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Abstract

Postdoctoral scholars constitute a sizeable population within the academic workforce. Given the intended role of a postdoc position as a time of advanced training and professional development for a future academic career, particularly in science, technology, engineering, and math (STEM) fields, it is important to understand whether and how well the career-related needs of postdocs are being met. The purpose of this research was to understand STEM postdoctoral scholars' career trajectories, with particular attention to the influences on their career-related decision making, by applying the Life Experiences and Role Negotiations (LEARN) model to qualitative data from interviews with 19 STEM postdocs. Findings reveal the multiple influences on postdocs' career-related decisions and how these shape postdocs' career trajectories. Based on our findings, we offer three suggestions for how institutional and national policies and programs can best support the career development of postdocs.

LEARN Model of Career Trajectories: Application to the STEM Postdoctoral Scholar

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Abstract

Postdoctoral scholars constitute a sizeable population within the academic workforce. Given the intended role of a postdoc position as a time of advanced training and professional development for a future academic career, particularly in science, technology, engineering, and math (STEM) fields, it is important to understand whether and how well the career-related needs of postdocs are being met. The purpose of this research was to understand STEM postdoctoral scholars' career trajectories, with particular attention to the influences on their career-related decision making, by applying the Life Experiences and Role Negotiations (LEARN) model to qualitative data from interviews with 19 STEM postdocs. Findings reveal the multiple influences on postdocs' career-related decisions and how these shape postdocs' career trajectories. Based on our findings, we offer three suggestions for how institutional and national policies and programs can best support the career development of postdocs.

Keywords: postdocs, postdoctoral fellows, graduate education

Introduction and Background

During the period 2002-2007, almost half (45%) of all Ph.D. recipients in United States institutions of higher education worked as postdoctoral scholars (Hoffer, Grigorian, & Hedberg, 2008). Reports of postdoc numbers range from 63,000 to 89,000 as reported by the National Postdoctoral Association (n.d.). U.S. National Academies (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2014) estimate a U.S. postdoc population of 60,000-100,000. As neither students nor faculty, postdocs are a marginalized and largely invisible group within the academy, despite their critical contributions to the work of academia (Jaeger & Dinin, 2015, 2018).

One of the key purposes of the postdoc role is to provide additional training and professional development for emerging professionals, particularly in science, technology, engineering, and

math (STEM) fields. The National Postdoctoral Association (n.d.) defines a postdoc as "an individual holding a doctoral degree who is engaged in a temporary period of mentored research and/or scholarly training for the purpose of acquiring the professional skills needed to pursue a career path of his or her choosing" (para. 1). The postdoc provides specific career benefits including advanced training in conducting research, time and space to refine a research agenda and publication record, professional development opportunities, and mentoring (Jaeger & Dinin, 2015; Maclachlan, Waraksa, & Williford, 2015; National Academies, 2014). A postdoctoral position is often seen as a prerequisite for a faculty career in STEM fields (Brown, 2011; Micoli & Wendell, 2018; National Science Board, 2016; Nerad & Cerny, 1999).

Postdocs are viewed as a valuable source of academic labor in laboratories, classrooms, and as project managers (Cantwell, 2011; Rybarczyk, Lerea, Lund, Whittington, & Dykstra, 2011). Principal investigators (or *PIs*) at institutions of higher education, government agencies, and other organizations acknowledge the relatively low cost of postdocs as a source of skilled research labor, particularly given the long-term commitment and high cost of faculty positions (Camacho & Rhoads, 2015; Cantwell, 2011; Cavanaugh, 2018; Micoli & Wendell, 2018; National Academies, 2014).

While the postdoc position offers benefits to individuals and institutions, many postdocs report the culture of their lab or related work environment is not conducive to receiving the scholarly training as described in the National Postdoctoral Association definition of a postdoc (Jaeger, Dinin, & Haley, 2014) and long hours are required, leaving little time for other activities (Freeman, Weinstein, Marincola, Rosenbaum, & Solomon, 2001). Postdocs report not receiving professional development or mentoring from their PIs, particularly in terms of preparing for a non-academic career (Scaffidi & Berman, 2011). Postdocs voice dissatisfaction with their experience due to low pay, low benefits, and concerns about advancement (Åkerlind, 2005) as well as job insecurity and lack of career paths (Scaffidi & Berman, 2011). In addition, the career support received is frequently ad hoc and unstructured and may not prepare individuals to move forward in their careers (Åkerlind, 2005). Support for postdoc career development and availability of professional development varies considerably across and within institutions (Camacho & Rhoads, 2015; Micoli & Wendell, 2018; National Academies, 2014; Puljak & Sharif, 2009). The limited number of open faculty positions relative to the supply of individuals with doctorate degrees results in many postdocs pursuing repeated postdoc appointments (contradicting the temporary intent of a postdoc appointment) or altering their career goals (Bonetta, 2010; Brown, 2011; Micoli & Wendell, 2018; National Academies, 2014; Puljak & Sharif, 2009).

Given the intended role of a postdoc position as a time of advanced training and professional development for a future academic career, it is important to understand whether and how well the career-related needs of postdocs are being met. Therefore, the purpose of this research was to understand the impact and value of postdoc positions on the careers of STEM scholars. Our findings inform the development of institutional and national policies and programs to best support the career development of postdocs. This study is guided by the following research question: *What are the career-related learning experiences of postdocs in STEM fields?*

Conceptual Framework

We use the Life Experiences and Role Negotiations (LEARN) model (Jaeger, Hudson, Pasque, & Ampaw, 2017) as a framework to guide data analyses and understand the unique experiences of postdocs (see Figure 1). The LEARN model is a synthesis and expansion of multiple theories of

lifespan learning and career decision making, including Super's (1980) Life-Span, Life-Space Theory of Career Development, Savickas and colleagues' (2009) Life Designing Model, Krumboltz's (1994) Social Learning Theory of Career Decision Making, and Lent and colleagues' Social Cognitive Career Theory (Lent, Brown, & Hackett, 2002). In congruence with these theories, the LEARN model does not view individuals as passive actors whose career choices are determined by their experiences and external forces; rather, the model centers the role of learning across the lifespan in shaping individuals' career-related decision making and career trajectories. Specifically, as detailed in Figure 1, a person's past and present experiences, along with the learning that results from those experiences, comprises their cumulative career-related learning. This learning shapes the decision made at a career decision point. The decision then becomes a new learning experience shaping future career decisions; cumulatively, these decisions determine the individual's career trajectory. The model also accounts for intrapersonal factors (personal determinants) such as identity, self-concept, and agency in addition to extrapersonal, situational determinants.
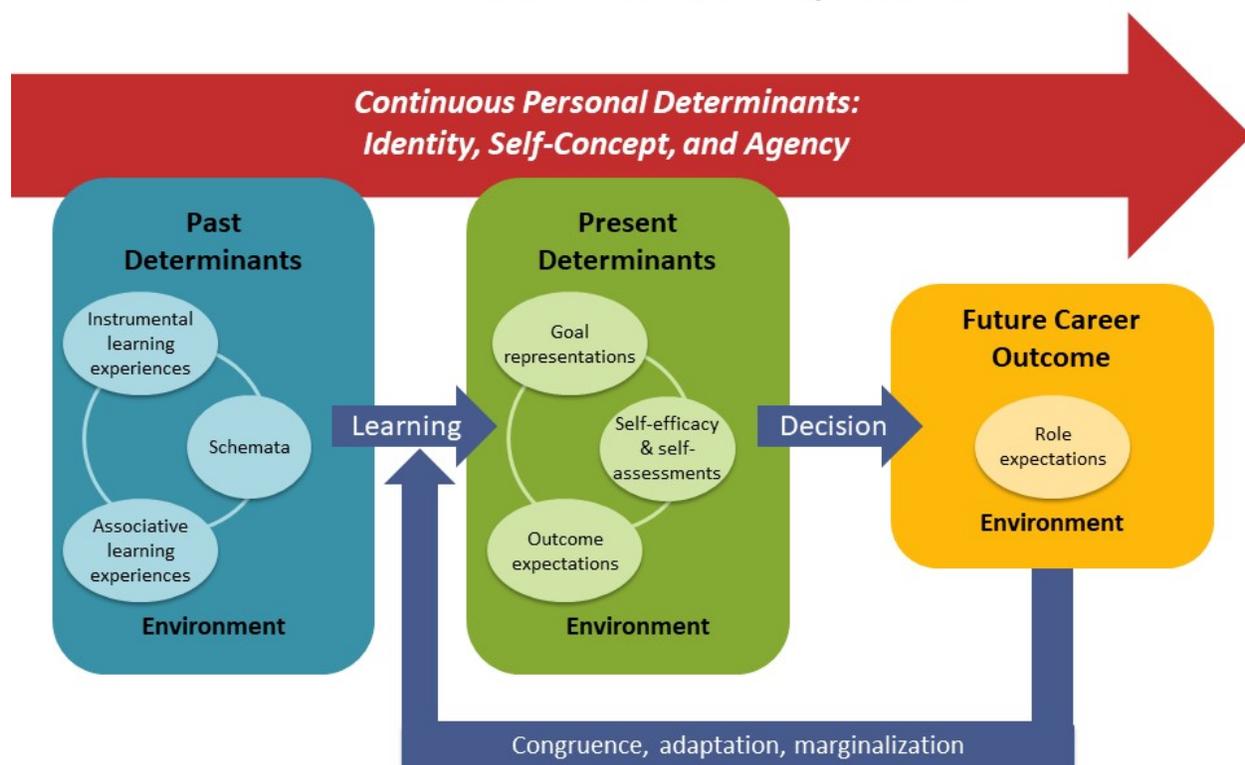
Source: Jaeger et al., 2017 (used with permission)
Figure 1. The LEARN model of career trajectories.

Because it accounts for a broader and more holistic range of factors, the LEARN model provides a richer understanding of individuals' career longitudinal decision making and trajectories than the career theories upon which it builds. Though the original LEARN model was developed to explain the career trajectories of women with STEM doctorates, the concepts contained within it are not gender- or discipline-specific, and we believe it is particularly useful for examining the careers of similarly understudied populations such as postdocs in STEM fields. In addition, because of its

longitudinal focus, the LEARN model is particularly apt for illuminating non-traditional career trajectories, such as the paths of postdocs who pursue alternatives to the traditional tenure-track faculty career (Bonetta, 2010; Maclachlan et al., 2015; Puljak & Sharif, 2009). Finally, the LEARN model recognizes that career-related learning and decision making are contextualized, shaped by the past and present environments in which an individual is situated. The interaction between intrapersonal and environmental factors means two individuals will have differing learning experiences even within the same environment (Krumboltz, 1994; Savickas et al., 2009; Super, 1980). It is important, therefore, to consider individuals' career environments to fully understand their career trajectories. Because the LEARN model is a relatively new conceptual framework, it has not yet been widely applied in empirical research. However, each component of the LEARN model is situated with a rich and comprehensive body of literature that is discussed in detail in Jaeger et al. (2017).

Methods

To consider the experiences of postdoctoral scholars, we selected a qualitative research approach (Creswell & Plano Clark, 2011). Because this design gives voice to participants, it provides a better understanding of complex phenomena than a quantitative approach (Creswell, 2007; Merriam, 2002; Miles, Huberman, & Saldaña, 2013). Qualitative research seeks to provide insight "into the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2007, p. 37) through data collection methods which involve face-to-face interaction between researchers and participants (e.g., interviews). This study considered many different facets of the experiences of postdoctoral scholars, with a particular focus on the *human problems* of career development, decision making, and advancement. A qualitative approach enabled us to examine these topics holistically rather than in isolation. Specifically, we utilized a basic interpretive qualitative design, which seeks to identify and describe patterns within the data relevant to the topic of inquiry (Merriam, 2002).

Site Selection and Participants

The site for this study is a predominantly White, land-grant, research institution in the American South. Due to its land-grant mission, this institution has a wide range of agriculture, science, and engineering programs (Marcus, 2015), which facilitated a diverse sample of postdoctoral scholars.

The present research is part of a larger study of STEM postdocs. Participants were recruited for the larger study by an email from the Office of Postdoctoral Affairs. Nineteen postdocs from this larger sample, selected for representation across disciplines, race/ethnicity, and gender, participated in the interviews which provided the data for the present study. Of the 19 participants, 12 (63%) identified as male and 7 (27%) as female; regarding ethnicity, 9 (47%) participants identified as Caucasian, 6 (32%) identified as Latino/Hispanic, 3 (16%) were international non-US citizens, and 1 (5%) identified as African-American. Table 1 summarizes interview participants' discipline, ethnicity, and gender.

Data Collection and Analysis

Data collection for the larger study consisted of two phases: an online survey and one-on-one, in-person interviews. In this paper we focus on findings about participants' career trajectories and career-related learning as revealed through the interviews. In the interviews, the research team used semi-structured questions to guide the discussion while providing an opportunity for

participants to tell their own story (Fontana & Frey, 2000). Specifically, questions asked participants about their postdoctoral experience, including their choice to enter a postdoc position, their roles and experience within the position, career goals, and immediate employment options. Interviews were held in mutually agreeable location. The transcriptions and the research team's field notes were coded using techniques detailed below. The various coding cycles and reading through the transcripts multiple times increased familiarity and understanding of the data (Creswell & Clark, 2011).

Table 1. Pseudonyms and Self-Identified Academic Discipline, Race/Ethnicity, and Gender

Pseudonym	Discipline	Ethnicity	Gender
Luca	Astrophysics	International (non US citizen)	Male
Francine	Biochemistry	Caucasian	Female
Sarah	Biology/Ecology	Caucasian	Female
Cecilia	Biology/Plant Pathology	Latino/Hispanic	Female
Bess	Biology/Science Education	Caucasian	Female
Miguel	Chemical Engineering	Latino/Hispanic	Male
Brady	Crop Science/Plant Biology	Caucasian	Male
Ben	Entomology	Caucasian	Male
Henry	Experimental Nuclear Physics	International (non-US citizen)	Male
Vlad	Fiber Polymer Science	International (non-US citizen)	Male
Linda	Food Safety	Caucasian	Female
Jessica	Forestry and Environmental Resources	Caucasian	Female
Wesley	Genetics	African-American	Male
Rafael	Geochemistry	Latino/Hispanic	Male
Eva	Mathematics Education	Latino/Hispanic	Female
Marco	Microbiology	Latino/Hispanic	Male
Dan	Poultry Science	Caucasian	Male
Ryan	Statistics	Caucasian	Male
Eric	Toxicology/Genetics	Latino/Hispanic	Male

The transcript and field note data were first analyzed using open coding methods (Saldaña, 2015). This elemental method lays a foundation for future coding cycles and it aims "to remain open to all possible theoretical directions indicated by your readings of the data" (Charmaz, 2006, p. 46). During this preliminary review, each member of the research team detailed her findings through memos. When the team brought their memos together, one *analytic lead* (Saldaña, 2015) was Jaeger et al.'s (2017) Life Experiences and Role Negotiations (LEARN) model, which suggested the purpose of the paper.

The research team then coded data to the LEARN model through theoretical and elaborative coding methods (Saldaña, 2015). Theoretical coding is typically ascribed to theory generation (Charmaz, 2006; Glaser, 2005), and elaborative coding is used to "build on or corroborate previous research and investigations" (Saldaña, 2015, p. 229). Since the LEARN model has not yet been used in an empirical study, our coding approach remained between these two methods. We sought to build upon the theoretical foundation of the LEARN model, to see if it is applicable to postdoctoral scholars. Data were coded for correspondence to components of the LEARN model (e.g., instrumental learning experiences, schemata, goal representations, etc.); we discuss evidence for each of these model components in the Findings section. For this study, different members of the research team also coded the data a third time to check each other's work and ensure trustworthiness. After coding the interview data utilizing the model, the research team then considered how applying the model provides insight into the career-related decision making of STEM postdoctoral scholars, and in particular how the intrapersonal and environmental factors

included within the model work together to provide a more holistic explanation of their career trajectories.

Trustworthiness

The research team for this study included faculty, doctoral students, and a postdoc. With multiple rounds of coding, the research team triangulated their findings (Merriam, 2002; Miles, Huberman, & Saldaña, 2013). Through detailed memoing about their coding processes, the research team also ensured this study was auditable (Merriam, 2002). To safeguard reliability and validity, the research team utilized rich, thick descriptions, which helped to ensure the data provided context and was connected to theory (the LEARN model).

Limitations

The study was based on current literature, an innovative framework, and the tenets of qualitative research methods, leading to insightful data and implications. However, due to the research decisions, there were several limitations. Qualitative interview data are only one data source and address the experiences of a limited number of participants and therefore does not lend itself to generalizable conclusions for the population as a whole, which would be expected with a quantitative research design. This study was completed at a single institution and other institutions may have different ways of managing and educating postdocs. Finally, the LEARN model has not been used before in this context. However, as noted previously, the model is not specific to the context in which it was developed; its elements are drawn from the broader literature on career decision making (see Jaeger et al., 2017). Our application of the model to understand the career decision making of STEM postdocs enables us to extend the model's application to additional populations. Additionally, the lens provided by this innovative model allows us to see trends in the data which might not have been revealed through a less holistic framework, enabling us to offer implications for practice to better serve the needs of postdocs, while also providing the next steps for further research.

Findings

This paper addresses the learning experiences of postdocs in STEM fields, specifically related to their career trajectories. We examined interview transcripts for evidence of the LEARN model's (Jaeger et al., 2017) components (see Figure 1): continuous personal determinants (identity-sociocultural, identity-science, self-concept, and agency), past determinants (instrumental learning experiences and schemata), present determinants (goal representations, self-efficacy, and outcome expectations), future career outcomes (role expectations), learning, decision making, and the environment (congruence, adaptation, and marginalization). Not as distinctly evident, so not explored here, are two additional elements of the Model: associative learning experiences and outcome expectations.

Who I am Leads to Where I Go (Identity-Sociocultural)

Central to the postdocs' experiences are their identities. Postdocs described their gender and nationality (sociocultural identities) when talking about their career trajectories. Issues related to gender mattered in terms of climate. For example, Marco said:

> For the first time, I'm working around basically with all males, and I went from a situation where I was working around a lot of females, and it changed a lot. And for the first time, I realized, I don't know, it's a feeling about differences between certain types of environments, and I think I was lucky because I had a female PI, a very strong woman figure, for Ph.D.

Moving from a supportive, female environment, Marco's male identity was now in conflict with his work environment. Gender was similarly important in terms of family. Francine explained:

> Well, I am not a typical doctoral student or postdoc since I went to school a little bit later. I always focus my decisions on what will be best for my children, and also where I'll be next because my husband moves every—usually every three years. So I have to think about what type of job that I'll be able to get next.

The career choices Francine made appeared to be associated with her gendered identity as a mother and her role within her family. Both Marco and Francine demonstrated the continuous interaction of gender with their career trajectories.

Nationality was also a salient sociocultural identity for participants. International postdocs spoke about the unique pressure of needing to find jobs before their visas expired. Sociocultural identities also manifested through the privilege afforded (or denied) to participants based on their racial or ethnic identities. Jessica described her desire to give back to her community because of the support she received:

> I think being Hispanic has always influenced me to go back. As an undergrad, in high school, I always had great teachers. My mother's a teacher so maybe the trend for me was already there. I've always wanted to go back and help others the same way I was helped.

Jessica's future career aspirations were shaped by her Hispanic identity and her instrumental learning experiences, which we will discuss more later. In all, participants' sociocultural identities, such as gender and nationality, were continuous personal determinants which shaped how they negotiated their current career experiences and future career choices.

I'm a Scientist (Identity-Science)

Another aspect of identity participants discussed was science identity. The postdocs sought future careers which would allow them to be scientists, but this looked different for different people. For some of the postdocs, being a scientist did not necessarily align with being a professor. Miguel explained:

> So obviously, everybody wants more money. Working in industry means higher pay, but that makes me kind of shallow. The truth is that—so I want to be a scientist. It's my childhood dream to be a scientist, it's what I really want to do. If I were to be a professor, it means that being a scientist would only be—it would be less than half of my responsibility whereas the remaining half would be teaching, mentoring, et cetera, et cetera.

To Miguel and others, teaching science did not necessarily equate with *doing* science.

Science identity was also discipline-specific. Many participants identified as a specific type of scientist, like Vlad: "I mean, being a faculty member is not, like, the goal. I am more driven by— I mean, I'm a geneticist. I am more driven by the need to just go and discover stuff." For other postdocs, this discipline-specific identity behavior trickled down to their work. As Bess explained, her work and the career experiences she sought out were directly tied to her science identity. Interestingly, for many participants, science identity was not necessarily congruent with a STEM faculty position, yet they still spoke of seeking these positions, perhaps not knowing other

alternatives. Science identity was an important continuous personal determinant in the career decisions of postdocs, so much so that we focus on it in a separate paper (Hudson, Haley, & Jaeger, 2018).

In Comparison to Others (Self-Concept)

Beyond identities, participants were aware of their individual characteristics and qualifications as compared to others and how those might pertain to future jobs. For example, Miguel talked about the confidence he has gained through his postdoc experience. He felt he had made strategic decisions which paid off in terms of his career, even though others did not always agree with them.

Other postdocs spoke about knowledge-related insecurities, or deficient self-concepts, like Henry:

> So, I'm bad actually at sitting down reading or writing papers and doing. . . math. I'm actually not good at math, but don't tell people that. So, I found I'm missing a lot of book knowledge, although I've got a lot of hands-on kind of street knowledge, as well, just from being out there. So I feel like I'm missing that, and now I'm trying to read these textbooks and learn from it, because I feel like I should know this stuff in detail. So, I'm seeing gaps.

Henry is an experimental nuclear physicist; to be a postdoc in this field, he surely possessed much greater book knowledge and math skill than he believes. Henry was possibly experiencing imposter syndrome—a self-concept in which an individual feels like an imposter compared to colleagues. He stated, "I don't think that at this point my resume is enough to do a tenured-path faculty position." The continuous personal determinant of self-concept was represented in how postdocs considered their competitiveness in advancing their careers, influencing their career decisions.

Many STEM postdocs were self-aware of what steps they could take to make themselves more competitive for faculty positions. Rafael compared himself to his colleagues as he talked about his readiness for a faculty role:

> I feel like I should get a little bit more training as a postdoc because I'm not sure I'm completely ready to jump to a faculty—apply for faculty positions because I haven't had enough time to get publications out. I got one publication from my thesis but I have to get one or two more out of that, and then here I'm not even done with my experiments yet. So I would like a little more time to develop my writing and some more ideas about what I want to do for research.

The majority of participants were preparing to be faculty in a STEM field, and they believed they knew what they needed to do to be competitive candidates. Yet their self-concepts as potential faculty members reflected a narrow frame of reference as they only compared themselves to the few other postdocs they knew who had secured faculty positions. Nonetheless, this limited source of evidence influenced their career decision making.

Am I Doing This Right? (Self-Efficacy)

Participants continually assessed their skills and experiences for future career roles. They also sought validation or feedback for their work from their PI/supervisor. Dan questioned himself, "Am I doing everything I need to be doing? My personality type is a little bit more of, I can't necessarily just subsist on, 'Oh my boss seems happy, so everything must be ok.'" Since the postdoc experience is often isolating, participants sought more than their own self-awareness or the acknowledgement of their supervisor. Vlad explained:

> I guess it's not all about just me telling myself, "You can do it, you can do it, come on, go get." It is also a process of talking to people and having people validate what you're doing, or I also try to get input from people around me.

Both Dan and Vlad needed verification they were on the *right track.* Other postdocs spoke about their confidence in the skills they had gained. Speaking about their professional development opportunities, Jessica explained, "And with the foundation of having different workshops and all the teaching workshops this place offers as well as a certificate program, you can actually say, 'This is what I've done. I think I'm prepared.'" Jessica and other postdocs were confident in their abilities as a direct result of their experiences as postdocs. The present determinant of self-efficacy was evident, to some extent, for all postdocs.

Acting Strategically (Agency)

The postdocs took on strategic perspectives and engaged in strategic actions to pursue their goals and seek out opportunities to advance their careers. These opportunities included first finding their postdoc position, like Eva identified:

> I sought out conversations with her [the PI], just about her work and her interests. And at the same time, she happened to get a large grant, and so as I was pursuing my PhD, I was able to become a part of that research team which funded my program.

Then, once in the postdoc position, participants sought professional development opportunities through the institution's Office of Postdoctoral Affairs, non-profit organizations like the American Association for the Advancement of Science, or even governmental organizations. The postdocs also sought career advice from people in a variety of positions, like Cecilia:

> Well, I been asking around and they told me that these colleges of liberal arts, you dedicate more time to teaching, being with the students, and of course, you do some research, but it's not the main concern, the research. So those are other options that I'm trying to look around and maybe get together with people who are working in that kind of institution and talk to them and see how it is different.

The STEM postdocs enacted agency to find their positions and to continue their professional development for their future endeavors. When postdocs did not know the answers, they sought resources, often independently of other mentors or supervisors. Postdocs described how they would seek out a variety of individuals, particularly different faculty, to gain advice, resources, and information about career opportunities. Even after seeking advice, postdocs used their agency to decipher what they would do with the information. Bess explained:

> I started just asking people, "How did you get to here?" And nobody had the same route. It was, "Oh, I did this for a couple of years, then I did this for a couple of years, and then I went back and got a graduate degree, and then I did a postdoc, and then I did this," and so instead of this positive correlation between years of work in science and a faculty position, [it was], you know, sometimes backwards, sometimes forwards.

Agency was an essential component of how postdocs advanced in their careers, and through their own agentic perspectives and actions, they made decisions to help reach their career-related goals.

Living and Learning (Instrumental Learning Experiences [+/-])

Instrumental learning experiences, or the experiences which generated an affinity or aversion to remaining in STEM, also affected the postdocs' career trajectories. Overwhelmingly, negative instrumental learning experiences had to do with funding (or the lack thereof). Henry explained:

> As a career choice, I mean, I love what I do, but then there's this money side, like writing grants every year just to fund your research and then having to tell someone, essentially fire someone and say, "I can't pay you because my grant didn't go through." That's got a lot of stress.

Many postdocs raised their concerns regarding these financial pressures of academia which were synonymous with STEM careers. Experiences with these financial pressures negatively affected their STEM career trajectories.

In contrast, positive instrumental learning experiences helped the postdocs feel reinvigorated in their career paths. Jessica was invigorated by her research opportunities and activities which showed her more about the possibility of a faculty career:

> I was really interested in infectious diseases, and I still am, and there was a program that allowed postdocs to shadow infectious disease physicians. This was a teaching program, so we were able to go out to some of the partner sites and guest lecture and see how faculty life was there—kind of compare and contrast with the life of a researcher or a faculty member at a research institution.

The interest in doing research was relevant to all participants. Others had positive instrumental learning experiences which guided them away from faculty positions, like Ben:

> And some of the postdoctorate experiences I've had have changed the way I look at things. In particular, the first postdoc I had was with a university collaborating with a government agency. I was separate from a tenured track position and reassured I don't want a faculty position.

For participants like Jessica and Ben, affinity experiences influenced them to remain in STEM, but alternate experiences led them to consider career options outside of academia.

The Way Things Work (Schemata)

The postdocs also had many assumptions, or schemata, about their future job prospects based on past experiences, and these schemata shaped their decisions. Vlad echoed the low number of available jobs in academia others had previously mentioned: "It's the law of demand and supply. It's just the way the market works. You have so many postdocs and very few faculty positions out there to be filled." Linda made assumptions about low salaries and had already accepted that "if I found a great job that I would be really happy with, I don't think I'd have any qualms with taking a salary that's lower than another position that I didn't like as much." Participants used their past experiences and assumptions to predict future job prospects.

While all participants shared concerns about job availability and salary, international postdocs faced additional issues such as visa restrictions, which Dan described:

> As an international student it was very important for me to get a job immediately, just after my graduation, because we have—I'm not sure whether you're aware of OPT, optional practical training. So once you graduate, within 90 days, which I mean for international students, he or she should have a job within 90 days, just after your graduation. Otherwise you will be kicked out of the country, because you have to have a job. It can be a postdoc or industry, it doesn't matter, but you should have a job immediately as soon as you graduate.

Whether or not the postdocs were international, like Dan, schemata (assumptions) about academia and industry directly influenced their career decisions. They had assumptions about what jobs would be available, whether or not they would attain those jobs, and what jobs were better than others. These past experiences influenced their current and future career decisions. Their career

trajectory or prediction of future career was often based on incomplete or perhaps even inaccurate information from the past. This may lead some postdocs to pursue an idealized career which may not actually exist. For example, one postdoc was pursuing industry because the schemata about academia and grant getting suggested he would not be able to do as much research as a faculty member, yet he had previously not considered industry positions and had no experience in industry. Ultimately the past schemata of academia positions lead postdocs to feeling trapped without other opportunities.

Where I Want to Be (Goal Representations)

Participants were purposeful in their rationale for participating in a postdoc position. They knew they wanted a STEM position after they completed their current postdoc role, and they were cognizant that their goals had changed over time. Eric elaborated:

> I think every graduate student always has this thought in their mind that it'll be easier if I can just get a job without doing a postdoc. But I think in order to widen your career path because you don't want to narrow too much and need a postdoc. For me it would've been—I wanted to do a postdoc personally because I wanted to gain more training, gain more skills in something that I had never done before.

For Eric, when he was a graduate student he wanted a job, but as he continued, he knew that to reach his career goals he needed more training. His desired outcome was a faculty position and he needed more experience to reach that goal.

Goal representations also manifested through specific requests such as not having to worry about funding, as Cecilia explained: "So I know funding is important for the research and everything, but I would like to find a way that I spend time in the lab with the students and things like that, and not become more administrative and worry about money." Previous experiences and the present job market led Cecilia to explore multiple paths.

Linda explained how her goal representations had changed over time:

> When I started my Ph.D., the way that I thought about my job opportunities is very different than how I think about it now, certainly because a lot of places are on hiring freezes now. I know that my own department has said that if someone retires or leaves in the next year or so they will not be actively searching for someone to fill the position simply because the funding situation is so unknown at the moment. . . . I've actually started looking outside the U.S. in terms of professor positions.

While her long-term goal of a obtaining a STEM career did not change, her specific goals had adjusted to her present circumstances. Overall, participants were purposeful in adjusting their future career goals in response to present determinants.

Aligning Their Lives (Role Expectations)

Participants' ideas about industry, academia, mentoring, etc. shaped their career trajectories as well. For Ben, work-life balance was important when considering positions:

> For a long time, originally back when I decided to pursue a degree, the goal was to get a faculty position. And then, once going through that process and becoming more aware of what that involves, the amount of grant work particularly and the competitiveness of it, the number of hours that most people work, and my desire to balance family life, I decided that that may not be my only goal.

Ben was not interested in seeking positions that limited the time he could spend with his family. Other postdocs spoke about balancing distinct responsibilities in their future positions. Sarah wanted a balance between research and teaching:

> I'd like to go into a career as a faculty member doing both research and teaching. One thing I'm still trying to figure out is what kind of balance I want. I like the variety of being able to do both; I genuinely like to teach and I genuinely love to do research. And so I think I'll be most happy in a place where I can do both.

When speaking about goal representations, participants defined what success looked like through the roles they played. They were not solely scientists, despite their love of science, nor were they solely researchers or project leaders. Rather, participants spoke of their personal and professional lives and sought career choices which aligned with their multiple roles now and in the future.

Learning How to Be a Good Postdoc (Learning)

The postdocs continuously learned throughout their experiences, emphasizing the central tenet of Jaeger et al.'s (2017) LEARN model, and they also spoke specifically about learning how to be a good postdoc. For example, Eva said:

> I think for me, when I started my postdoc, and I had a couple of job interviews that didn't necessarily go the way I had hoped. I was able to take those experiences and work with my advisor to create some different opportunities in my postdoc that gave me more of the experience that I wanted and needed.

For Eva, she learned from unsuccessful interviews what skills she needed to gain and was able to work with her advisor to make strategic career decisions to develop these skills and advance her career goals. Luca also discussed learning through during his postdoc: "You have to stop thinking like a postdoc. . . you have to think as a professor." Luca learned to think about the position he wanted, not the position he had already attained.

All of the postdocs discussed some type of learning experience, whether it was learning a particular skill in a lab or a networking strategy. This paper focuses only on learning that postdocs directly related to their career choice or career trajectory. This learning was often expressed through an intentional reflection on their own experiences and growth from those experiences. Participants used their learning as a feedback mechanism to shape their present and future career goals. For example, one postdoc discussed her positive teaching experiences and suggested after such experiences, she knew she no longer wanted to seek a faculty career at a research university but rather at a small institution. These pivotal learning experiences lead to particular career decisions.

Decision Points (Decision Making)

Another central tenet of Jaeger et al.'s (2017) LEARN model is deciding to stay in or depart from STEM. Participants had a lifetime of experiences representing their decision making around this choice. These decisions included seeking their current postdoc position, like Henry:

> So after I finished my doctorate, there weren't any positions in academia that were open. I knew there would probably be some in the next year or two. I didn't have any job offers, so I was really, really excited I decided to come and do this [postdoc].

All of the postdocs had to make a decision to accept their current position and remain in STEM. They also spoke about the decisions they would have to make about their career after their current postdoc. Eric explained:

> You have to go with how the economy is doing. If you know where the jobs are—if there are any jobs—you could definitely take advantage of that, do that—see—if you know somebody who knows where the money is going, then you follow it. But you know, it's pretty difficult in this day and age to get a job, even after being a graduate student. It's too hard.

Like Eric, all of the participants' decisions about their career trajectories were affected by the economy, the availability of jobs, and the nature of academia.

Fitting in (Congruence)

The environment and its interaction with participants also affected participants' career trajectories. Some postdocs spoke about congruence with their environment. Ryan explained:

> The department is great, so is my advisor. So it's a really well-rounded department and very active, and everyone's super friendly. It's been really easy to become—not acclimated, but just immersed into the department community. There is a culture of encouragement and acceptance and all that. So it sounds like I'm getting paid to say these things, but it really is; I mean, it's really great. So in terms of influencing my ability to pursue my goals, the department has been really awesome.

Ryan finds himself in a supportive environment where he can pursue his goals and where he finds a connection. This good fit was not always expected, as participants weren't certain of their interest in the role until after it was offered to them. As Dan notes, "I wouldn't be in the position that I'm in if I hadn't decided to seek faculty jobs in the first place. It ended up being a really good opportunity for me."

Making the Postdoc Work (Adaptation)

Unfortunately, many participants did not have experience congruence; some spoke about having to adapt to their environments. To do so, they were flexible in how they framed their roles. Some postdocs adapted their roles to meet their career-seeking needs, like Ben:

> I was able to seek out projects—side projects even, when I got a little cooped up or stir-crazy with the project at hand, where people had other needs and they needed some help with this type of analysis or helping them do some stats for something.

Ben was able to participate in projects outside the scope of his postdoc, being flexible in how he defined his role to gain what he needed. Other postdocs, like Francine, sought out positions to fit her unique needs of balancing other commitments. Most postdocs seemed resilient in making the most of their situation and gaining something from the experience. When the postdocs could not adapt to make their situation work, they felt marginalized.

Isolated Based on Identity (Marginalization)

Marginalization was an issue when a sociocultural identity did not match with another person's perspective of the participant. Cecilia talked about this marginalization in terms of earning respect as a Mexican instructor:

> Sometimes I feel like I need to earn respect, even with some students. But I earn it in a good way, so I don't try to be mean or anything. With my knowledge, with my experience, with the way I treat people, I think they realize, "Oh, wow, she knows what she's doing." They respect me, not just because I'm Mexican or not.

In contrast to Cecilia, other postdocs spoke more frequently about seeking respect from their PIs rather than students. This respect extended beyond the work environment to support life choices which would affect their career trajectory. Eva explained:

> Sometimes there's this feeling like, "Is it me? Did I really hear that?" in ways, as women, and, personally, for me, as a person of color. And I think, also, watching a lot of female colleagues get pregnant and the view toward them, I think that's something that can be quite negative. And I have not had kids, so I haven't had to go through it personally, but watching it, and I think that it happens everywhere. . . . I've seen a female graduate student get pregnant, and people think that she's not taking her work as seriously.

Eva and Cecilia were not alone, as other postdocs felted isolated based on their ethnicity or gender. Although this caused participants to pause, it did not appear to affect their career decision making.

Discussion and Implications

The purpose of this research was to understand STEM postdoctoral scholars' career trajectories, with particular attention to the influences on their career-related decision making. Applying the LEARN model (Jaeger et al., 2017) to this population revealed how continuous personal determinants (including identity, agency, and self-concept), past and present situational determinants (such as learning experiences and schemata), and expectations for future career outcomes shaped participants' career trajectories by influencing their career decisions. These findings led us to three suggestions for how institutional and national policies and programs can best support the career development of postdocs.

First, most of the postdocs in our study discussed taking agentic action to align their postdoc experiences with their short- and long-term career goals. While postdocs' development and exercise of agency is unequivocally positive as it will continue to benefit them throughout their careers, what concerned us as researchers was that in many cases the postdocs in our study exercised agency to compensate for a lack of access to mentorship and professional development or to adapt to a less-than-ideal work environment. As Marco put it, "Everything I have done, I have gone out and done myself." It seems, then, while postdoctoral positions may foster the development of agency among postdocs, this outcome results from of a *lack* of support rather than from intentional career development and mentorship. The lack of professional development, mentorship, and support postdocs receive, especially in regards to career planning, has been well documented in the literature (e.g., Camacho & Rhoads, 2015; Chen, McAlpine, & Amundsen, 2015; Haley et al., 2018; National Academies, 2014; Hokanson & Goldberg, 2018; Puljak & Sharif, 2009; Scaffidi & Berman, 2011).

Therefore, we first and foremost encourage institutional postdoctoral offices as well as those who supervise postdocs to provide more intentional and intensive career guidance and professional development to the postdocs they employ. In particular, those supervising postdocs should be required to attend regular trainings offered by institutional postdoctoral offices focused on best practices for meeting postdocs' career needs. In addition, institutions should also set an expectation that postdocs be released from their regular work duties for a minimum amount of time per month (e.g., 1-2 full workdays per month) in order to engage in career development, so such work can be considered part of the postdocs' job responsibilities rather than an *add-on* of lesser priority (National Academies, 2014). This suggestion directly connects to our research findings that postdocs were making career decisions on past schemata (past determinants) or comparisons to

peers in terms of career preparation/marketability (identity—self-concept) which may not accurately represent a particular career opportunity. Finally, performance evaluations of both postdocs and their supervisors should include attention to the quantity and quality of time spent on career development. Ultimately, if the postdoc role is truly developmental, as it is defined to be, then the burden should not rest exclusively or even primarily upon the postdocs themselves to shape their postdoc to fit their career goals.

Second, some of the postdocs in our study had learning experiences through their postdoc appointments prompted them to reconsider how much they truly desired a faculty career. Interestingly, these negative experiences were not associative learning experiences—experiences driven by society that reinforces gender or racial stereotypes about who can and cannot be a scientist, documented in the extensive literature on the leakage of women and people of Color from the STEM pipeline (e.g., Rosser, 2012; Williams, Phillips, & Hall, 2014). In fact, we found very few examples of associative learning. Rather, some participants discussed negative instrumental learning experiences related to perceiving that their supervisors were *forced* to prioritize seeking funding over research and teaching, shaping their schemata (or what they held to be true) regarding the faculty role and leading them to consider leaving academia for careers in industry. While the unfortunate reality is there are many more postdocs seeking faculty careers than available tenure-track positions (Bonetta, 2010; Micoli & Wendell, 2018; National Academies, 2014; Puljak & Sharif, 2009), postdocs who choose alternatives to the traditional faculty path should make that decision in order to align their own career goals and values with their career options and on the basis of complete information, not because incomplete or inaccurate information (past determinants) has led them to pursue an idealized career which does not actually exist.

The experiences of many of the postdocs in our study suggest their major supervisors may not recognize or fully comprehend (or, in some cases, welcome) the major influence they have in modeling the role of a scientist and thereby shaping their postdocs' career trajectories. Supervisors need to provide guidance to postdocs in making sense of their experiences relative to their career plans; a negative experience which may seem relatively unremarkable to a seasoned faculty member may be monumental to postdocs, who are constantly assessing whether they belong and can succeed in science, especially if they have limited information with which to contextualize that experience. Therefore, we echo the National Academies (2014) and other scholars (Hokanson & Goldberg, 2018) in emphasizing the need for postdoc supervisors to receive structured training in how to provide effective career-related mentoring to their postdocs. We propose this initiative be led at the national level, perhaps by the National Postdoctoral Association in cooperation with federal funding agencies. Individual institutions can then adopt the national training model and associated best practices to deploy training on their campuses to ensure the quality of support offered to their postdocs is consistent across laboratories and departments.

The decision to pursue a postdoc appointment should be an intentional step in the postdoc's plan to reach his or her desired career. Accordingly, our third recommendation is that applications for postdoc positions require purpose statements indicating how the position will aid applicants in achieving their career goals. These purpose statements should then serve as the basis for the individual development plans which are required by federal funding agencies, although these are often neglected by postdoc supervisors. Additionally, institutional postdoctoral offices should require supervisors and postdocs to jointly submit updated purpose statements and individual development plans each year as a condition of reappointment and performance evaluation (Cavanaugh, 2018; National Academies, 2014). We also encourage federal funding agencies (e.g., the National Science Foundation) to revise their individual development plan format to center

career-related learning and development and to more stringently enforce the creation of and adherence to mentoring plans as a condition of their funding (Camacho & Rhoads, 2015; Hokanson & Goldberg, 2018; National Academies, 2014).

Applying the LEARN model to the experiences of STEM postdocs illuminates the way in which learning permeates the postdoc experience, as it should. Overall, the STEM postdocs in our study clearly exhibited career-related learning and discussed how that learning had shaped or would shape their past, present, and future career decision making. This is an encouraging finding given that the postdoc role is intended to be a time for focused career development. Furthermore, examining postdocs' career experiences through the lens of a model focused on lifelong career trajectories—rather than simply examining the postdoc period as an isolated career moment— provides unique insight into the support postdocs need to be successful both in their present roles as well as in their future careers, whether within or outside of academia. We hope those who work with postdocs at the laboratory, institutional, and national levels will use the findings of this study to infuse learning more explicitly and thoroughly into their programming and policies, to ensure postdocs receive the career-related support and development opportunities which will aid their career decision making and position them for success in their future science careers.

Finally, we encourage future research to address some of our unanswered questions about the postdoc experience. Other perspectives about the role of the postdoc could be addressed through interviews with postdoc supervisors and mentors. While best practices have been put forth in this and other articles, we need to follow up with how those best practices have been implemented and assessed. Additional quantitative studies can now be conducted based on these findings and the LEARN model in order to get a broader range of both participants and institutions.

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