unconnected to a postdoc's own development goals. For instance, advisors' hiring requirements around domain knowledge and skills may focus on skills to be applied in the lab but may not be a target for development during the duration of employment. At the same time, potential postdocs may be seeking to develop further or refine that same subject-based knowledge or skill. Advisors may be clear about why they need subject-based knowledge and skills, while that need remains unclear or poorly defined for the postdoc. The KSA connections between hiring and development offer advisors the opportunity to detail the needs and expectations of postdoc scholars. From a Leader-Member exchange perspective, the role must be clearly defined for the relationship to function successfully. Advisors may define the role as using, but not developing, specific knowledge or skills with the postdoc expecting to both use and develop the same knowledge or skills. Clarifying the role from the outset will benefit the leader-member relationship.

Lastly, our study highlights not just the problematic nature of the misalignments and quasi-alignments between KSAs but also the problematic nature with the normative hiring processes for postdoctoral scholars in engineering and computer science. Even if there are clear Incoming Expectations for a postdoctoral scholar tailored to a specific project, it is difficult for faculty to assess actual knowledge, skills, and attributes of an incoming scholar. To this end, most of our participants discussed their preference to hire postdocs with whom they already have personal connections in order to try to ensure a productive short-term research position. However, this practice has ramifications for inclusion, equity, and diversity at the postdoctoral level.

5.1 Future Work

Quantitative measurement of KSAs may provide a clearer understanding of the expectations and priorities of advisors. Differences in priority between engineering and computer science disciplines or academic and industry expectations may better inform postdoc development plans. As postdocs clarify their goals, a more accurate assessment of KSAs could assist in identifying areas in need of additional professional development and mentorship.

Further, future work could assess the mis/alignment between individual development plans, postdoc career needs, and development experiences. While IDPs are valuable tools, assessing them and their implementation could provide guidance for future postdocs and advisors. We anticipate that spending the time tailoring, following, and revisiting IDPs may fall into the category of other long-term professional development activities that gets waylaid when research deadlines loom [12] or that feel like "busy work" to stressed faculty and postdoctoral scholars. Future work should also continue to describe the expectations and experiences of postdoctoral scholars from their point of view in order to highlight different stakeholders' perceptions of the postdoctoral position as an educational stage. Exploring the structure and planning for postdoc development pay provide significant areas for improving the experience and success of postdoc scholars. For instance, further exploring the transitive nature of the postdoc and the sociocultural context that postdocs inhabit between doctoral studies and long-term employment within the specific disciplinary contexts of engineering and computer science may better illuminate the needs of these postdocs.

5.2 Action Items for Postdoctoral Advisors and Postdocs

Advisors and postdocs may benefit from specific action items to eliminate misaligned expectations in the postdoc hiring and development processes. We provide the following list of talking points and questions as a starting place for advisors and postdocs to consider and discuss as they identify knowledge, skills, and attributes expected and those that will be developed during the postdoc traineeship (Table 2). From a Leader-Member Exchange Theory perspective, clarifying the role definition and expectations for both the advisor and postdoc creates greater potential for success.

Open and honest consideration of these items may assist advisors in preparing for a new postdoc. Similarly, the postdoc questions may help postdocs identify their own needs and expectations from the postdoc. Together, advisors and postdocs can consider how knowledge, skills, and attributes will be used and developed throughout the postdoc fellow-

Table 2. Action Items for Postdoctoral Advisors and Postdocs

Advisors – Before Hiring a Postdoc	Evidence Required for Beginning	Postdocs – Questions to Ask Yourself or Your Advisor	Together – Goals and Development
Specify the scientific, subject, methods, and experience knowledge required for the postdoc.	How can postdocs demonstrate these specific sets of knowledge?	Does the use, refinement, or acquisition of this knowledge serve my needs?	What knowledge development is expected during the fellowship?
Clearly define the skills needed for the postdoc.	What evidence demonstrates each skill?	Does the use of these skills fulfill my needs for skill development?	What skills will be developed during the fellowship?
Exactly, what technical skills are required on day one, and what technical skill development will be offered to a postdoc?	How will technical skills be evaluated? How will postdocs be trained in new skills?	What technical skills am I prepared to utilize on day one, and which will I need to develop?	What technical skills are required for hiring or developed during the fellowship?
Honestly evaluate and clearly define your communication needs for lab, publication, and collaborations.	What demonstrates communication abilities? (e.g., first-authorships, recommendations)	Do my communication skills and goals match those needed?	What communication skills can be developed or improved during the fellowship?
Identify professional attributes required for the postdoc.	How can postdocs demonstrate possession of each professional attribute?	Do these professional attributes fit my experiences and goals?	How will professional attributes be developed during the postdoc?
Specifically identify personal attributes and why they are necessary for the postdoc.	How can postdocs demonstrate possession of each personal attribute?	Do these personal attributes fit my experiences and goals?	How can personal attributes be developed during the postdoc?

ship. When combined, the action items provide a basis for communication, mutual understanding, and alignment of hiring needs and development expectations for advisors and postdocs.

6. Conclusions

Advisors have incoming expectations and development expectations for postdocs' KSAs. When these expectations do not match, the misalignment contributes to friction in relationships and missed opportunities. Clearly defining expectations at each stage of the postdoc fellowship removes misalignments in expectations allowing postdocs and advisors to develop a successful research and training experience. Advisors can achieve this by clearly defining their needs and expectations of a postdoc at the beginning of a new fellowship. Postdocs can improve their experience by requesting clarity in expectations and goals for the advisor as well as the tools the advisor has available to assist postdocs to thrive.

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