Beyond The PhD

STEM Postdoc Identities, Interactions, and Outcomes

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TABLE OF CONTENTS

PREFACE

According to an American Association for the Advancement of Science survey of more than 2,300 postdoctoral trainees, while most postdoctoral fellowships take place in academic contexts, many trainees are only partially committed to pursuing academic positions. These findings are supported by a 2015 study that shows many scholars enter postdoctoral positions with somewhat "unformed" interests in academic careers only to leave them wanting to start charter schools with science emphases, do research and development for industry firms, or pursue careers in drug marketing, etc. (Gibbs et al. 2015).

In November 2016, I and colleagues at Vanderbilt University, Fisk University, and Wake Forest University were awarded a grant from the National Science Foundation: *Bridging the PhD to Postdoc to Faculty Transitions for Women of Color in STEM*. The funding supported the implementation of an innovative program of postdoctoral recruitment, training, and transition to tenure-track faculty positions. This program, the **Academic Pathways Postdoctoral Fellowship**, was designed to prepare recently graduated doctoral students (PhD, EdD, etc.) and/or a law degree (JD) for competitive academic careers. The need is particularly acute to develop faculty candidates who come from diverse racial, ethnic, and other backgrounds and experiences, as differing experiences, views, and perspectives are of exceptional value for academic institutions in their research and educational roles.

The Academic Pathways Postdoctoral Fellowship creates a bridge between academic training and entry-level faculty positions at colleges and universities throughout the United States. Essential elements of the program include the creation of substantial "protected time" for the pursuit of the fellow's academic and scholarly objectives, the construction of a robust mentoring architecture, and the development of the "soft skills" so important for success in today's academic setting. Specific elements of the program include leadership training, grant and manuscript writing and preparation, a multi-level mentoring framework, and connections to relevant resources and training across campus. These opportunities are individualized based on the academic discipline of fellows with similar formats for the humanities, social science, and life/physical/biomedical science areas.

We also charted an ambitious process for studying the postdoctoral "career" across 30 universities. While it is true that there are insufficient numbers of academic positions for the number of students seeking those jobs, "demand" for talented scientists and engineers is only part of the story. A major impediment to increasing female and underrepresented minority (URM) representation in academic positions is a failure to induce those who persist to the postdoc stage to enter careers as faculty members. The hard work of developing women's and URMs'

interests in research training is, ultimately, futile if something in that training dampens their interests in academic careers. We argue that understanding the experiences of postdocs through three lenses—identity, interactions, and institutions—gives us more clarity in the reasons for attrition from or persistence in STEM academic careers, clarity that should not only be useful for scholarship on the STEM pipeline, but also useful for practitioners in programs and offices engaged in the development of postdoctoral trainees.

Now at the end of our investigation, we have fielded three waves of a 700+ variable survey and interview protocol. With 215 survey respondents (65 percent of them women, 23 percent non-White U.S. citizens and permanent residents) and 50 interviewees, we have amassed a remarkable amount of information about the lives of postdoctoral appointees and trainees. This report describes what we have learned.

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EXECUTIVE SUMMARY

Often research on STEM career trajectories and experiences focuses on undergraduate STEM majors and, more recently, graduate students in STEM. For the most part, research on postdocs is a new area, with the vast majority of research on them being published since 2000 when the National Academies of Science released its report, *Enhancing the Postdoctoral Experience for Scientists and Engineers*. That report was a response to the explosion of postdoctoral traineeships at the end of the 20th century, particularly during the 1990s.

In addition to the expansion of the STEM-training research agenda to include postdocs, many universities that had, until then, mostly ignored postdocs—treating them as STEM faculty's employees—created offices of postdoctoral affairs (OPAs) whose job was to create student affairs structures parallel to those offered for decades to undergraduate and graduate trainees. In 2003, postdoctoral researchers created the National Postdoctoral Association (NPA) to, according to its vision statement, build a "community where all postdocs are empowered, valued, recognized, and supported in their current and future endeavors."

As more attention was paid to the postdoc population, it has become clear how important it was to understand their experiences, experiences which, like those of graduate students, are often critical to the decision to pursue academic careers. STEM postdoctoral trainees are situated in an unusual space in the academic pipeline. They are not full-time students like they were when pursuing the doctorate and they are not full-time workers as they might be if they had taken a faculty or industry position upon graduating. Instead, they are more like medical residents and house staff, still in a training position where they work full-time employee-like hours either learning new skills, deepening their knowledge in material/skills gained in graduate school, or accumulating additional credentials (e.g., publications) necessary for a competitive application for employment beyond the postdoc appointment.

This report draws on a mixed-methods approach to analyze the characteristics, experiences, and motivations of this substantial, but poorly understood, group of STEM trainees. While we recognize that STEM training doesn't always, or even primarily, lead to academic careers, our particular interest in diversifying the STEM professoriate led us to focus on ways identity, interactions, and institutional culture may be related to that goal. With that in mind, this research had four broad aims borne out of preliminary interviews with STEM graduate students and postdoctoral appointees. Below we list those aims and a representative quote that drove our inquiry in that area.

Aim #1: To examine potential racial and gender *identity interactions* in their experiences that may shape the meaning of, salience of, and strength of a professor identity: *"I came to see some of the limitations in academia, especially for single women, especially if you're Black. I only had two women role models by the time I finished school. That was it. One didn't have a family; the other struggled for tenure with small children. Without support, forget thinking about a family."*

Aim #2. To understand the ways the *academic-professional culture* these trainees are embedded in make faculty careers more or less attractive to them: *"If you work fifty hours, you might be successful. If you work sixty, even better. The more unhealthy lifestyle you can have, the more success you see. I go to conferences and people are praised for being so very productive, and I'm like, yeah but that's only one side of the story. What does the rest of their life look like?"*

Aim #3. To examine how *social relationships* with peers, faculty, and their families either promote or hinder the development of a "professor" identity among postdoctoral trainees: *"My PI has crushed my spirit. I have no confidence in myself as a scientist and I find academia incredibly toxic for a variety of reasons. A full professor I know recently told me that he still has impostor syndrome. That was the final nail in the proverbial coffin."*

Aim #4. To examine the influence of *institutional context* on processes shaping the development of "professor" identities: "*I don't have the personality for it. I am easily frustrated by putting forth effort that doesn't lead to something productive, something that is much too common in this kind of basic research environment. Having to fit your research into what is 'trendy' to get published was a huge wakeup call. It made me realize pure research wasn't enough."*

No single storyline emerges from our research. Overall, we find that all of these things play different roles in the decisions STEM postdoctoral trainees make about their futures beyond their appointment. In particular, we discovered the following twelve broad findings. These and more will be described in this report. We argue that postdocs and those who care about them need to understand these dynamics in order to consider how identities, interactions, and institutional cultures ultimately impact postdoc outcomes.

SPECIFIC FINDINGS

1. In the past two decades, commitments to postdoctoral positions have increased across all STEM disciplines except the life sciences. However, only half of our surveyed STEM postdocs believe that their appointments are necessary for their career progress, whether they intend to remain in the academy or leave for other sectors.

2. PhD recipients are motivated to take postdoctoral appointments to increase their knowledge and because these positions are perceived as steps in the academic

career process. However, some are motivated by the fact that postdoc positions leave career options open while offering short term employment.

3. The primary purpose of postdoctoral appointments is to assist in the training of academia-ready professionals. However, the majority of STEM postdocs have no intention of remaining in academia for their careers. Among those who intend to remain, nearly half are interested in research staff positions rather than tenure-track faculty positions.

4. Postdoc appointments provide opportunities for PhDs to build their academic vitas. Postdocs are more productive in collaborative research activities than their own independent research, such as working on solo publications. However, more men than women reported research collaborations which resulted in the acceptance of solo and team papers.

5. We find significant differences in the proportion of postdocs reporting a range of accomplishments in the first year of their appointments compared to the second or third years. Among first years, about half reported acceptances for publication of co-authored papers. This proportion is more than two-thirds among third-years. Longer appointments may be necessary to mount a competitive application for faculty positions.

6. Most postdocs have a faculty mentor and report positive mentoring experiences. However, mentorship exhibits limitations detrimental to postdocs' career development, including little close career advising and lacking support with professional networks. Postdocs are mentored like bench scientists or staff researchers rather than as trainees building their careers' foundations.

7. Much of the work performed by successful STEM faculty is entrepreneurial in nature, including finding funding and constituencies for their "product" (e.g., peers, journals, industry). However, most postdocs are not trained to perform these crucial practices and few hold characteristics commonly found among successful entrepreneurs, such as tolerance of ambiguity and competitiveness.

8. Postdocs experiencing work-to-life conflict are less interested in faculty careers and more interested in staff positions in academic institutions, compared to those who do not experience this conflict. Postdocs experiencing work-to-family imbalance suffer more mental health issues, including anxiety symptoms, high levels of stress, and low life satisfaction.

9. Postdocs who have been discriminated against because of their race or gender were more likely than their peers to report mental health issues, including high levels of stress and depressive symptoms. Those who reported experiencing general maltreatment during their postdoc were more likely to report high levels of stress, depressive symptoms, and generalized anxiety.

10. Coupled and single postdocs exhibit different preferences for non-academic career paths. Compared to single postdocs, coupled postdocs were much more likely to report a career in industry as a primary choice. On the other hand, single postdocs were more likely to report government or other non-academic and non-industry work as their primary choice.

11. Postdocs interested in faculty careers are more likely to perceive benefits in the academy compared to those planning non-faculty careers. In particular, postdocs interested in faculty careers view the position as favorable for producing broad impacts through their research as well as providing a better professional network and rewarding career.

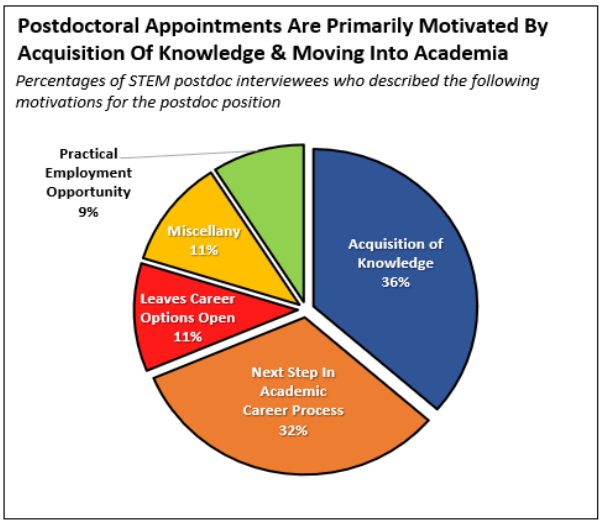
12. Most postdocs believe the benefits of non-academic careers include better pay, work-life balance, and job security. Beliefs about the relative weaknesses of academic careers are largely informed by the experiences of others' working outside the academy, as a minority of postdocs have firsthand work experience outside academia.

Section I
Understanding Postdocs

C. Reasons For Doing Postdocs

Motivations For A Postdoctoral Appointment.

With the increase of postdoctoral appointments, exploring postdocs' motivations may help to explain why it is becoming more common for PhDs to pursue postdocs. As discussed above, the original (and we argue, main) purpose of postdoctoral appointments is to extend or continue training in preparation for research careers in academia.[1] However, not all postdocs continue on into academia after their appointments conclude. This study examines how doctorate recipients' motivations for pursuing postdoctoral appointments may shed light on postdocs' career paths. In this section, we identify what postdocs hope to receive and actually receive through their postdoc experiences. First, we will review the motivations that STEM postdocs shared during interviews.



When asked to detail their motivations for pursuing a postdoctoral appointment, our postdocs expressed motivations in four areas: a postdoc (1) allows for the acquisition of new knowledge, (2) permits more time to decide on career path, (3) is the most practical position to get after receiving a STEM doctorate, and (4) is the next step in pursuit of an academic career.[2] Here we expand on each of these categories.

Acquisition of New Knowledge. Within the academy, academic researchers' primary goals are to acquire and subsequently create knowledge. While in graduate school, doctoral students train to conduct research and acquire expertise in order to make contributors to their fields of study. Obtaining a postdoctoral appointment can be an extension of graduate training with the same goal of making contributions to research and knowledge. Therefore, it is unsurprising that the most commonly reported motivation for postdoctoral appointments was that these positions

[1] As we'll discuss later in this report, there is little demand from industry and government for a postdoctoral appointment (relative to hiring someone directly from the PhD program) and, likewise, little benefit financially for doing a postdoc as a non-academic researcher.
[2] Miscellaneous includes responses that were not common and thus could not be categorized into one theme.

allow for continued learning and expansion of knowledge. Eva (Life Science) explained how her postdoc expanded the breadth of her knowledge and skills, comparing it to how doctors do residencies: "I'm not doing research in the same field. I'm getting training in other things, too. So, it's like when doctors do their residency, and then they want to get some extra training in different things, different technologies, they can go do a fellowship. To me, that's the whole reason of doing a postdoc." Many postdocs reported that their appointments increase current skills and provide opportunities to develop new ones. This is a central motivation for engaging in postdoc appointments.

Leaves Career Options Open. Although some doctorate recipients are sure of their desired career paths before completing their doctorates, others are less certain. These aspirations can change during the course of graduate training. In some cases, doctorate recipients may struggle with determining their best options, even though they were likely trained with an academic career in mind. For those doctorate recipients who remain unsure, many reported that they utilize postdoctoral appointments in order to take more time making decisions about their careers. While they are intended to lead to academic careers, engaging in postdocs leaves open options in academia, industry, and government. Mary (Physical Science) emphasized how much she enjoyed the "freedom" she experienced in graduate school and described her postdoc in similar terms related to her ultimate career goals: "I really wasn't ready to leave [the academic] setting. Being able to choose between academia and industry, I definitely wanted to do a postdoc because I knew I was going to keep both avenues open." Nearly a third of our interview respondents described their motivations to take postdocs in order to acquire more information and experiences with various tasks that might contribute to their decisions whether to remain in or leave the academic career pathway.

Practical Employment Opportunity. Typically, graduate students go on the job market before they complete their doctorate, a process that overlaps with the application processes for postdoctoral appointments. A postdoctoral appointment may be among the easiest and most practical employment opportunities as academics finish graduate school. This theme appeared in interviews with several postdocs. For instance, Albert (Life Science) stated: "I needed health insurance, I needed to get something, and a postdoc is kind of the easiest job to get in a short period of time." He explained that he "could have maybe waited longer," but that doing so would have forced him to "dip into [his] emergency fund." Depending on the conditions of the job market and their experiences completing graduate school, some doctorate recipients look to postdoc appointments as convenient next steps that likely provide benefits and additional training.

Next Step in Academic Career Process. Deciding what one will do once they have received their doctorate can be difficult and is dependent on the job market.

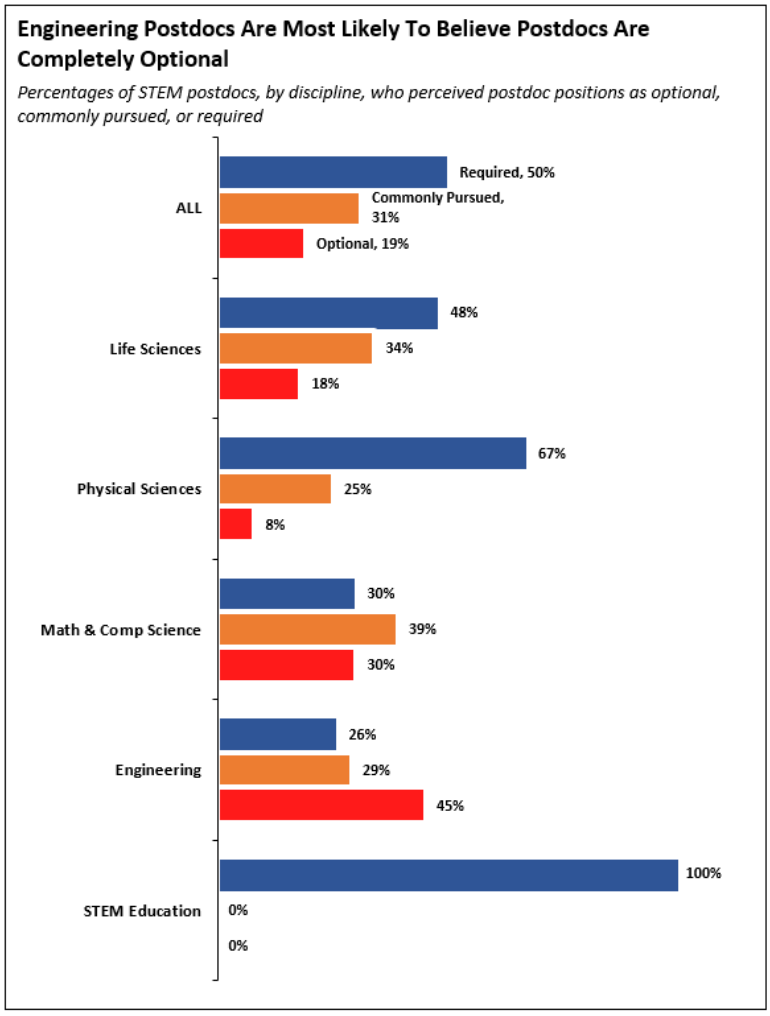
There are fewer positions available in academic careers than in industry and government. The lack of academic faculty positions may contribute to the increase in postdoctoral appointments. According to the Survey of Earned Doctorates (2017), 32 percent of STEM doctorates pursuing academic careers enter into postdoc positions. Nearly a third of our interviewed postdocs described their motivations to pursue their appointment in terms of its quality as a positive step toward an academic career. Indeed, some expressed the view that it was a requirement to continue in academia and eventually enter a faculty position. Kurt (Physical Science) emphasized this point as well as the rarity in his field of faculty members who did not do one or more postdoctoral appointments: "In most science fields, especially in experimental astrophysics, a postdoc is totally required. For research faculty at the top institutions, it's almost unheard of to get a faculty job immediately after grad school. In my field, most new faculty have done maybe five years postdoc." He explained that he learned this during his graduate training, and it was during grad school that it became "pretty clear" that he too would need to do a postdoc. For many STEM postdocs, pursuing a postdoc is a perceived as necessary for their ultimate career goals. The next section reviews this theme in the context of postdocs further career aspirations.

Are Postdocs Necessary For Career Goals?

Postdoctoral appointments are intended to be a transitional step between graduate school and an academic career. However, it is not understood whether postdoc positions are necessary for an individual's career goals or if this is an instance of "up-credentialing." The number of postdocs has increased as the academic job market remains small, particularly for tenure-track faculty positions. The impact of completing a postdoc for doctorate recipient's employment opportunities in the academy is not well understood, however research on biomedical PhDs reveals that those who participate in postdocs do not benefit from increased salaries later in their careers compared to PhDs who do not do postdoc appointments (Kahn and Ginther 2017). In order to better understand the relationship between postdocs and academic careers, we asked our STEM postdocs about their perceptions of the necessity of postdoctoral appointments for achieving their career goals. Below we share our findings related to this question.

Postdocs are Necessary. Postdoc positions may attract PhD recipients because they are viewed as necessary for achieving one's academic career goals, as opposed to being desired for the features of these appointments themselves. Half of our STEM postdocs (50%) expressed their belief that postdoctoral appointments are necessary for their career progress, whether they envision pursuing a career in academia or outside of academia. Recall Kurt's statement above that it is "unheard of" in physics for faculty at top institutions to receive their current positions immediately after completing their PhD and without a postdoc. Ernie (Life Science), expressed a similar understanding of the postdocs' role: "for me, [the] post-doc

was quite necessary and part of the plan for most of my PhD, actually." This view was common among our postdocs.



Many (31%) also identified that postdocs were in fact beneficial for their career goals, but not strictly necessary. Adrian (Life Science) stated: "I will say that my postdoc was useful to me because it wasn't until my postdoc that I learned about this career. But, in general, no. I don't think a post doc is necessary." Drew (Physical Science) shared a similar sentiment: "I think the PhD is absolutely necessary. I think the postdoc has been beneficial, but maybe not necessary. I've definitely learned a lot and grown a lot more confident in my abilities and my knowledge." However, Drew pointed out that his work during graduate school is more salient for his performance on job interviews, because this previous research experience tells "more of a story" about himself and his work over a longer period of time ("six years instead of two"). During his graduate studies he "saw [a] project from the beginning to the end" while during his postdoc he "picked up something mid-stream, and pushed it along, and probably won't see it to the end." These remarks reveal something of a contradiction related to the potential meaning of a postdoc appointment for STEM scholars who must sell themselves as productive, independent scholars when applying for faculty positions. While postdoc appointments are

meant to improve preparedness for academic careers, compared to graduate training their liminality and brevity precludes some of the professionalization and long-term scholarship for which applicants to faculty positions are judged.

While postdocs can increase knowledge and experience, which can assist PhDs on the job market, they may supplement rather than provided further opportunities for the experiences and achievements salient on the academic job market. For instance, some postdocs described the effect of their appointments to broaden, but not necessarily deepen, their expertise. Carl (Physical Science) discussed the benefits of his postdoc along these lines: "The way that I view it is that I have the skillset to do these sorts of things. I have a PhD and a postdoc in two different fields, so I have the breadth of experience in different areas." Some postdocs expressed the view that their appointments were beneficial for careers outside of academia, like Bob (Mathematics) who stated: "I definitely feel like the postdoc is valued because they see it as sort of broadening your skillset and learning. I think some additional useful things beyond just being a student, which can be a little bit focused on your specific dissertation topics. Hopefully, with a postdoc you get a little bit broader perspective. So, I think that's useful." While postdocs perceive the advantages of broadening their abilities, the question remains whether or how this additional experience translates into greater preparedness for academic careers or improved prospects on the academic job market. We take up this topic below in our discussion of postdocs' work activities.

Postdocs perceive their positions as very influential for securing an academic career. The chances of having a successful academic career are viewed as higher after a postdoc than after completing just a PhD June (Life Science) shared this belief. She did not think that it was very likely that someone in her field could get a tenure-track position without having a postdoc: "You would have to be really exceptional to jump from PhD to a faculty position. I've seen it happen, but I can only think of one person." June believed that getting a tenure-track position is still very difficult after a postdoc appointment, but that the chances are better, particularly because certain faculty positions do include a requirement that applicants have postgraduate training. In some STEM fields such as the life sciences, a postdoc appointment was viewed by our postdocs as vital for acquiring a tenure-track position. George (Life Science) estimated that it increases one's prospects for a faculty job by 25 percent despite his additional perception that postdocs tend to be more serious about academic careers than compared to PhD recipients in general. In his view, the "herd is thinned a little bit" through the postdoc stage as PhDs who never intended to remain in academia depart for industry or other sectors: "I feel like most of the people who are going into a postdoc are looking for a tenure-track position at the end of it." As we'll reveal in Section III, he's wrong; most postdocs are *not* looking for tenure-track positions. But, from his perspective, the advantages of a STEM postdoc—learning new skills, increasing one's scholarly impact, and expanding social capital—are most impactful within academia.

The majority of STEM postdocs, across all disciplines, reported beliefs that postdocs are required—or so common as to feel required—for their careers. This likely motivates PhD recipients to pursue postdocs. However, interestingly, engineering postdocs were less concerned with their appointment's salience for subsequent career opportunities compared to postdocs in other fields, and were more likely to specify that postdoctoral appointments are optional. However, we should distinguish between the perception that postdocs are required and reality. While postdocs in certain fields may not be strictly necessary, the lack of opportunities on the academic job market may make these appointments practically inevitable for some STEM PhD recipients. Postdoctoral appointments may be viewed as a means of gaining advantage for future success and career placement.

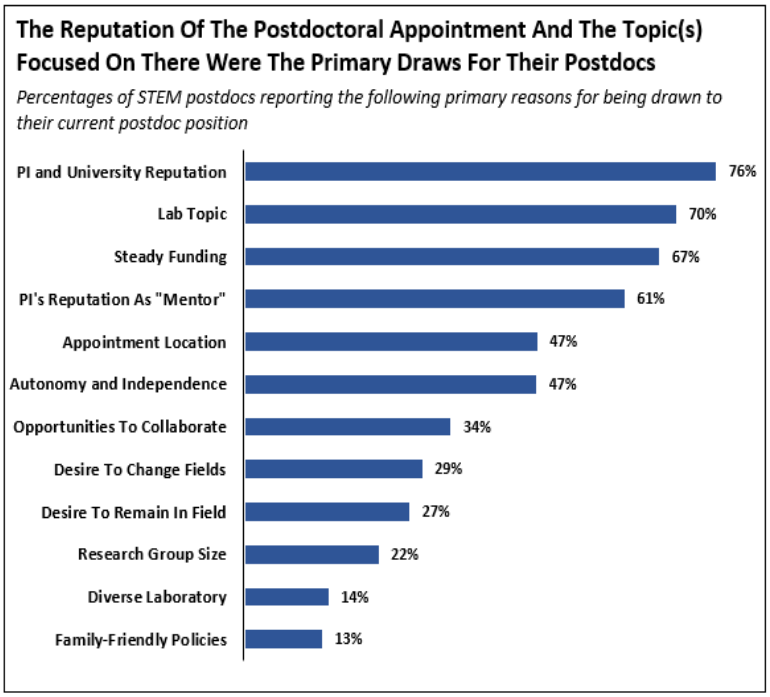
Postdocs are Not Necessary. A small minority of our postdocs (19%) reported that, while postdocs are readily available, they are truly optional. For these few members of our sample, a postdoctoral appointment does not carry the same weight in industry. Tyler (Life Science) "[i]f somebody's not doing academia, and they have a pretty good skillset that they know is wanted in industry, I don't think a postdoc is necessary." Similarly, Albert (Life Science) expressed doubt that a postdoc is helpful for his current career goals, despite participating in one: "That's what you have to do if you want to become a professor, you have to get a PhD, you have to get a postdoc. But to do what I'm doing now, I could have just done any job and then done it. Or done some job, gone to business school and done it." These two respondents reflect how postdoctoral appointments are important for some but not other career paths, particularly non-academic ones.

Some postdocs reported the belief that postdoctoral appointments can be a hindrance for a PhD's career trajectory, particularly in industry or government (e.g., not academia) careers. This view is supported by some research that shows that among biomedical PhDs, the salaries of those who do postdocs never end up exceeding PhD recipients' salaries who enter into other positions instead of doing postdocs after completing graduate school (Kahn and Ginther 2017). Mary (Life Science) expressed the view that postdoc appointments can be detrimental to non-academic careers: "I think people usually start out [in government careers] by either doing an internship or writing policy or something like that. That's their way of getting into government. For most of these jobs a postdoc is actually discouraged because, especially for industry, it is often seen as if while you were trying to go into academia, you didn't make it and that's why you want to come into industry." Postdoctoral appointments for non-academic positions are generally thought to be unnecessary and if an applicant does have one on their resume, it might make an employer "question your allegiance to industry," according to Enjo (Life Science).

Despite only nineteen percent of our postdocs across all disciplines reporting that postdocs are optional, 45 percent of engineering postdocs and 30 percent of mathematics and computer science postdocs reported postdocs were optional. This may reflect differences across these disciplines in the patterns of PhD recipients' movement into academic or non-academic careers. If postdocs are unnecessary for non-academic careers and more engineers, mathematicians, and computer scientist enter industry compared to life scientists and physical scientists, these patterns may shape views about the necessity of postdocs. Indeed, engineering, mathematics, and computer science were less likely to have postdoctoral appointees, in our sample, compared to the life and physical sciences, indicating that the relationship between postdoc appointments and career success vary across disciplines.

Contributing Factors For Postdoc Appointment Acceptance

For our postdocs, the three most important contributing factors for their selection of their current postdoctoral appointments were (1) the reputation of the lab and PI, (2) the lab research topic, and (3) steady funding for several years. The least important factors include family-friendly environment and policies and a diverse lab environment.



Factors for selecting postdoc positions vary across disciplines, although a family-friendly environment is the least influential factor across the board. The reputation of the lab, PI, or university is the most important factor for all the STEM disciplines except engineering, where the research topic of the lab is most important. For the life sciences, the research topic of the lab is just as important for postdoc selection as reputation.

Interestingly, postdocs in math, computer science, and engineering care much more than their peers in the life and physical sciences about the independence and

autonomy afforded by their postdoc position. Traditionally, independence and autonomy are understood to be important to academic scientists. Further research should explore how the liminality of postdoctoral appointments might intersect with scientific norms. For postdocs motivated to seek their appointments because of practical concerns, traditional scientific norms may be less salient than they would be for more permanent academic employment.

Further, for postdocs who view their appointments as important stepping-stones along their journey to the tenure track, or for a transitional period in which to top off their academic record with additional publications, perhaps interest in autonomy and independence are less salient for these temporary postdoc positions. This topic is taken up in a later section on postdocs' "professor" identity.

Examining these contributing factors is important for understanding STEM postdocs' career aspirations. As reported above, many STEM postdocs describe their positions as beneficial for academic careers but not beneficial (or even detrimental) to non-academic STEM careers. Their accounts indicate that postdoctoral appointments are primarily pursued by doctorate recipients to help ensure their transition into the academy; a job sector that has few employment opportunities relative to the number of PhD recipients. If we want to increase doctorate recipients' chances of entering academia, encouraging them to pursue postdoctoral appointments may be the most viable option for continuing on into the academy.

Section II
The Postdoc Experience

B. POSTDOCTORAL MENTORS AND SUPERVISORS

Postdoctoral appointments are typically overseen by a principal investigator or mentor. Mentors play a vital role in postdocs' work to increase their skills and impact as junior scholars. Mentorship activities may include advising on research projects and publications, grant writing, presentations and talks, and even guidance on matters in one's personal life.

Most Postdocs Say They Have A Faculty Mentor And That Mentor Is Almost Always Their Postdoc Appointment "P.I."

Percentages of STEM postdocs reporting the following characteristics of their mentors

	%
Have a faculty mentor	79%
If postdoc has a faculty mentor, that mentor is their "P.I."	91%
Postdocs whose PI is an early-career (yr 1-4) assistant professor	21%
Postdocs whose PI is a full professor	46%
Postdocs with mentors whose mentor is a woman	36%
Postdocs with mentors whose mentor is non-White*	18%
Postdocs with mentors who share their gender	59%
• Women postdocs with women mentors	44%
Postdocs with mentors who share their race/ethnicity	70%
• Non-White postdocs with mentors who share their race	14%

** 3% are uncertain about mentor's race*

Effective mentoring encourages postdoctoral performance, success, and career development (Eby et al. 2008, Hund et al. 2018, Long and McGinnis 1985, Lyonset al. 1990, Mullen et al. 2010, Paglis et al. 2006, Tenenbaum et al. 2001). The increased performance that STEM postdocs are likely to encounter due to effective mentoring results in increased interest in research, publications, and conference presentations (Cronan-Hillix et al. 1986, Lunsford 2012, Nettles and Millett 2006, Paglis et al. 2006), and decreases stress, depression, and anxiety (Levecque et al. 2017, Panger and Janell 2014, Peluso et al. 2011).

Unfortunately, not all mentorship received in academia is effective and positive. Negative relationships between junior scholars and their mentors can have adverse effects on productivity and efficiency, and can increase stress and attrition (Hund et al. 2018). Postdocs are intended as transitional periods between graduate school and academic employment, but poor mentorship can contribute to the loss of junior STEM scholars from the academy. This section reviews the mentor characteristics reported by our STEM postdocs in order to better understand the impact that mentors may have on postdocs and their career trajectories.

Postdocs' Supervisor/Mentor Characteristics

The majority of our postdocs reported having a faculty mentor (79%) and nearly all of their mentors were supervisors or principal investigators (91%). These mentors can be faculty at various stages of their own academic careers. However, more of our postdocs had PIs who are full professors (46%) than PIs in the first

four years of their position as assistant professors (only 2%). This is likely a good thing as senior supervisors are likely more capable of reflecting success and stability for their trainees rather than the uncertainty that many assistant professors are working through.

Our STEM postdocs reported that junior faculty mentors are less desirable because they are less well-known in their fields, less willing to protect their postdocs, and may be more likely to engage in micromanagement. For example, Marie (Life Science) said that she experienced low independence in her appointment and linked this to her PI's experience level: "I've been in a [postdoc] position where I work with a little less independence than I would like, and I sometimes think that it's because my PI is currently young. He is not tenured and so a lot of it is that he has this urge to micromanage." Marie, however, put some of the responsibility on herself to "push back" against this micromanagement. Given that so few of our postdocs had PIs who were in their first five years as faculty, pushing back could prove to be intimidating and difficult. As mentioned above, opportunities to engage in and improve one's abilities as an academic mentorship may be limited throughout graduate school, so one factor in positive mentorship may be senior PIs' greater level of experience as mentors.

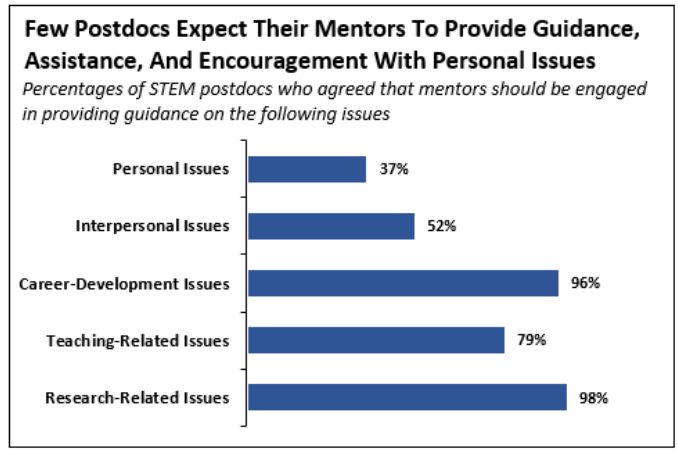
Our postdocs' mentors were typically male (64% in our sample). Only eighteen percent of postdocs reported having mentors who were non-White. These characteristics are representative of faculty demographics in general and are unsurprising given the underrepresentation of female faculty and faculty of color in STEM disciplines. Only 35 percent of STEM faculty are female (NCSES 2019) and minority faculty are also underrepresented (Li and Koedel 2017).

Mentors who match female and non-White students' gender and/or race lead to more assistance for students and can lead to greater success, although studies do not show a specific impact on academic outcomes (Blake-Beard et al. 2011, Noe 1988). The same is likely true for STEM postdocs. Thus, we examined the gender and race/ethnicity matching between our STEM postdocs and their postdoctoral mentors. In our sample, 59 percent of postdocs shared the same gender as their mentors and seventy percent shared the same race/ethnicity as their mentors. Just fourteen percent of non-White postdocs had a mentor who share their race/ethnicity. Less than half (44%) of female postdocs reported having female mentors.

Mentorship Provided By Postdoc Supervisors and PIs

Mentors can provide guidance, assistance, and encouragement on matters both personal and professional. However, our postdocs reported having expectations that mentorship would revolve around academic issues, like career development (96% of postdocs), research-related guidance (98%), and teaching-related

guidance (79%). More than half of STEM postdocs expected mentorship regarding interpersonal issues, but only 37 percent expected mentorship related to personal issues.



In general, the majority of STEM postdocs (65%) report that their mentor operated as a role model for them in both their life and career. How this mentorship is performed is important for understanding postdocs' experiences and how they impact career aspirations. In this section, we break down the types of mentorship that mentors provide their postdocs into three categories: mentorship that is (1) caring, (2) career motivated, and (3) and confidante centered.

Caring Mentorship. A caring mentor is important for building junior scholars' confidence. Postdocs report that their mentors are likely to participate in acts of caring mentoring "to a large extent"; very few say they "never" experience this from their supervisors. Majorities of our postdocs reported mentors who stimulate respectful environments (64%), are especially empathetic (57%), and promote the interests of their postdocs (57%). These findings indicate that most STEM postdocs perceive their mentors to be caring, which can be important for success within and beyond the postdoc appointment. Ernie (Life Science) shared that his mentor's support was not conditional on his particular interests or career aspirations: "my current boss is extremely supportive. She's been really great through the whole process. There are four post-docs in the lab and we are all on very different tracks. She's very open to all of [these tracks], so I feel very supported here." Providing caring mentorship may serve as a model for postdocs' own performance of mentorship, in academia and elsewhere.

Career Mentorship. As stated above, postdoctoral positions are intended to assist in the further training of doctorate recipients and their transition into qualified candidates for tenure-track faculty position. Therefore, this training period should include mentorship related to career preparation and professional networking. The majority of our STEM postdocs (66%) reported that their mentors often encourage them to prepare for next career steps. Such preparation can involve learning what it means to be a PI.

Mary (Physical Science) explained how her knowledge of what is required to run an academic lab grew more during her postdoc than during her graduate training:

"Just last week my PI shared how funding works. Compared to my grad school career, I did experience a lot more of how a lab is run. The lab that I was in moved to a different core facility within the university and I had hands-on experience with how the entire lab would move." Her experience with her PI and at the end of her graduate training has contributed to the preparation for the next step in her career, regardless of that being in academia or not.

Fewer Than Half Of Postdocs Receive Close Career Advising, Support With Networks, Or Close-Up Looks At Mentor's Lives

Percentages of STEM postdocs who reported the following experiences with mentors "to a large extent" and, in parentheses, "never"

	%
Mentor has served as a role model for me in life and career	65% (0%)
CARING MENTORING	
Mentor conveyed feelings of respect for me	64% (3%)
Mentor conveyed empathy for my concerns or feelings	57% (6%)
Mentor has gone out of their way to promote me and my interests	57% (2%)
CAREER MENTORING	
Mentor encouraged me to prepare for career next steps	66% (2%)
Mentor helped me meet people outside of our institution	47% (10%)
Mentor explored career options with me	34% (9%)
CONFIDANTE MENTORING	
Mentor has shared personal experiences with me	51 (4%)%
Mentor has shared the history of their own career with me	44% (3%)
Mentor has discussed their family life with me	25% (12%)

While encouraging career preparation is common, mentorship promoting professional networking was reported by less than half of our postdocs. Only 47 percent reported that their mentor helped them network to a large extent and meet people outside of their institution. The potential impact of expanding one's network during the postdoc stage, and the role mentorship can play in acheving this, is evident in one remark made by Bob (Math and Computer Science), who when asked about mentorship stated, "I've been extremely blessed, very fortunate with a network, the community I've been a part of. My graduate advisor connected me with my current postdoc advisor, who connected with me with many of my future colleagues at the national lab. It's been sort of a natural progression for me from one institution to the next." A significant minority (10%) of our postdocs reported that their mentors never helped them meet people outside their institution. Only discussions of family life were more likely to never happen between our postdocs and their mentors (12%).

Over a third of our STEM postdocs (34%) reported exploring career options both inside and outside of academia. Some reported mentors who were willing to discuss and support non-academic career tracks. Kurt (Physical Science) shared that he felt no pressure in either direction from faculty members during grad school and his postdoc: "We've had postdoc people [go into] industry. Everyone seems supportive. I've never heard any faculty at either place say negative things about going into industry, for sure." In Kurt's experience, his mentor did not put pressure

on him to pick academia over industry and instead was willing to discuss multiple career options. This is not the case with all mentors, however, as nine percent of postdocs reported that they never received mentorship related to exploring career options and only 34 percent reported they received this mentorship to a large extent. These proprtions are surprising given that postdoctoral appointments are only temporary training positions and, presumably, launching grounds into actual careers. Most postdocs would likely benefit from mentorship related to career exploration.

Confidante Mentoring. Mentorship can go beyond career-related preparation to include compassionate guidance related to personal experiences and issues. This confidante mentorship includes discussion of experiences insided and outside of PIs' academic careers. Just over half of our STEM postdocs (55%) reported that their mentors discussed personal experiences "to a large extent" and 44 percent reported that their mentors shared information about their career history "to a large extent." Sharing information with mentees can be very helpful and provide useful insight. Mary (Physical Science) explained how she was able to put her own difficulties into perspective when her PI shared that they experienced similar struggles. Mary said her PI expressed she was "glad [I was] having these problems now as a postdoc before having to deal with all the other issues of starting a lab." Mary described this perspective as a helpful insight. A mentor like the one Mary has can acknowledge and validate postdocs' experiences as legitimate and even beneficial or timely. This is essential for junior scholars' confidence and can have a positive impact on their future progress in their field.

Our postdocs were much less likely to report mentorship involving discussion of family. Only 25 percent of our postdocs reported that such discussions with mentors happened "to a large extent" and twelve percent reported that they "never" happened. Family may fall outside the boundaries of some mentor relationships, despite the topic being very salient for postdocs' career choices and progress (discussed below). This indicates that family life is not something mentors discuss regularly, which might deter postdocs from discussing their own family or personal lives and related issues with their mentors. Families are a huge component of postdocs' lives (three-quarters of them have spouses and/or children) and they do impact postdocs' appointments and career aspirations. More effective mentoring might include acknowledgement and guidance regarding both personal and professional matters.

Indeed, STEM postdocs feel like this type of personal mentoring is vital. Enjo (Life Science) expressed this feeling in his account of building connections during his postdoc. He explained that his mentor recognized the importance of having lab outings as a group, things such as kayaking or holiday celebrations. Enjo expressed that these events showed the group that "they're valued and that as individuals they also matter," and shared that these experiences helped "build relationships on

a personal level so that you do not feel like you're a cog in some kind of input machine, but that you're valued as a person who has a family life and a home life and other interests." Being valued as a person who has a family by someone who may also have a family or who has had similar past experiences, as Enjo said, is important and may positively contribute to postdocs academic and career success, so it should be encouraged between mentors and their STEM postdocs.

Postdoc Supervisors As Problems?

While the majority (65%) of postdocs report positive mentoring experiences—if we expand their reports from "very large extent" to the lower "large extent" threshold—a third of postdocs aren't experiencing much caring, career, or confidante-type mentoring. While most of them see their supervisor as their "mentor," many are not getting actual mentoring in the area of career development that they believe (at 96%) is a responsibility of their mentor. Sometimes postdocs said it directly. For example, Elle (Life Science), who had had a very "hands on" graduate school mentor, experienced her postdoc supervisor very differently: "He was just way too hands off. It really came down to the fact that he just didn't seem to care about me or my future.

For other postdocs, this disinterest in their career beyond the postdoc appointment was not always reflected in a lack of specific conversations about that career. Often it was the PI's lack of attention to the fact that they were trainees and not permanent staff. This lack of recognition that the postdoc *had* a career beyond the postdoc appointment left the postdoc with virtually no training for a career as an independent assistant professor; they were still receiving training—if it could be called that—as, only, a bench scientist or staff researcher. Because many of postdocs felt that their supervisors saw them as research personnel rather than future colleagues in training, they questioned whether PIs were even capable of thinking of them as trainees. Speaking of this, Sarah (Life Science) complained, "When you think about the postdoc, we say it's for training, but as a PI, you write postdocs into a grant if you want someone to do almost exclusively research. The training is not necessarily part of that."

As Sarah went on, she recounted ways that her PI, while a good boss, never seemed to consider that her appointment was temporary and that she would need to learn how to operate on her own once she took an assistant professor appointment. Other postdocs echoed this idea, that many of the tasks faculty engage in were not taught in their graduate program and, because of the "employee" structure of the postdoc, were not taught in their postdoc appointment either. Jane (Life Science) said that, instead of learning how to do the more difficult work of running or managing a lab—tasks she will have to begin doing immediately as a new biology professor,

she's only getting this "training" vicariously. She said, "it's just emotionally draining. I'm learning how to manage and lead by watching the failures of my mentor. That's not the way this should work."

Postdocs speculated that the fact they are not their PI's graduate trainee places them in an awkward position. They argue that faculty fully understand their role and the related responsibilities of "graduate mentor or supervisor". Because the postdoc has a PhD, sometimes from institutions, labs, and mentors their current PI has been competing with (even if unconsciously), some PIs—especially early career ones—never quite understood their relationship and responsibilities to the postdoc. Caroline's (Physical Science) PI, who she described as an "incredible boss," was "really awful and passive-aggressive and difficult" when she tried to do things as a "trainee" rather than an "employee". This tension was exacerbated by the fact that Caroline was not funded by her supervisor. She explained, "There's a bit of a power struggle in me him being an assistant professor and me *about to be* an assistant professor. For example, I was Skyping with some collaborators on a project unrelated to my postdoc and my PI barged in and told me I couldn't work on outside projects while I was at work. He didn't care if I was independently funded." She went on to say, "He's having a hard time getting tenure—everyone here does—so he wants to expand what he's doing. My attempts at independence make him see me as competition."

Postdocs like Sarah and Caroline attributed their negative experiences with their supervisors to misunderstandings of the postdoc position. Other attributed these experiences to structural problem in the training of the supervisors. Just as they themselves were not being trained as managers of research regimes, they believe their PI's had not been trained to manage one either. Albert (Life Science) said, "People become PIs because they were great scientists, but they're not necessarily good at training other people to be good scientists. They're also not necessarily good managers; often they're not. In industry, you receive training to be a manager and one's management ability would determine how high they could go up the management chain. It's weird that, in academia, that's based on your ability to publish, which is a very different skill."

Albert and other postdocs say that PIs tend to present a problem in their unprofessional behavior and lack of lab management that affects working conditions. Some postdocs recounted seeing their PIs and other faculty members behaving in hostile ways towards each other as a major turnoff when considering whether or not they wanted to pursue science research within the academy. Although politics are likely to come into play in every work environment, multiple STEM postdocs mentioned how shocked they were to see infighting and sometimes sabotage seemingly go unchecked. Similarly, problematic PIs' lack of effective lab management impacted interpersonal dynamics within labs/research groups. PIs who turned a blind eye to

inappropriate behavior or problems—we will see some of that in the next two sections—that arise leave trainees feeling frustrated and unsure of whom to turn to for a resolution. Although postdocs observe these problems with specific faculty supervisors, the fact that they do not see structural supports for addressing these issues leaves them disillusioned with academia in general.

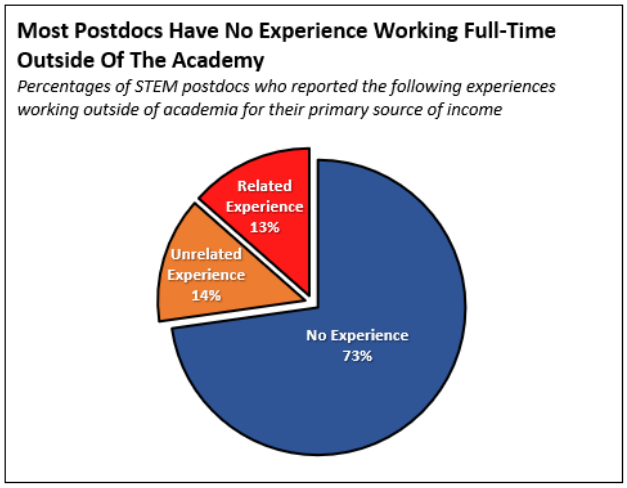
Section III
Beyond The Postdoc

B. Perceived (Dis)Amenities Of Academic Careers

The advantages and disadvantages of work in the academy compared to other domains loom large when postdocs consider decisions about their career paths. However, the source of postdocs' ideas about the differences of work in academic and non-academic settings is poorly understood. How do STEM postdocs form their opinions about benefits and costs, the pros and cons, of work in the academy compared to industry or government? In this section, we examine these ideas of the amenities and disamenities of academic careers. Understandings of attrition out of the academy can be improved by identifying the source of individuals' ideas about the disadvantages and advantages of working in academia.

Most Postdocs Have Not Worked Outside Of Academia

The majority of our postdocs (73%) have no experience working outside of the academy and must draw from others' experiences in order to form expectations about non-academic careers. Of the remaining 27%, only half of them had full-time jobs they state are related to their research area(s). With an average of about four years of work, about half (47%) worked in either healthcare or the government.



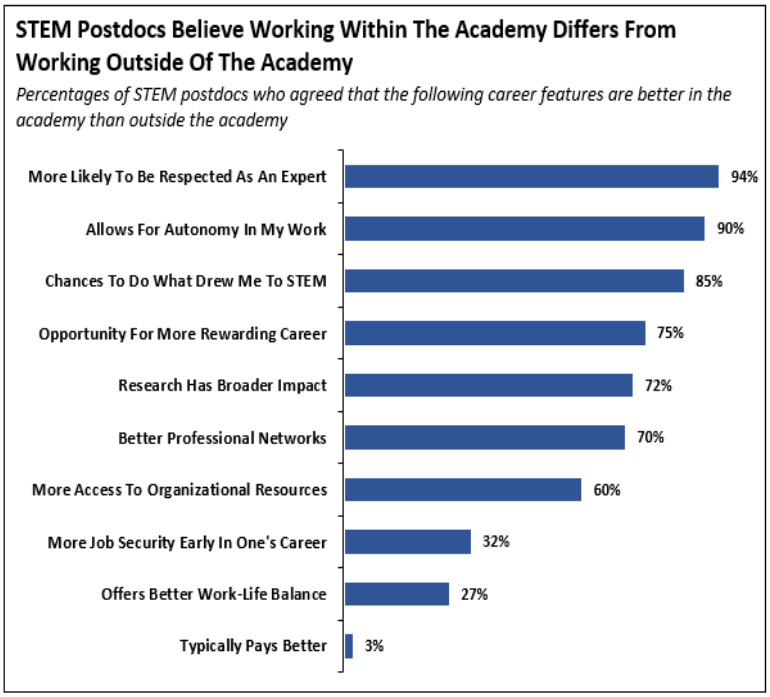
Inexperience with non-academic work did not preclude most postdocs from expressing strong preferences. This is unsurprising because individuals work with the knowledge available to them to make decisions. However, our postdocs stated preferences at times acknowledged a level of ambiguity or partial knowledge. For instance, Garrett (Life Science) remarked that his desire to stay in academia is perhaps not fair to industry, which he never had the chance to experience: "I think I would probably benefit from experiencing industry some more or experiencing it at all, for that matter."

In the absence of personal experience, postdocs often pointed to others' experiences working in different spaces. When asked how he compares academic to non-academic jobs, Matt (Life Science) replied: "Honestly, it's really hard for me to comment because I have no industrial experience at all except for what I see from friends or what I think or already know." Concerning his remarks about industry

working, he reported that "probably all the things I've said are directly from hearing from other people." Elle (Life Science) was also clear about the source of her views on industry careers: "I don't have any personal experience, so this is just talking to friends and people that come to give seminars about careers, just based on things that I've heard."

Amenities Of Academic Careers

How do the STEM postdocs' perspectives differ concerning careers in academy versus careers outside the academy? The majority of respondents stated that academic careers were better than nonacademic careers in the following ways: (1) increased chance of being respected as an expert in the field, (2) greater autonomy in work, (3) more chances to do what one likes in science, (3) potential for a more rewarding career, (4) allow for the broadest impact of one's research, (5) better professional network, and (6) increased access to organizational resources. All of these indicators are important for understanding what makes the academy a desirable job for the postdocs.



Respect for Expertise and More Rewarding Career Many people desire jobs where their expertise will be acknowledged by others. It is known that this will bring prestige and monetary gain, and will help individuals to better contribute to institutions (Sternberg and Frensch 1992). Being recognized for expert knowledge also decreases turnover in organizations (Tinypulse Employee Retention Report 2018). Furthermore, the opportunities for having more rewards throughout a career increases job satisfaction (Ekaterini et al. 2010). The vast majority of our STEM postdocs (94%) reported the belief that by securing a position in the academy, they were more likely to be viewed as experts in their fields. Many (75%) expressed belief that there were more opportunities for a rewarding

career and that their research has broader impact (72%) when they are in the academy. When discussing the potential impact of his research, Ernie (Life Science) referenced the trust society has in academic institutions, describing perceptions of the academy as a "rock" or "foundation of society." Ernie continued to characterize academic science as important because of the special conditions under which scientific research is produced, in contrast to industry research. Academic work is "an important foundation when, say, making decisions where people ask, 'what does the science say?' We need people who study science in a very pure, isolated environment to avoid other influences." Ernie argued that working as a scientist in industry, where organizations are motivated by profit, is less desirable compared to the academy in which discovery is the main purpose: "Exxon has research on climate change. They could be doing good science, but they have a huge conflict of interest. The purity of academia is what's really appealing to me." Remarks like Ernie's illustrate the connection between many postdocs' aspirations and the work conditions in academia or industry that align or conflict with these desires.

Autonomy and Appeal of the Academy Almost all of our postdocs (90%) reported that there is more autonomy possible in academy than elsewhere. Continuing with his comparison of industry and academia, Ernie (Life Science) returned to this theme of control: "there is a much greater amount of control that you have over what you do, as opposed to some board of directors who say, 'This isn't profitable. So therefore, you all work on X now, and drop this project.' That intellectual freedom and control over your own direction is the other major benefit of the academy."

Our postdocs explained that control over research decisions is an advantage in academia that they have enjoyed since their time in graduate school. Prior research supports these experiences. Learning to work in a more autonomous way in an academic job is an important feature of becoming a good academic because the professoriate is an entrepreneurial activity (Pitt et al. 2020). Autonomy is not only a required skill, but it improves wellbeing and outcomes (Saragih 2011, Schwalbe 1985). Jenna (Life Science) also expressed how she values autonomy in her work: "I wanted to be at a position where, no matter what I am doing, I am in control or I have some measure of control. Obviously, if you are in a company, you always answer to somebody, but I really like being the person who is driving the intellectual decisions." She explained that exercising this intellectual autonomy is a skill she learned from her PI, who was very hands off and provided the opportunity to practice independence: "I really got to experience trying to do that, of really pushing my own project forward and making a lot of my own decisions." Autonomy is not merely a trait individuals do or do not have; it can be a feature of one's work experience and academic training.

Corresponding with autonomy in academia, 85 percent of postdocs expressed the belief that the academy provides greater opportunities to do the things that initially

drew them to STEM. Matt (Life Science) contrasted industry to academia in this regard: "even if you are working on something really interesting, if someone else decides that it's not important, even with no good reason, then you can no longer work on that." Research shows that liking one's job contributes to both better work outcomes and increased wellbeing (Chen et al. 2019). Further, intellectual freedom, which in this case is the opportunity to control one's research pursuits, drives innovation, while stifling intellectual freedom can hinder intellectual production (Thomas 2013).

Professional Networks and Organizational Resources Many of our postdocs (70%) reported beliefs that a position in an academic career would widen their professional networks. Networks are very important for climbing one's career ladder (Montgomery 1992) and are particularly important in research-centered careers. These networks provide a particular advantage for work involving scientific research, which itself is often and increasingly collaborative and more productive when performed collaboratively (Lee and Bozeman 2005). Thus, social ties are of particular importance for academic careers. Caroline (Physical Science) expressed her desire to broaden her network and accelerate her academic productivity: "For me now, it's about making connections. It's about getting my project done so I have something that I can publish as soon as I start being a professor, so it'll count for the tenure clock." She also considered the benefits of forming connections with sources of research funding. These considerations align with research suggesting that peoples' decisions about their careers are based, in part, on the type of network a job provides (Brown 2004).

In order to generate the greatest return on their efforts, one has to make use of as many organizational resources as possible (Albrecht 2012). More than half of our postdocs (60%) expressed the belief that working in academia would expand their access to organizational resources. Resources differ across universities and from one lab to another, but can include equipment, financial capital, and human resources such as other staff or postdocs. All these assets support researchers' work to answer questions and/or create new things, impacting topic selection, the pace of research, and the outcomes of projects. However, some postdocs (40%) perceived that non-university settings offer access to greater resources. Bob (Math and Computer Science) described his preferences for industry settings in terms of the availability and flexibility of resources: "Many national labs have such diverse skill sets and equipment that there is the opportunity to work on very different types of projects throughout your career. So one thing that is nice about industry is that I can be at the company and if my interests change or if I want to do something new, I can move within the company to do something different." Future research should investigate how postdocs' perceptions about resources relate to their attitudes toward autonomy. These factors may shape preference for industry or academic careers.

Disamenities Of Academic Careers

The three career features that the fewest postdocs reported as favorable in academia compared to industry were: job security in one's early career, work-life balance, and pay. The percentage of our postdocs reporting that these features were *better* in academia than industry is 32 percent, 27 percent, and three percent, respectively. Research suggests that job security, work-life balance, and financial gain impact career choices and are particularly important for decisions about STEM careers (Xu 2013). In general, perceptions of greater job security increase job performance (Kuhnert et al. 1989, Yousef 1998), as does good work-life balance (Badri 2019) and greater monetary gain (Xu 2013).

More than two-thirds of postdocs (68%) reported beliefs that there is better job security early in non-academic careers. When reflecting on this in their interviews, postdocs pointed to fears that they might not find an academic job and, not surprisingly given the supposed "publish or perish" culture in the academy, fears that they wouldn't be able to keep them. Matt (Life Science) said this directly when he was listing cons of academic careers as "competitiveness of getting a position and then, I think, the stress and pressure of the tenure process which is an extended seven or whatever years of uncertainty." The stress of the impending sword of Damocles that tenure and promotion represents was the most common concern raised in the interviews. Tim (Life Science) worried that—even with the autonomy that academic positions provide—it is difficult to do the many things faculty have to do, at a high enough level, "to convince the tenure committee that you're worthwhile keeping at the end of that six or seven years."

It was somewhat surprising that these postdocs, most of whom graduated from top PhD programs and now have postdocs at top research departments in their areas, were so convinced that they might not get tenured or promoted. Three-quarters (74%) of postdocs work with PIs who are tenured; nearly half of them are full professors who, by most measures, model success and stability. That even these prospective academics believe there is no stability in the academy says something about the strength of academia's main cultural myth: that most assistant professors do not get tenured. While very few studies have been done that disprove this myth, one study of the tenure rates of faculty at one world-class, research-intensive, doctoral university reveals that a) the vast majority (97%) of their tenure-track faculty received positive department and dean level interim/retention reviews and b) just as many (93%) of those who went up for tenure received it. Looking at a ten-year average of incoming assistant professors who were tenured at this university, 58 percent of them were tenured at this university; the majority of those who were not had left the university before having a tenure decision. Given that most two-year and four-year retention reviews are positive, it may well be the case that these exits have nothing to do with the likelihood that those faculty would have been denied tenure had they stayed.

As we explained in greater detail in the section on family, many postdocs say they experience poor work-life balance. It makes sense then that 73 percent believe that, relative to other career contexts, academics are more likely to experience work-life and life-work conflict. Makeba (Life Science) reported poor work-life balance as an academic disamenity. However, she expressed belief in individuals' abilities to manage or improve their work-life balance and reported seeking out those mentors who can show her what a more balanced lifestyle looks like. The main obstacle, in her view, is that a professors' work typically has no end or bottom, and that those with poor work-life balance are rewarded. She said, "If you work 50 hours you might be successful. If you work 60, even better. The people who are able to narrow their lives and put the science first and sleep less—the more unhealthy lifestyle you can have—the more success you see. I go to these conferences and people are praised for being so very, very productive, and I'm like, yeah but that's only one side of the story. What does the rest of their life look like?"

Lastly, nearly all of our postdocs (97%) believe that non-academic careers pay better. Jennifer (Life Science), who has decided to stay in academia, explained that salary—like job insecurity and work-life balance—is a downside of a career in academe: "Industry was offering relocation benefits. They were offering bonuses. They were offering job security. And they were offering a 9 to 5 job. They were serious about 9 to 5. People do not work weekends and part of the reason they ask about hobbies during the interview is to make sure that you have some." Of course, while it becomes obvious what careers in industry and government offer—salaries are often listed in job advertisements—postdocs often have no actual idea what faculty salaries, bonus structures, startup packages, and relocation benefits are. As most of them say their mentors don't discuss these things and many of their peers are, like them, also in postdoc appointments, they are likely to have an incomplete knowledge of what academic careers pay.

When asked, directly, how they would compare academic careers to industry ones, postdocs often compared their *current* situation as a postdoc to peers who are in industry, not taking into account that, like medical residents, they were still trainees. For example, Emmalyn (Life Science) explained, "I am able to pay everything now, even on my post-doc salary, but I think I could pay things more comfortably if I had a higher salary. I look at some of my friends that have transitioned into industry and some don't even have a master's degree or a PhD and they're making at least 20 to thirty percent more than what I am." Research on biomedical careers—the area many of our postdocs are considering—reveals that biomed scholars who received a PhD and went into industry have a median salary of $75,677 and those who went into government or non-profit work have a median salary of $67,775 (Kahn and Ginther 2017). Comparing those salaries to an R1 postdoc salary rather than the salary they would receive as an R1 assistant professor in bioinformatics or genetics is, of course, a flawed comparison, but likely one that factors into postdocs' decisions to leave the academy.

Viewpoints Differ Based On Interests In Faculty Careers

Postdocs' views about the amenities and disamenities in academia are connected to their interest in faculty careers. There are statistically significant differences in our postdocs' views regarding the following amenities in the academy: autonomy, chances to do what they like in science, a more rewarding career, broadest impact of research, and a better professional network. The only statistically significant difference among the postdocs planning faculty and non-faculty careers related to their views of poor work-life balance as a disamenity in academia.

Almost all of our postdocs planning a faculty career said that the academy will increase their chances of being respected as an expert (96%), allow for the greatest autonomy in their work (96%), provide more chances to do what they like in science (93%), and allow for the broadest impact of their research (94%). While a similarly high number of postdocs planning for non-faculty careers (92%) also agree that expertise might be more visible in academia than outside of it, fewer agree with their pro-faculty-career peers that the academy provides more autonomy (86%), more chances to do what they like (79%), and allows for the broadest impact of their work (62%). Only 59 percent of them believe academia will provide them with better networks.

Postdocs Mostly Differ On Strengths Of Academic Careers Based On Interests In Faculty Careers

Percentages of STEM postdocs, by type of planned career, who responded that the following career features are benefits of a faculty career compared to a career outside of academia

	All Postdocs	Planning Faculty Career	Planning Non-Faculty Career
Increases chances of being respected as an expert	94%	96%	92%
Will allow for the greatest autonomy in my work	90%	96%	86%
Provides more chances to do what I like in science	85%	93%	79%
Provides opportunity for a more rewarding career	75%	94%	61%
Will allow for the broadest impact of my research	72%	86%	62%
Will provide me with a better professional network	70%	86%	59%
Provides more access to organizational resources	60%	60%	60%
Allows for more job security early in my career	32%	38%	27%
Offers a better work-life balance	27%	34%	21%
Typically pays better	3%	2%	3%

When it comes to disamenities of academic careers, both pro-faculty and pro-non-faculty postdocs seem to agree. There aren't significant differences between them on beliefs that non-academic jobs allow more job security or pay better. Strikingly,

almost eighty percent of postdocs planning non-faculty careers believe industry and government jobs would provide them with a better work-life balance, in spite of the fact that even more of them (86%) believe they'll have more flexibility and autonomy in academia.

Elle (Life Science) explained her primary interest in an industry job in terms of academic pros and cons, where the pros focus on freedom, but the cons focus on accountability that nevertheless exists in spite of those freedoms. She said, "The pros are flexibility. You can kind of work when you want. There's no set schedule. It's super flexible and you're allowed to be super creative. The cons, though, are pressure to publish, pressure to get grants, odd working hours, just higher stress. Sure, this is stress that you put on yourself rather than a superior or a boss putting stress on you, but it is stressful regardless." While she recognizes that there is much less flexibility in industry because, as she says, "you're fulfilling the goals of the company," she (like most postdocs) ultimately thinks industry is better when it comes to "working hours, higher salaries, and less internal pressure to be successful."

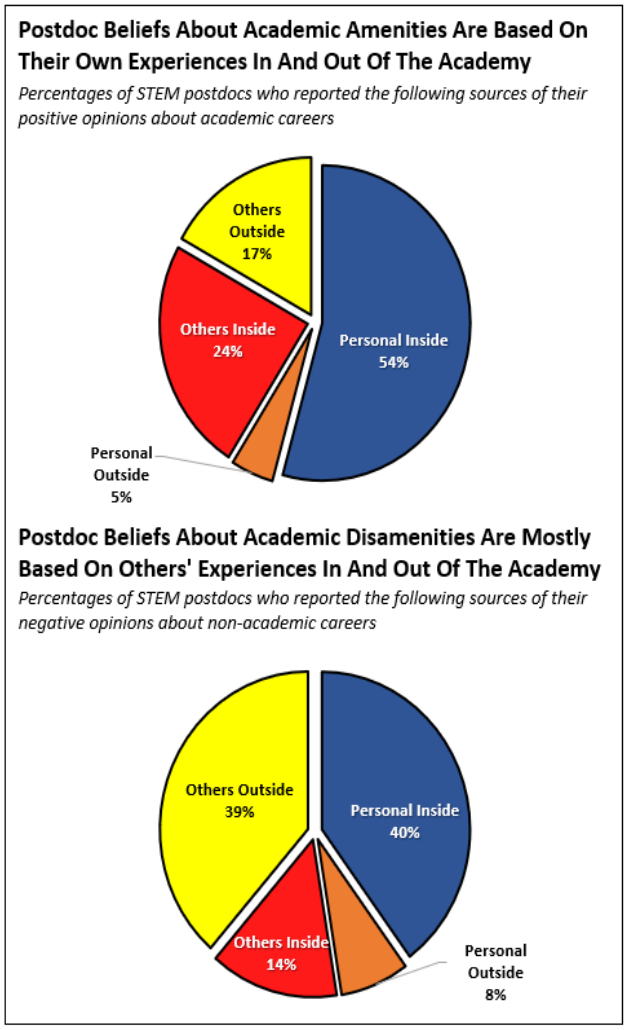
Conversely, Mike (Life Science) explained his preference for academic jobs by referring to the potential impact of his research. He reported being ready to move on from "six years of working on quite abstract things" during his time in the academy earning a PhD: "I was ready to start figuring out how I could work on things that were more directly useful to the world." For Mike, the important question was, "what is the most valuable thing I could be doing?" He considered work in science policy, believing that he might be able to have "a much bigger impact" outside of academia than inside it, but ultimately has focused on having that impact in academic contexts. Interestingly, Mike's indicated ambivalence toward the amenities most postdocs associated with industry. He stated that working in industry "just to have a reliable paycheck and job security is less attractive to me."

Experience Also Matters

Personal experiences and discussions with others about different careers impact career choice and aspirations (Ikonen et al. 2017, Wang et al. 2013). Likewise, postdocs' comparisons of the benefits and costs that come with an academic career are derived from different sources. We asked the postdocs to tell us which of the following were the primary sources of their opinions about each of the ten characteristics: their personal experiences inside the academy, their person experiences outside the academy, others' experiences inside the academy, and others' experiences outside of the academy. The Figures show a) what the primary sources were for the postdocs' responses that the academy was better than alternatives and b) what the primary sources were for postdocs' responses that alternatives were better than the academy. In general, postdocs referred more to their own experiences when deciding what is good in the academy. However, when deciding what is bad

about the academy, they referred to others' experiences that they have observed or that had been shared with them.

Positive Attitudes Toward the Academy. More than half (54%) of our postdocs said that they base their positive beliefs about the academy as a workplace on their own experiences in academic spaces. That is followed by about a quarter (24%) of postdocs pointing to the experiences of others who also work in these spaces, likely their peers and faculty. Only five percent say their positive views are based on their own experiences with something other than academic employment. This is unsurprising given that the majority of postdocs (86%) have never held a full-time, non-academic, job engaged in work related to the scientific expertise. While we expected that postdoc's positive impressions of things like autonomy and impact might come from their own or others' academic experience, we were surprised to find that those few postdocs who thought the academy was better for work-life balance (only 27%) and salary (only 3%) also got their opinions from their own or others' academic experience. Ninety-five percent and sixty-five percent, respectively, of those postdocs who thought the academy was better than alternatives for balance and salary said their opinions came from either their or someone else's experience in academic spaces.



Negative Attitudes Toward The Academy. A slight majority of our postdocs' negative attitudes about academic careers are based on others' experiences. Only 48 percent of postdocs say their ideas about the disadvantages of an academic career came from their own experiences, either in (40%) or out (8%) of the academy. Again, given that most postdocs have virtually no experience working outside of the academy, there appears to be some room to shape postdocs' experiences *in the*

academy so that more of them experience it positively rather than negatively. Add to this that another fourteen percent of them say their negative attitudes about the academy are based on what others inside the academy reveal to them and it is clear that, for those who see the academy as the worst of two options in regard to some work benefits, they are getting these impressions mainly from someone's negative experiences with academic contexts, almost exclusively. If other postdocs and many STEM faculty are like our postdocs, practically none of the people they might consult with who work in the academy have any experience working outside of it.

For about forty percent of postdocs, their negative impressions of the academy relative to its alternatives come vicariously, in conversations with and observations of peers, friends, and family who work in industry, government, non-profits, and other non-academic contexts. In the inverse of their pro-academy evaluations regarding work traits like autonomy, opportunities to express passions, and opportunities to garner respect, very few postdocs with negative evaluations of the academy relative to these traits say their impressions come from non-academics. For example, only fourteen percent of the few (10%) postdocs who say industry or government is better for autonomy say they learned this from peers/family who work in those contexts; surprisingly seventy percent of them say it was their own academic or other academics' experiences that taught them this.

If we focus exclusively on the three attributes—job security, work-life balance, and pay—most postdocs agree are worse in academic careers, we get a more complicated, but not necessarily surprising story. For those postdocs who say there is more job security outside of the academy (68%), the majority of them (59%) have come to this opinion based on interactions with other people working in the academy; only five percent say they decided this based on what non-academic workers have revealed. Alternately, for those who say work-life balance is better outside of the academy (73%), there is a nearly even split between their own experience inside the academy (37%) and others' experience outside the academy (36%); in this case other people's experience inside the academy only shapes eighteen percent of their negative impressions.

TECHNICAL NOTES AND METHODOLOGY

We used a web-based survey as the principal tool to gather information from STEM postdoctoral appointees. In 2017, staff members in the Offices of Postdoctoral Affairs (OPA) at 30 research-intensive doctoral universities forwarded our invitation to participate in the research to their cohort of postdoctoral trainees. In all cases, the offices were not allowed to give us names and other details of their postdoctoral population. As a result, we could not constrain the list of invitees to only those postdocs who met our study parameters. The invitation described the parameters for involvement in the research, specifically, that potential respondents be U.S. citizens or permanent residents in the first, second, or third year of their first postdoctoral appointment in one of five broad STEM categories: agriculture and conservation resources, biological and biomedical sciences, STEM education, engineering and computer science, or the physical sciences and math.

As a key motivator of this study was broadening participation in STEM training and diversifying the STEM professoriate, we followed the lead of the National Academy of Sciences (2011) in focusing our attention on the physical and life sciences, engineering, and mathematics only. We, therefore, exclude the social sciences (e.g., sociology, psychology, history) and social-science focused agriculture/conservation postdocs. We also excluded foreign postdocs, whose career motivations, pathways to postdocs, and ability to "diversify the professoriate" have been shown to be significantly different from non-foreign STEM doctorate recipients, particularly non-Whites (Amuedo-Dorantes and Furtado 2019, Stephan and Ma 2005, Zeithammer and Kellogg 2013). First-time postdocs were chosen because we were interested in the pathway from receipt of doctorate through the first postdoc position to faculty, other postdoc positions, or non-academic jobs. The OPA staff were informed that we were particularly interested in understanding the experiences of women; as a result, this population was oversampled.

While an accurate accounting of how many potential respondents were exposed to the recruitment materials was unavailable to us, more than 750 postdocs responded positively to the invitation. Most of those potential respondents were ineligible to participate because they did not meet the base requirements for inclusion in the study. Ultimately, we ended with a sample of 215 postdoctoral trainees. Of these respondents, 65% are women. We weighted our analyses to account for the oversampling that created this conflict. We used the proportion of STEM postdoctoral recipients (35%; NCSES 2017a) who are women as a target population for this weighting. The racial balance—77% White, 23% non-White—more closely approximates the percentages of White/non-White U.S. citizens and permanent residents with STEM doctorates in the disciplines we analyze (NCSES

2017b). More than half (51%) of our respondents were in their first year of the postdoc. Representation among the disciplines was as follows: agriculture (6.5%), biological and biomedical sciences (56.3%), STEM education (3.3%), engineering (14.4%), and the physical sciences (19.5%); these percentages differ from the national postdoc population by less than 10% (NCSES 2017a).

The first-year postdocs were also recruited for a much more involved three-year longitudinal survey. This survey was intended to capture the changes—in attitudes, aspirations, and interactions—that inevitably occur over time. These postdocs were surveyed in the fall semester of their second and third years. Their first survey, intended as a baseline, gave us a sense of background characteristics that have informed the postdocs' aspirations. Follow-up surveys showed any changes over time, particularly in the important issues of sense of readiness, identity negotiation, and degree of information about opportunities in or barriers to careers in academic STEM careers. In each of the follow-up years, we encountered postdocs who were no longer in their original postdoc appointments, but had left them for other opportunities, either in different postdoc appointments or for jobs. For those who had left for jobs, we used a different survey tailored for a work environment; there were inquiries in that survey about the reasons for the change. We had a 76 percent response rate for the second wave and 63 percent response rate for the third wave. Analyses revealed no major differences between those who continued in the project and those who did not.

Throughout the report, we point to what we sometimes call "statistically significant" differences. Because of the size of our final sample, we report "marginally statistically significant" differences ($p<.10$) as we suspect many of them would be more certain (i.e., at a p-value less than .05) if we had many more respondents; we do report the actual mean/median amount in the figures.

Additional data was drawn from interviews with fifty of the postdocs (some were interviewed again after the second wave of surveys). Interview questions generated more subtle and textured information about postdocs' experiences in their doctoral departments and the departments they work in now as postdocs. The interviews helped uncover important dynamics in their backgrounds or training that impacted aspects of professional identity and vocational aspiration; these impacts are difficult to ascertain from a close-ended survey instrument. These interviews focused on patterns—recurrent themes, perceptions and incidents—that go beyond individual experiences and capture the analytical richness of their collective stories. Each of the seventy-five 90-minute interviews was digitally recorded, transcribed, checked for accuracy, and then loaded into qualitative software for analysis. Our analytical strategy was primarily inductive, a strategy of expansion that took us from the particular themes represented in the interviewees' narratives to more generalizable understandings of macro-level phenomena. Data analysis consisted of carefully

reading the transcripts, exploring and coding responses, and allowing new themes, issues, and questions to emerge during that process. The data gleaned from these conversations was, as you've seen, critical to our need to understand the social *processes* producing the broad *outcome* patterns we found in the survey data.