Volunteered or Voluntold? The Motivations and Perceived Outcomes of Graduate and Postdoctoral Mentors of Undergraduate Researchers

Lisa B. Limeri, Muhammad Zaka Asif, and Erin L. Dolan*
Department of Biochemistry & Molecular Biology, University of Georgia, Athens, GA 30602

ABSTRACT

Graduate students and postdoctoral researchers (postgraduates) in the life sciences frequently mentor undergraduate researchers, especially at research universities. Yet there has been only modest investigation of this relationship from the postgraduate perspective. We conducted an exploratory study of the experiences of 32 postgraduate mentors from diverse institutions, life sciences disciplines, and types of research to examine their motivations for mentoring and their perceived outcomes. Although some postgraduates reported feeling pressured to mentor undergraduate researchers, all expressed personal motivations, including both agentic (self-focused) and communal (community-focused) motivations. These postgraduates reported benefits and costs of mentoring that had both vocational and psychosocial elements. Given that our results indicated that even postgraduates who engaged in mentoring at the request of their faculty advisors had their own motivations, we conducted a second phase of analysis to determine the extent to which our results aligned with different theories of motivation (self-determination theory, social cognitive career theory, expectancy-value theory, social exchange theory). We end by proposing a model of postgraduate mentoring of undergraduate researchers that integrates the theories supported by our findings.

INTRODUCTION

Expectations that undergraduates participate in research are growing (National Academies of Sciences, Engineering, and Medicine [NASEM], 2017). For the most part, however, these recommendations do not account for the experiences and outcomes of their mentors (Lopatto, 2004; Dolan and Johnson, 2009; Haeger and Fresquez, 2016; Hernandez *et al.*, 2017). At research-intensive universities, undergraduate research mentors are most commonly graduate students or postdoctoral researchers (i.e., postgraduates; Thiry and Laursen, 2011; Aikens *et al.*, 2016). A recent report by the National Academies acknowledged that more than 94% of science, technology, engineering, and mathematics (STEM) doctoral students teach or mentor undergraduates at some point during their degree programs. Yet the impact of these experiences on *postgraduates'* personal and professional growth remains unclear (NASEM, 2018). There has been some work investigating the effects of teaching on graduate students (e.g., Feldon *et al.*, 2011), but less on how graduate students are influenced by mentoring undergraduate researchers. Furthermore, postdoctoral researchers, who are also themselves still in training and frequently involved in mentoring undergraduate researchers, have received even less attention in studies of STEM teaching and mentoring (Gibbs and Griffin, 2013).

It is important to note that there is ongoing debate about whether to consider the working relationship between undergraduate researchers and postgraduates "mentoring" per se, versus supervisory or advisory (Crisp and Cruz, 2009; Haggard *et al.*, 2011; Gershenfeld, 2014; Hayward *et al.*, 2017). Mentoring scholars typically describe

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*Address correspondence to: Erin L. Dolan (eldolan@uga.edu).

mentoring as a relationship in which more experienced individuals, the mentors, provide both psychosocial and career-related support to less experienced individuals, the protégés, to help achieve their goals (Haggard *et al.*, 2011; Kram, 1983). We have chosen to refer to the relationship between postgraduates and the undergraduate researchers who work with them as a "mentoring" relationship because training in the life sciences follows an apprenticeship model (Lave and Wenger, 1991), and postgraduates oversee the day-to-day work of the undergraduates (Thiry and Laursen, 2011; Aikens *et al.*, 2016). Furthermore, postgraduates who serve in this role are often referred to as mentors in practice (e.g., Handelsman, 2005; Pfund *et al.*, 2006), regardless of whether their undergraduate protégés view them as mentors.

The dearth of research on how mentoring affects postgraduate mentors is not surprising, as much of the research on mentoring has focused on protégés rather than mentors (Haggard *et al.*, 2011). Yet mentoring is an interpersonal relationship and thus cannot be fully understood without accounting for the perspectives of both mentors and protégés. In fact, at least one review of research on mentoring has called for more mentor-centric research (Haggard *et al.*, 2011). Studies from mentoring in workplace settings indicate several reasons why we can reasonably expect the experience of mentoring to benefit mentors in other settings, such as academia (Ghosh and Reio, 2013). First, mentors in a variety of contexts report experiencing a sense of satisfaction and fulfillment from the experience of mentoring (Ragins and Scandura, 1999; Ghosh and Reio, 2013). Second, the experience of mentoring can provide career-related benefits by improving mentors' overall job performance and success (Ghosh and Reio, 2013). For instance, mentors may be positively recognized for developing talent, may have increased access to information through their protégés, and may receive substantive assistance from their protégés (Kram, 1983; Mullen, 1994; Ghosh and Reio, 2013). Finally, mentoring provides opportunities for learning and for personal and professional growth (Allen *et al.*, 1997; Allen and Eby, 2003). For example, mentors can gain technical expertise and improve their leadership skills through the process of mentoring (Wanberg *et al.*, 2006; Ghosh and Reio, 2013). Framing mentoring as a learning experience may be particularly relevant for postgraduates because they are training undergraduates while being trainees themselves.

Prior research also suggests that mentors can experience costs, although investigations into costs are much more limited. Mentoring can be time-consuming and can demand substantial energy (Halatin and Knotts, 1982; Dolan and Johnson, 2009). For postgraduates, this may pose special challenges related to managing time and reconciling the roles and responsibilities of their own work with those of being a mentor (Dolan and Johnson, 2009). Furthermore, although high-performing protégés may reflect positively on mentors, poorly performing protégés may reflect badly and harm their reputations (Kram, 1983; Ragins, 1997). One of the few investigations of postgraduate mentors revealed that they experience affective and instrumental costs (e.g., frustration, reduced productivity; Dolan and Johnson, 2009). Mentors in this study also reported challenges that are perhaps unique to the academic setting. Specifically, when postgraduates comentor with faculty, ambiguity or lack of communication about mentoring roles and responsibilities can lead to confusion and conflict (Dolan and Johnson, 2009). Expected costs and benefits of mentoring may influence career decisions, which is especially salient for postgraduates who are still early in their career development.

The extent to which postgraduates experience benefits and costs associated with mentoring may be influenced by their motivations for mentoring. Studies in workplace settings indicate that formal, assigned mentoring relationships are typically less beneficial for protégés than informal, emergent relationships (Ragins and Cotton, 1999). This may be because formal mentoring relationships are less likely to be enduring and to foster the development of trust and reciprocity, which are more common in informal mentoring relationships and are indicators of a quality mentoring relationship (Ragins and Cotton, 1999; Allen and Eby, 2003). Other studies of workplace mentoring have shown that the more a mentor invests in the mentoring relationship, the more the mentor benefits (Wanberg *et al.*, 2006). Mentors who reported higher levels of mentoring also reported greater positive effects on their careers and higher levels of satisfaction (Wanberg *et al.*, 2006). If postgraduates are assigned the responsibility of mentoring (i.e., extrinsically motivated) or view mentoring simply as a transaction ("I mentor you, you do work for me"), rather than undertaking mentoring because they have a personal interest in doing so (i.e., intrinsically motivated), they may invest less in the relationship, resulting in less positive outcomes for both themselves and their protégés. Furthermore, mentor motivations can affect the mentoring functions they perform (Allen, 2003). For example, mentors motivated by learning and self-improvement report providing career-related mentoring (mentoring functions that prepare a protégé for career advancement), such as introducing a protégé to colleagues and providing opportunities to learn new skills (Noe, 1988; Allen, 2003). Mentors who report intrinsic motivations for mentoring also report providing greater psychosocial support, such as serving as a role model and offering advice and counseling (Noe, 1988; Allen, 2003). More importantly, the forms of support mentors provide relate to the outcomes they experience. For example, mentors who provide psychosocial support report higher organizational commitment (Ghosh and Reio, 2013), and mentors who provide career-related mentoring report experiencing improved career success from mentoring (Wanberg *et al.*, 2006; Ghosh and Reio, 2013).

The motivations and outcomes experienced by faculty mentors in academic settings have been investigated in a handful of studies (Baker *et al.*, 2015; Morales *et al.*, 2017). Faculty are motivated to mentor by diverse intrinsic and extrinsic reasons, including feeling of scientific duty, intrinsic desire and enjoyment, and increased research productivity (Morales *et al.*, 2017). These studies also document a range of barriers to mentoring, such as limited time and funding and a lack of formal recognition (Baker *et al.*, 2015). There are a number of reasons to believe that the motivations and outcomes of postgraduates may differ from those of faculty mentors. Researchers have found evidence that motivation to mentor can differ among career stages. A survey of more than 500 faculty revealed that midcareer faculty were more likely to want to mentor than late-career faculty (Morales *et al.*, 2017). Additionally, postgraduates are unique because of the dual roles they hold as both trainees themselves and mentors of undergraduate researchers. This duality means that postgraduates face unique

challenges associated with balancing tasks and responsibilities (including mentoring) between their two roles. Further, as trainees, postgraduates may have less autonomy in their professional activities than faculty. This raises questions about whether postgraduate involvement in undergraduate research mentoring should even be conceptualized from a motivational perspective. It may be that the majority of postgraduates are "voluntold" to mentor undergraduates by their faculty advisors, thus undermining the utility of motivation as a framework for thinking about how postgraduates experience mentoring undergraduates.

Some research has also been done to identify and describe postgraduates' motivations to mentor undergraduate researchers. Dolan and Johnson (2009) conducted an exploratory interview study of eight postgraduate mentors. The postgraduates in this study reported either instrumental motives for mentoring—mentoring as the means to an end, similar to extrinsic motivation—or socioemotional motives—mentoring for personal growth or increased satisfaction and fulfillment, similar to intrinsic motivation. Hayward *et al.* (2017) conducted a larger interview study of 30 mentors, including 18 postgraduates, and found that postgraduate mentors tended to have more extrinsic motivations, while faculty mentors tended to be more intrinsically motivated (Hayward *et al.*, 2017). Both of these studies were limited to small samples from a single lab (Dolan and Johnson, 2009) or a single program (Hayward *et al.*, 2017).

Here, we present a two-part, exploratory interview-based study aimed at documenting and characterizing the mentoring experiences of a larger and more diverse sample of postgraduates than has previously been studied (Dolan and Johnson, 2009; Hayward *et al.*, 2017). First, we sought to identify and characterize motivations for mentoring and outcomes attributed to mentoring for a group of 32 postgraduates representing 10 institutions. Although this sample is still limited in size, it extends beyond the study of single labs or programs and purposefully captures the motivations and outcomes of postgraduates who had both positive and negative experiences mentoring undergraduates. We found in our initial analyses that even postgraduates who engaged in mentoring at the request of their faculty advisors had their own motivations for mentoring undergraduates. Thus, we conducted a second phase of analysis to determine the extent to which our results aligned with different theories of motivation. The results of this analysis should be useful for designing future investigation of the effects on postgraduates of mentoring undergraduate researchers.

METHODS

Research Design

This study was designed to explore the landscape of postgraduate mentoring motivations and outcomes and to evaluate the utility of motivation frameworks for explaining how postgraduates experience the process of mentoring undergraduate researchers. Identification of relevant theoretical frameworks is a necessary step toward generating and testing hypotheses about postgraduate mentoring. To accomplish this, we conducted semistructured interviews with postgraduate mentors in the life sciences and analyzed the transcripts using constant comparative coding processes as described in detail in the following sections. This study was reviewed and determined to be exempt by the University of Georgia Institutional Review Board (protocol #STUDY00005150).

Participants and Data Collection

We recruited participants by sending invitations to email addresses of graduate students and postdoctoral associates gathered from publicly available department and lab websites at a variety of institutions. We also used snowball recruiting, asking our participants to share study information with people they personally knew whom they thought would be a good fit for the study. We directly invited 170 postgraduates to participate, and an unknown number were contacted through snowball recruiting. We used screening questions to ensure that our sample included perspectives from postgraduates with a range of experiences. Specifically, we screened potential participants using two sets of the same six seven-point Likert-scale items (see the Supplemental Material): one item related to the mentor's overall level of satisfaction with the experience mentoring an undergraduate researcher and five items related to the quality of the mentoring relationship (Allen and Eby, 2003). Participants were prompted to respond to the items once based on their *most positive mentoring experience* and a second time based on their *most negative or least positive experience*. We found that mentors' responses on the relationship-quality items appeared closely related to the single satisfaction item, so we exclusively used the satisfaction item to select participants. We purposively selected participants who spanned the range of experiences; collectively, our sample includes a minimum of five participants representing each point on the satisfaction scale (five with a 1 rating, five with a 2 rating, etc.). Thirty-five participants answered the screening questions, and of these, we selected 32 participants to interview. We did not collect demographic information from our participants, but approximately half of our participants presented as women (18 apparent women, 14 apparent men). Most participants were graduate students (25 graduate students, seven postdoctoral associates). Participants spanned 10 different public and private research universities across the United States, and five made comments during the interviews that their backgrounds as international scholars related to their mentoring experiences. We also targeted a variety of types of research in the life sciences (i.e., bench or wet lab, field, and computational or theoretical research).

We conducted semistructured interviews to gain rich, detailed information about postgraduates' mentoring experiences; we identify these postgraduates using pseudonyms throughout. Interviews are commonly used to understand complex social processes or interactions that are relatively uninvestigated (Fontana and Frey, 2000). In semistructured interviews, researchers construct and use a uniform list of questions (see the Supplemental Material) but are free to ask the questions in any order and to ask spontaneous follow-up questions for clarity or to pursue unanticipated, relevant, interesting themes. The semistructured format fosters a conversational rather than a formulaic tone, while also enabling the interviewer to follow up on participants' comments. The interview questions were designed to gain in-depth understanding of the participants' motivations to mentor, their mentoring activities and experiences, the outcomes they experienced from mentoring (both positive and negative), and their intentions to engage with or avoid mentoring in the future. For instance, we queried

participants about their initial reasons for working with an undergraduate researcher, what made them interested or hesitant to do so, and the extent to which they had control over the decision to work with an undergraduate. We asked participants to describe a typical week working with their undergraduate researchers and to explain how they helped the undergraduates; how the undergraduates helped, benefited, or hindered them; and whether they would work with an undergraduate again. Interviews lasted 30–60 minutes.

Data Analysis

All interviews were transcribed verbatim and analyzed both inductively and deductively in two phases. In phase 1, we identified and characterized motivations for mentoring and outcomes that participants attributed to their mentoring experiences. In phase 2, we evaluated the extent to which our results aligned with different theories of motivation.

For phase 1, we began coding by using existing frameworks of benefits and motivations from Dolan and Johnson (2009) and Hayward *et al.* (2017). We coded using a constant comparative method, in which researchers develop concepts from the data by coding and analyzing at the same time (Kolb, 2012). We analyzed the interview transcripts using the qualitative analysis software MaxQDA. We started by prepopulating the codebook with themes from the existing frameworks, including instrumental and intrinsic/socioemotional motivations, and outcomes related to instrumental, intrinsic/socioemotional, interpersonal, professional, and cognitive benefits and costs (Dolan and Johnson, 2009; Hayward *et al.*, 2017). Then we read interview transcripts and identified sections of text representing distinct ideas. We tagged and labeled (i.e., "coded") sections of text either by using an existing code from the codebook or by generating a new code if no existing codes were appropriate. We continued the analysis through an iterative process of coding, evaluating themes and subthemes, and recoding. One author (L.B.L.) coded all interviews first to create a preliminary codebook. Using that codebook, a second author (M.Z.A.) coded all interviews, and the two met to discuss and revise all codes and themes to consensus. When necessary, previously discussed interviews were revisited and analyzed with a revised version of the codebook. When the codebook was finalized, all three authors met to discuss overarching themes and generate conclusions. The final codebook organized themes into motivations, hesitations, and positive and negative outcomes. Within these large groupings, themes were also categorized as being either vocational or psychosocial.

In phase 2, we used the results from phase 1 to evaluate the fit of the data to different motivational theories (see *Results, Theory Alignment*). We identified major concepts in each theory and examined whether ideas discussed by participants reflected or related to the major concepts in each theory. We examined literature on each of the theories and reviewed participant quotes to evaluate conceptual alignment. One author (M.Z.A.) evaluated the fit of the theories initially, and all three authors met to discuss fit to consensus.

RESULTS

Here, we present the variety of motivations reported by mentors and reservations that made them hesitant to mentor. Then, we present outcomes that mentors reported, many of which were directly related to their motivations and hesitations, as well as outcomes that were unanticipated or unrelated to their initial motivations. We report the number of participants who made comments related to each theme to provide a sense of the relatively commonality of each theme within our study sample. However, inferences about the prevalence or relative importance of these themes in the larger population cannot be drawn from these counts. We report participants' quotes using pseudonyms that were picked to reflect the apparent gender and racial/ethnic background of the participant to provide context for the quotes. Because of the limited sample size and data-collection methods, inferences about cultural or gender differences cannot be made. Finally, we evaluated the utility of theories related to motivation to understand the experience of postgraduate mentors. Our findings reflect the results of consensus among the researchers.

Motivations and Hesitations to Mentor

Mentors reported a wide range of reasons they wanted to engage in or avoid mentoring undergraduate researchers. We categorized these motivations and hesitations as being *agentic* (focused on the outcomes for the mentor) or *communal* (focused on outcomes for other individuals or the scientific community as a whole; Abele and Wojciszke, 2014). Agentic motivations and hesitations (presented in Table 1) involved vocational (career-related) factors, such as increasing or compromising research productivity, gaining technical and interpersonal skills and knowledge, and improving their mentoring ability. Agentic motivations and hesitations also had psychosocial elements, such as high or low self-efficacy about mentoring ability as well as the potential to experience enjoyment or fulfillment, or not. Communal motivations (presented in Table 2) included two vocational factors, benefiting the scientific community and fulfilling social norms, and one psychosocial factor, altruism or benefiting other individuals. Mentors in this study did not express any communally oriented hesitations to mentor. Each of these results is described in the following sections and accompanied by illustrative quotes.

Agentic Motivations and Hesitations. Motivations and hesitations about research productivity were among the most prominent; 25 of our 32 participants made comments related to anticipated impacts on their research productivity. Approximately two-thirds of our participants ($n = 22$) were motivated to mentor because they thought it would increase their research productivity. Some mentors hoped that mentoring undergraduates would help them by decreasing their workloads. For example, Huang noted, "I have a lot of manual work that needs to be done and someone needs to do it. And it's going to help me spend less time in the lab and actually focus on developing research questions."

Although some mentors emphasized person-power, meaning that they would have additional "hands" to get their research done, others noted access to additional "minds" because undergraduates could contribute intellectually to their work, as Gabriela explains, "A lot of times, your mentees also bring fresh ideas or questions that maybe you have not thought about and might give you a good insight."

In contrast, about one-third of the mentors ($n = 10$) mentioned concern or hesitation about mentoring because of its potential to limit their research productivity or to be excessively

TABLE 1. Postgraduates' agentic motivations and hesitations regarding mentoring undergraduate researchers

		Motivations	Hesitations
Vocational	Research productivity: Anticipated effects on scholarly output	I think [I was motivated to mentor] because I had one project that had a lot of benchwork component, so by having some help on the side, that was really useful.—Mei	So, my project is really big, and it requires a lot of work, so I was nervous about… getting students that required more assistance than ended up really being beneficial to me. I've had students like that, where how much I gave them was considerably more than what I ended up getting back.—Abigail
	Technical knowledge and skills: Anticipated gains in scientific knowledge and skills	I knew that having an assistant would not only help me with my research but it would also make me teach them the system. So, I would be learning myself. I would be learning what we researched here and also teaching it to them.—Jose	None observed
	Interpersonal skills: Anticipated gains in skills related to working with others	I feel like if I do eventually become faculty, that I'm doing a service to my future students by getting a lot of experience in [mentoring]. Most of that job is mentoring other people, right? And managing other people, so while I might complain that it's a lot of work, it's really good for my training.—Sophia	None observed
Psychosocial	Enjoyment: Anticipation that mentoring will or will not be fun or enjoyable	I think it was just the joy of sharing science and getting to see how excited the students get when things work or even when things don't work you teach them how to handle the problem solving and the troubleshooting. That's what science is, and being able to share that with someone was really fun.—Isabella	I really like doing benchwork, and I don't necessarily like doing some of the other things that seems like in academia you're really worried about. I guess mentoring, teaching, kind of falls in that category. It's something that I've enjoyed doing when I've done it, but I could also never do it again and be fine with it.—Henry
	Fulfillment: Anticipated feeling of satisfaction or fulfillment from mentoring	I like the relationships I form and seeing the students learn and grow… my student was looking at her data sheet and she said, "I really didn't think of how to make my data sheet so it's easy for me to enter it later." I was like, "Ah, you see, that's something we could have talked about but we didn't." So, it's that growth that I see in the students that is really, it's rewarding for me.—Victoria	None observed
	Mentoring self-efficacy: Hesitation due to lack of confidence in mentoring ability	None observed	I don't feel comfortable, like confident enough to teach college students. I don't want to teach them the wrong thing. Especially [because] I'm from [a] foreign country, so I'm not sure if I can communicate good enough with them.—Jiang

TABLE 2. Postgraduates' communal motivations for mentoring undergraduate researchers[a]

		Motivations
Vocational	Scientific community development: Anticipation that mentoring will benefit the scientific community	Your mentor–mentee relationships is very, very important for science. It's something that helped me along the way a lot of times, professionally growing up. I had good mentors and I wanted to be a good mentor to the next generation of scientists there.—Aiden
	Social norms: Perception that mentoring is a common or expected activity of their position	Before I was here, I was in the UK at [university], and [mentoring is] something we always did … it's good training also for postdocs and PhD students.—Grace
Psychosocial	Altruism: Desire to serve others through mentoring	I feel like I learn a lot in training other people… I get a lot back out of it. You feel valuable to other people, and it feels… like a valuable use of my time… I'm making a big difference in someone else's life, and I like that.—Samantha

[a]None of the mentors expressed communally oriented hesitations.

time-consuming. For example, one mentor explains how he wanted to mentor undergraduates only if he was sure that the students would be around long enough for his time investment to pay off:

> The time commitment [of mentoring] was a big hesitation. So, I wouldn't take on an undergrad mentee that I wouldn't know in advance that I have at least a year that I can put towards training that person to become productive in the lab and actually get the benefits out of their lab experience.—Aiden

The psychosocial agentic motivations, anticipating that mentoring would provide a sense of fulfillment and be enjoyable, were also expressed by a majority of the participants ($n = 23$). Most of these mentors ($n = 19$) anticipated that mentoring a student would be fun or enjoyable. Akito described how working with undergraduates would make day-to-day life in the research group more enjoyable, noting that mentoring "is a nice break from just slouching over my keyboard and staring at my screen for a long time and doing some of the other less fun parts of research."

Only a few mentors ($n = 3$) indicated that they were not eager to mentor because they did not think that they would enjoy it. One mentor anticipated that teaching others how to do things he already knew would be annoying and feel like a waste of his time:

> In the beginning, I felt it was going to be a little bit annoying. Like, the undergrads are gonna keep asking you questions. And also, it's gonna take a lot of my time to teach them the thing I already know. So, I feel like I'm doing something that is not important to me, but is actually important to them.—Jiang

A handful of mentors ($n = 8$) thought that mentoring would help them feel fulfilled, satisfied, or rewarded. Even though few mentors expressed this motivation, it was sometimes an important motivator for those individuals who mentioned it. For example, Hannah described feeling satisfied about helping another person as her only motivation, explaining "I would like to help a younger student into science. That satisfaction is really why I would mentor. I guess there's no other personal gain that I would want."

A few mentors indicated that having a successful mentoring experience was an important part of being satisfied with their graduate school experience. For example, one late-stage graduate student who had had a negative experience working with an unmotivated student in the past wanted to mentor again with a more motivated student because he would not have felt like a successful, fulfilled graduate student without this experience:

> I didn't want to leave grad school without having a positive experience training someone and I'm aiming to finish up like a year from now.… by having a student like that [motivated], I'd be able to answer the question, am I just really bad at training students?—Ben

About half of the mentors in our study ($n = 18$) noted that mentoring would help them develop valuable knowledge and skills, including both interpersonal skills and technical knowledge and skills related to their research. A handful of these mentors ($n = 6$) were motivated by the opportunity to relearn basic research skills and techniques alongside undergraduates, as this mentor explains:

> At the time, I was working really heavily with parasites like mosquitoes, so the parasite culturing, infecting the mosquito, quantifying parasites, all of that kind of stuff, relatively basic lab work, the things that she [the undergraduate] hadn't done. It was a chance for me to reinforce my own methods and also teach her at the same time.—Jackson

Most mentors ($n = 14$) who mentioned gaining skills were motivated by the opportunity to improve their interpersonal skills, such as their communication, mentoring, teaching, and managing skills. Some mentors wanted to gain these skills because they anticipated that having such skills would benefit their careers in the future. For example, Hailey explained that she wanted to mentor as a graduate student because it would help her later in her career: "I'd like to be a PI. I want to gain experience mentoring students as well because that's a big part of being a PI."

Strengthening their interpersonal skills was especially important for some international scholars who were learning about American culture and norms of communication in academic settings in the United States. For instance, Jiang thought that mentoring would "help me learn how to build a positive relationship with others. Especially being from foreign country, I can learn more about communication skills."

While some mentors saw this new experience as a learning opportunity, other international mentors saw this lack of familiarity with American academic culture as a barrier that made them hesitant to mentor:

> During my first year I was slightly apprehensive whether or not I'll be able to communicate effectively. Because that was my first year in [the] U.S., I was slightly aware of the communication barrier that I might have. And the undergrad system in India and here is very different. So, I wasn't sure what to expect.… That was the initial hesitation point in my mind, that I should not be responsible for breaking down a person or I should not be responsible for someone else's failure because I did not put forward myself coherently or clearly.—Lakshmi

Concerns about mentoring ability were not limited to international mentors. Thirteen participants reported being initially hesitant to mentor because they worried that they did not have strong mentoring skills. For example, when asked whether there was anything she was worried about or anything that made her hesitant to mentor, Zoe replied,

> Oh, yeah. Constantly. Starting with, do I have the knowledge to be able to direct somebody to do this research? Is it going to work? Is it going to take up too much of my time? Am I going to take up too much of the students' time and then is their schoolwork going to suffer? All sorts of doubts.

Communal Motivations. Although every participant in our study mentioned at least one agentic motivation, only about two-thirds of the mentors ($n = 20$) also expressed communal

motivations, such as the opportunity to provide benefits to other individuals, develop the scientific community, or fulfill a social norm (Table 2). No communal hesitations were expressed by any participant. The most common communal motivation, expressed by about half of our participants ($n = 15$), was altruism, or the desire to help others. For those who mentioned altruistic motivations, such motivations were clearly quite important, often overshadowing other motivations such as research productivity, as expressed by this mentor:

> I think mentoring and really committing to helping people out, it's a fundamental thing that we can do in academia. Forget all the experiments … I think making a connection with another human being and really getting to know them and telling them, "I'm also human. I know what you're going through. If you're stressed out, I've been stressed out. We can work through this together."—Jose

Altruistic motivations were often fueled by participants' prior positive and negative experiences with their own former mentors. Participants who had experiences with good mentors wanted to pay it forward. For example, Jose, who expressed strong altruistic motivations, described why he was so motivated to help others:

> I had one specific teacher who really took me under her wing and totally changed my life because I had a death in the family… That really changed the way that I function as a human being and my appreciation for people … I think that, to me, is the catalyst for really improving who I am as a teacher, as someone who's guiding people.

Participants who had had poor mentors in the past were sometimes motivated to protect others from that experience, as described by Sarah,

> There were things that bothered me about the mentorship I received from older graduate students and from my advisor that I didn't want to have reflected in other students. It was my opportunity to be like, "Okay, this is how I think it should be done."

About one-third of the mentors in our study ($n = 10$) were motivated to contribute to the greater scientific community. Participants viewed mentoring as a critical part of preparing the next generation of scientists and building a society that values science:

> If you have an opportunity to teach, teach. Because that's how things get better. That's how things improve. That's how you get a robust scientific community and a robust lay community that supports the scientific community. Mentoring is very important for that.—Liam

Some mentors expressed the feeling that because they had been mentored as undergraduates, it was their duty to pay it forward by mentoring current undergraduates. A few participants noted that, through mentoring, they could help diversify the scientific workforce by working with scientists in training from underrepresented backgrounds:

> I have only mentored two male students at this point, and both of them were white. I would like to diversify my mentoring profile a little bit and reach out to students who are underrepresented in STEM and in my field.—Leah

A related motivation was the notion that mentoring is a social norm within the scientific community and part of the duties of a being postgraduate. A few mentors ($n = 4$) noted that everyone around them was mentoring and felt it was an expectation of their position:

> Our lab traditionally has had a lot of undergrads working in the lab. So, the first time I did it [mentored], it was just [that] there were a lot of undergrads in the lab, all other grad students were mentoring undergraduate students, and it seemed like it worked really well for everybody involved.—Rajiv

Outcomes Realized by Mentors

Mentors reported a variety of positive and negative outcomes from mentoring, including outcomes that aligned well with their original motivations and outcomes they had not anticipated. In general, mentors spoke about outcomes in terms of motivations that were realized, such as being motivated to mentor in order to increase research productivity and actually being able to get more research done or experiencing decreased productivity. In addition to these realized motivations, mentors also discussed unanticipated positive and negative consequences, such as feeling inspired or frustrated and changes in mentoring self-efficacy. Mentors reported both vocational outcomes (increased or decreased research productivity, technical and interpersonal skill gains, and career preparation gains or costs) and psychosocial outcomes (experiencing positive or negative emotions, increased or decreased stress and anxiety, increased or decreased mentoring self-efficacy, and increased self-awareness, and forming positive personal relationships). In addition, mentors reported gaining diversified perspectives, which they described as both vocationally and psychosocially beneficial.

Vocational Outcomes. Vocational outcomes were reported by every mentor, suggesting that mentors thought of their experiences mentoring undergraduate researchers in relation to their own career development (Table 3). These outcomes included the effects of mentoring on their research productivity, gains in technical and interpersonal knowledge and skills, and impacts of mentoring on their career preparation.

Most of the mentors in our sample ($n = 24$) mentioned the benefits of mentoring for their research, which is not surprising, given that increasing research productivity was a prevalent motivation. Mentors reported increases in both the amount and quality of their research as well as new research directions that resulted from their work with undergraduates. For example, this mentor explained how working with undergraduates allowed for progress on side projects that she did not otherwise have time for:

> She really got this project off the ground, and we got a publication out of it. It was a total side project that we never would have done without having undergraduate hands on it, and she really took it and ran.—Samantha

TABLE 3. Postgraduates' vocationally related benefits and costs of mentoring undergraduate researchers

	Benefits	Costs
Research productivity: Increase or decrease in professional output	I gained a lot in terms of research because I actually just finished the manuscript with her work in it, so I am getting something from the research side.—Mei	It's a big time commitment. You kind of have to babysit them for the first few months at least, and even later. If they have to do anything in the lab, officially we are not allowed to let them work by themselves so anything they do, you have to stay with them and a lot of time, especially in the beginning, is a duplication of effort.—Rajiv
Technical knowledge and skills: Gains in scientific knowledge and skills	Explaining concepts and teaching techniques helps me do it better because I'm constantly going back to the fundamentals and realizing, "Oh, right. You do need to do this. Oh, right. This is a very important foundational." Every time you explain it, you have a slightly different understanding of it, so to speak. It helps me learn my science better, when I'm explaining it to somebody else.—Zoe	None observed
Interpersonal skills: Improved skills related to working with others	One thing he [the undergrad] did very well was provide me honest feedback. If I wasn't explaining something clearly or if I was giving him too much workload or too little. There was that real good feedback from him. That helped me realize how to read people and manage an individual.—Yuan	None observed
Career preparation: Effects on qualifications, career clarification, and degree progress	A lot of people say that being a PI is kind of like managing a small company. It's definitely about science, but then it's more so about managing different people. Learning this skill from early on that was something unexpected that I think is really fruitful right now.—Huang	The time thing [commitment] is probably the most frustrating because in the end, we're here a long time in grad school. I think average is like five and a half right now in the United States or something like that for a Ph.D., so every hour counts the way I see it. Especially as I'm getting closer to the end here, every hour counts. So I'm trying to work on a lot of things, trying to wrap things up. It's frustrating to have to train people in that same light.—David
Diverse perspectives: Undergraduates' diverse ideas affected postgraduates' research	Another set of skills that I've been able to implement have been to understand really who my students are. Really appreciate their differences. From those differences, I really get to take out as much as I can because I'm bringing new ideas, novel ideas, even when they're from different cultures, they have a different way of thinking, different way of tag-teaming issues and problems. —Jose	None observed

Although three-quarters of the mentors in our study reported research benefits, about as many (n = 25) also described ways in which mentoring harmed their research productivity, primarily through dedicating time to mentoring. In fact, a handful of mentors only discussed how mentoring hindered their research productivity. For example, one mentor described research productivity as a "fake incentive" for mentoring students:

> It would have been nice to have help with my project. It's like sort of a fake incentive to graduate students to mentor undergrads, right? They want undergrads because they want help, but then you put a ton of work into it, and then you don't get help.—Sophia

About one-third of the mentors (n = 10) reported that mentoring helped them improve their technical knowledge and skills by reinforcing background scientific knowledge, improving research skills, and clarifying their thoughts about their research. Some mentors reported that working with students helped them review the basics of their field, ultimately strengthening their foundational science knowledge, as this mentor described:

> [Mentoring] makes me really have to know my stuff because [undergraduates] ask me questions and I realize I have no idea. That happens all the time. I get stumped by undergrad questions embarrassingly often. I'm like, "Oh, let me do some research. I'll tell you tomorrow." … So, it's really made me be on my game. Most of the time they're asking big questions. Like, "Why does this matter? Why are we doing this?" Those are harder to answer. And I'm [a] very like small-minded person. I'm really, really focused on piddly little details and I'm like really bogged down in the weeds. But undergrads who

> come in with an open mind aren't. So I have to sort of recalibrate, which is very good for me.—Charlotte

Beyond reviewing the basics, mentors noted that working with undergraduates helped deepen or expand their scientific thinking. Sometimes, needing to explain their research ideas to someone forced mentors to clarify their own thoughts:

> I think one of the ways that I do science, actually, is figuring out how to communicate ideas to people. So, "Oh, you have to do this additional experiment because of the thought process it's going to go through explaining something." That explanation process with them is really valuable.—Olivia

Most mentors (n = 25) also reported that mentoring helped them improve a variety of interpersonal skills (e.g., mentoring, teaching, communication, management), which they also described as being relevant to their future careers. For example, one mentor described how learning leadership and management skills would help him in his future career:

> I definitely want to be in a leadership position when I get out of here … so all of this training with undergrads, that's why I try to frame it, even when it's frustrating stuff, that you're going to be facing this the rest of your life so as far as benefits go, it's good to have undergrads as grad students, I think. If you don't work with them well, I think it might hurt you in the end.—David

Another mentor described how working with multiple students simultaneously helped him learn how to manage multiple different personalities on a team:

> I've learned a lot about teaching. It was nice to have three undergrads at once because then I could see how I interact with each of them. They struggle with different things and they're good at different things. It was just really good teaching experience. I think I also learned things about how to manage a team. They all have quite unique personalities.—Li

Some mentors thought that the benefits of developing new knowledge and improving their skills was so valuable that gains in these areas compensated for other costs, such as declined productivity. For example, one mentor explained that he was satisfied with his experience, even though it was stressful and decreased his productivity because he was able to learn from it:

> Even though the last one [was] a bad relationship experience, that didn't really stop me [from mentoring again] because, again, I learned some stuff from there. I learned a lot of stuff from them as well, so that kind of motivated me to keep mentoring undergrads.—Jiang

While many of these outcomes likely affect participants' career progress, about two-thirds of participants (n = 22) explicitly described how the benefits or costs that they incurred from mentoring helped or harmed their career preparation and advancement. Most of these mentors (n = 20) reported that mentoring helped them prepare for careers within and outside academia through improved qualifications, improved performance at their current jobs, and career clarification. One mentor described how mentoring helped her decide to pursue an academic career:

> I think some of my successful undergrads have given me a lot of clarity on why I do what I do.… The process of integrating my research program with [the undergraduates'] development has been very fulfilling. It was around the time that I started really heavily working with undergrads that I thought, "Okay, yeah, I definitely want to continue in academia."—Olivia

Some mentors noted how mentoring helped them improve their performance in their current positions. One mentor described how being responsible for working with a student made him "step up":

> I feel like all the aspects of being a good researcher, a good field biologist, you have to step up every single aspect when you have an undergrad because you have to manage yourself and another person as well. I mean you've been managing yourself, obviously, but you have to be on top of it as well. So, you have to be organized but you also have to think about, are they organized and help them organize and teach them how to be more organized and time management, and all that sort of thing.—Li

On the other hand, a few mentors (n = 4) described how mentoring was directly detrimental to their career progress, primarily by reducing their research productivity or delaying their professional advancement (e.g., graduation for graduate students). One postdoctoral scholar applying for faculty positions became concerned that he had spent so much time and effort mentoring as a graduate student that he might not be competitive on the job market:

> I don't have any mentorship opportunities here [as a postdoc]. I realized how much work I wasn't getting done [as a graduate student]. I didn't really think about it at the time.… I don't want to make it seem like all I care about is publications because I don't. But now in my current standing, it's what I'm thinking about a lot. I do recognize mentorship has a lot of value way beyond that, but what I think about now is, "Well, what does my CV look like? How do I compare to these other 300 people applying to the same job?"—Jackson

Psychosocial Outcomes. Mentors reported a variety of positive and negative psychosocial outcomes (Table 4). Affective outcomes were among the most commonly discussed, mentioned by all but two participants (n = 30). Positive affective outcomes were particularly common, reported by 26 mentors. Given how frequently mentors were motivated by anticipated enjoyment and satisfaction, it is unsurprising that many mentors reported enjoying mentoring and feeling fulfilled. For example, Zoe succinctly described both the fun and satisfaction she derives from mentoring: "Just the personal pleasure of seeing somebody succeed is something that is always a lot of fun. Especially succeed at something that you're really excited about and passionate about."

Mentors also reported a number of unanticipated positive affective outcomes, including feeling excited, inspired, or just generally positive. For example, Leah described how the idea of

TABLE 4. Postgraduates' psychosocially related benefits and costs of mentoring undergraduate researchers

	Benefits	Costs
Affect: Positive and negative emotions	I didn't expect some of my students would go on to, I think, surpass me. Which is actually a great feeling. I had one brilliant student who went on to develop some sort of HIV research tool … it's really cool to see stuff like that happen… I like to hear from them and see their successes. —Charlotte	I probably mistreated this student without realizing it… It resulted in me not mentoring an undergrad for one or two years after. I feel like in hindsight it did hit me pretty hard. Whatever I said to her or however I treated her was not the best thing to do.—Rajiv
Stress and anxiety: Increased or decreased stress or anxiety	It also helped sometimes because by having all these students around, if I did take vacation, it's not like everything would just die because we have people that we've trained to take care of things. That was very nice. Right now, it's hard for me to take vacation because I'm the only one that does anything on my project. If I leave, it stops. Nothing happens.—Jackson	I've been really stressed out about my students. [They] were having personal problems that caused a lot of the stress. I was pretty concerned about their well-being and their deadlines. In many ways, it's easier than your own stress because it's not on your plate all the time. But it's harder than your own stress in some ways because I had very little control over it.—Olivia
Mentoring self-efficacy: Increased or decreased confidence in mentoring ability	She was very easy to work with. It really made me feel that yes, I can certainly do this, even if I'm not an expert in the field where I do research, I can very easily bring someone with me and work on this… this person can learn from me and we can learn together. She gave me that level of comfort that I was doubting myself. Am I really ready to be a mentor? She showed me that, yes, I was ready to be a mentor.—Jose	My experiences with these students in a lot of ways frustrated me because they made me think, "If I've had two undergrads and they've both gone super poorly, is that on me?" … Having such bad relationships with them and such bad experiences made me constantly question my ability to be a mentor. Being a good scientist is being good at communicating. If these students aren't picking these things up and understanding what I'm saying, does that mean I'm bad at communicating or I'm bad [at] whatever else?—Ben
Self-awareness: Increased knowledge of own tendencies, strengths, or weaknesses	[Mentoring has] also been really good in calibrating my understanding of where people are when they come to my research because I've definitely had some, "Oh, gosh" moments where I realized I'm working at what I think is level two, but it's level eight. These students have no idea what I'm talking about. That's a consistent thing with the students I'm talking with, so it's clearly me, and it's not them.—Abigail	None observed
Relationships: Formed new positive interpersonal relationships	I've made friends. I feel like the two students that have been a really good experience are, I feel, I have a mentee and a friend. So, it's been nice.—Victoria	None observed
Diverse perspectives Personal benefits from exposure to diverse perspectives and ideas	[The undergraduate] challenged my outlook and perceptions on a lot of topical, social things that are going on, on campus and in general. That was one of the big things I took away from it that didn't have anything to do with science at all.—Aiden	None observed

working with undergraduates made her excited for future research projects, saying, "It [mentoring] actually got me excited about doing more kinds of projects where I could bring in undergrads."

There were also a number of unanticipated negative affective outcomes reported by participants, including anger, frustration, annoyance, disappointment, guilt, and discomfort, as well as feeling disrespected or emotionally drained. In most cases, mentors reported experiencing both positive and negative affect resulting from mentoring. Of the 23 mentors who mentioned negative affect, 19 also mentioned positive affective outcomes. Negative emotions were often caused by experiences such as needing to dedicate time to train undergraduates or instances of undergraduates making mistakes or not performing as well as the mentor hoped. For example, one mentor describes being frustrated by a student's persistent low performance and not knowing how to fix the problem:

> I felt like it was draining me. It was also getting into and realizing he didn't have the capacity to do the things that I really had wanted him to do. So, having to readjust my expectations, and just getting, flat out, frustrated at times, at having to explain something a thousand times, and not knowing where I'm failing to get that across.—Abigail

Negative emotions were also caused by mentoring relationships ending, either through a student graduating and moving on or otherwise leaving the lab. One mentor described the disappointment and frustration she felt when a student she had invested time and effort in training lost interest and left the lab:

> It was kind of disheartening. You spend a lot of time developing a relationship with this person and helping them grow, and then they just stop caring, or they just stopped being there. It was like, "Man I just spent so much time training you and now you've just decided to stop caring."—Isabella

Increased or decreased stress and anxiety levels were mentioned by about half of the participants (n = 17). Of these, only four participants reported that mentoring decreased their stress or anxiety. For example, mentoring may decrease stress and anxiety because working with undergraduates serves as a break from normal work activities or helps to reduce workload, as Hailey explained in describing how undergraduates "really helped me ease the workload. I think if anything, it's lessened the workload or lessened the stress level."

Conversely, 14 mentors experienced increased stress and anxiety levels due to conflicts with undergraduates, undergraduates' poor performance or mistakes, concern about the quality of mentorship they were providing, and vicarious stress when undergraduates were experiencing problems. A few mentors recounted interpersonal or professional conflicts with undergraduates that caused them stress. For example, one mentor described an incident in which she was yelled at by the undergraduate working with her, who perceived that she was not doing an adequate job as a mentor:

> It all culminated with her yelling at me and telling me that I was a terrible mentor because I wasn't making sure that she knew and understood everything. I was like, "That's not my job." It was really bad.… It was a bit stressful.—Samantha

Although no mentors indicated that they were motivated or hesitant to mentor because of the potential impact on their professional reputations, several mentors became concerned about the risk that poor performance by their students would reflect poorly on them. One mentor explained,

> I was invested in making sure that … if my name was going to be on something, that it wasn't a piece of garbage. That stressed me out a lot, especially when they [the undergrads] were sending me drafts super late. It stressed me out thinking that if [my PI] saw a product and read something and was like, "What? This kid is an idiot, this is terrible." That it would reflect poorly on me as the person who was supposed to have been training them and who's a graduate student in his lab.—Ben

Several mentors described experiencing increased anxiety over the quality of the mentorship that they were providing. For example, one particularly thoughtful mentor described the emotional weight of her internal conversation about how to best mentor:

> I have a lot of concerns.… I just have a lot of anxiety about, "Am I being lazy by not sitting down and reading papers with them, or am I just being realistic about what we can accomplish together?" So, I think that's kind of been an ongoing anxiety that started pretty early on, of "what is my role?" and "how much is driven by me, and how much is driven by them?" … I have a lot of anxiety about it.—Olivia

When undergraduates have personal problems, it can cause the mentor to experience vicarious anxiety due to concern over the undergraduates' well-being. Such situations can also create an uncomfortable work environment if personal problems affect the undergraduate's behavior in the lab. One mentor reported that difficulties with an undergraduate created an uncomfortable work environment for him and other members of the lab. He described how the undergraduate was having personal problems that made it difficult for the student to regulate her emotions and behave professionally. He further described being in a difficult position—sympathetic to the student's plight but mindful of the reality of how the student's behavior was disrupting the working environment:

> She [the mentee] was going through a lot of tough things. The biggest problem was that she couldn't keep her time commitments and she was really hard on herself if she made any kind of very minor mistake. If she knocked something over, she would just start screaming at herself. It was really upsetting to be in the room with her for that reason. It was wearing on the other students too. I think it was all because of what she was going through,… but it was really hard on me and everyone else in the lab, and we didn't really want to work with her anymore. It was a weird experience, but I think everybody at the time recognized what was going on, so nobody held it against her. We just didn't want her in the lab because it was not productive for anyone involved.—Jackson

Participants' mentoring experiences sometimes impacted their confidence in their ability to mentor. Experiencing difficulties and frustrations sometimes dampened mentors' confidence in their mentoring ability. Four mentors reported having decreased confidence in their mentoring ability after having bad experiences mentoring. One mentor explained how multiple negative experiences and outcomes interacted simultaneously, decreasing her mentoring self-efficacy:

> It was definitely frustrating, time-consuming, and emotionally draining.… It made me doubt my abilities. I think that was the worst part. I was like, "Maybe I can't teach. Maybe I can't do science. Maybe I'm not good at mentoring." In your darkest times, when you're having problems with an undergrad, that's the thoughts [*sic*] that go through your mind.—Isabella

Lack of mentoring self-efficacy was a commonly cited factor of mentors' hesitations to mentor, so decreased mentoring self-efficacy resulting from negative experience could have important consequences on a postgraduate's intentions to mentor in the future. On the other hand, positive mentoring experiences frequently increased mentors' sense of self-efficacy (n = 11). In particular, some mentors noted how having increased mentoring self-efficacy resulting from a successful mentoring relationship made them more confident and more willing to mentor in the future. One mentor explained that increased confidence from her mentoring experiences prompted her to accept a faculty position that would involve substantial mentoring of undergraduates:

> I'm moving to a position where … It's like an R1 [research-intensive university], but it's also heavily undergraduate.… That was kind of what I wanted, was a huge draw of that place was

> like, "Okay, I can also have really productive research interactions with undergraduates." … I've slowly increased the number of students that I mentor since I've been here. I'm getting more and more comfortable with it [mentoring].—Olivia

One unanticipated benefit reported by a handful of mentors (n = 7) was enhanced self-awareness. Through mentoring, mentors learned about their own interpersonal styles and tendencies. For example, one mentor described,

> I learn a lot about myself as what kind of advisor I would be like and what sort of things I would probably struggle with and the sort of things I would be good at. That explaining certain things, I think I would be able to do certain things, or teach certain things, then I'm forced to and I'm like, "Oh, okay, I can do this." I guess learning things about, like insight into what I'll be like as a mentor.—Li

Mentors reported a range of gains in their relationships, none of which were mentioned as motivations or hesitations to mentor. Half of the mentors (n = 16) reported forming positive relationships with undergraduates they mentored, describing undergraduates as friends or like family. For example, one mentor described forming a close friendship with a student she mentored:

> We also became sort of friends, like we hung out outside of class because we were so similar in age at the time, and just having another person that's outside of academia was really nice to have.—Mei

A couple of mentors (n = 2) also expressed that mentoring affected their existing relationships with their own mentors. For instance, one mentor recognized how important it was to communicate regularly with his undergraduate, and thus he put more effort into his existing relationship with his PI:

> I do use my mentor training to be a better mentee for my PI. As a mentee, training has demonstrated to me the importance of frequent communication with a mentor. I make more active attempts to communicate with my PI than I naturally would because that has been shown to provide better outcomes for both.—Aiden

Crosscutting Outcome. About one-third of mentors (n = 10) described one outcome that they framed in both vocational and psychosocial terms: diversified perspectives. Specifically, some mentors reported that working with undergraduates helped them gain new and different perspectives, which they found both personally and professionally valuable. One mentor explained both of these values by describing how working with undergraduates pushed her to think differently and to understand others' viewpoints, while serving as important training for her career as a professor who would ultimately be working with students who would not be "like her":

> I feel like it's really easy to interact with somebody that's exactly like me, I understand where they're coming from. I understand how they're thinking, how they're processing, where they're going with things. So, it's really helpful for me to stop and force myself to understand somebody that doesn't think like me.… I need to have a very open viewpoint of how other people think and are looking at this stuff. Also, I'm planning on pursuing a professor position when I'm done, and I'm not going to be recruiting students that are only like me. In fact, I *need* to recruit students that are not like me. One thing I noticed in a lab is different personalities can actually be very beneficial in some ways, so I need to be able to effectively guide these personalities that are not like mine.—Zoe

Other mentors explained that undergraduates brought new perspectives and ideas that encouraged the mentors to think about their research differently. One mentor described how diverse student interests drove his research in new directions and helped him learn new topics:

> I learn a lot of stuff from undergrad[s], so they all [have] different backgrounds.… They have different way[s] to think. That's what I have been learning from them as well, and every one of them has different interests. That makes me feel excited as well because our research is getting more diverse and diverse because of their different interests. Some of them like evolution, some of them [are] more into ecology, and one of them more into biochemistry. So, our lab has become more diverse and [is] studying different things, and that also helped me to learn a lot of stuff from them as well. So, I am [did] not really know much about biochemistry, but since [undergraduate] came in, our lab started learning more and more about it, so that helps me a lot as well.—Jiang

Testing for Theory Alignment

Our results indicated that even postgraduates who engaged in mentoring at the request of their faculty advisors had their own motivations for mentoring undergraduates. In fact, most of our participants stated that they actively chose to mentor; only five of the 32 participants reported being required to mentor in some way. Of these five, one mentor explained that, due to the nature of the research, projects could not be completed without help from undergraduates, and thus the mentor had no choice but to take on undergraduate researchers. The other four described being told to or pressured to mentor by their PIs. In some of these cases, the mentor simply assigned an undergraduate to the postgraduate without asking. In other cases, the PI exerted sustained, low-level pressure on the postgraduate to mentor a student, to which the postgraduate eventually succumbed. Regardless, all of the mentors in our study, even the ones who experienced some requirement or pressure to mentor, cited personal motivations, as reported by this participant:

> I really like teaching, and I like sharing my passion for science. But I'm going to be honest, most of it was, "you're a grad student, you have to mentor an undergrad." That was the rule. My PI had a term, he would "voluntell" us to do things and that was one of the things. But I really enjoyed it, so I didn't mind.—Isabella

In addition to citing personal motivations, most mentors in our study also viewed mentoring as a career development opportunity. Thus, we conducted a second phase of analyses to

determine the extent to which our results aligned with four different theories of motivation and career development: self-determination theory, social cognitive career theory, expectancy-value theory, and social exchange theory.

Self-determination theory (SDT) is a broad theory of motivation that applies generally to all human behavior (Deci and Ryan, 2000). According to self-determination theory, people are intrinsically motivated to do things that fulfill three basic needs: feeling capable and efficacious (competence), feeling connected to others and a sense of belonging (relatedness), and having a sense that one's actions are self-chosen and concordant with one's own interests and values (autonomy). With respect to mentoring, SDT would predict that postgraduates would be motivated to mentor if they felt they would be competent at it or mentoring would enhance their feelings of competence (e.g., by learning new skills), if it would help them fulfill their role or identity in the scientific community, and if they are choosing to mentor for personal (intrinsic) reasons. We found that all three elements of SDT were represented by motivations and hesitations described by mentors (Table 5). Competence was represented by mentors being motivated to increase their competence by developing technical and interpersonal skills and mentors expressing hesitation to engage in mentoring because they were underconfident about their mentoring abilities. Relatedness was represented in the communal motivations expressed by some but not all of the mentors in our study. Autonomy is enhanced when individuals feel that the activity aligns with their personal values and interests. Thus, autonomy was represented in mentors' comments about the personal value they saw in mentoring, such as anticipating enjoyment, fulfillment, and increased research productivity, as well as the desire to benefit others and the scientific community.

Social cognitive career theory (SCCT) is more narrowly defined than SDT, as it describes motivations in terms of career development per se (Lent *et al.*, 1994). SCCT posits that people are primarily motivated to take career-related actions if they think they will be able to do so successfully (self-efficacy expectations) and if they expect those actions will yield positive outcomes that they value (outcomes expectations). With respect to mentoring, postgraduates would be motivated to mentor undergraduates if they felt they would be successful in doing so and if they felt that mentoring had the potential to yield positive career-related outcomes, such as research productivity or interpersonal skill development. Our results also aligned with this theory because both self-efficacy and outcomes expectations are represented by motivations and hesitations discussed by mentors (Table 5). However, SCCT is quite broad and thus does not allow us to discriminate among the various outcome expectations expressed by postgraduate mentors in our sample.

Expectancy-value theory (EVT) has the potential to allow for finer-grained analysis of outcome expectations (Wigfield and Eccles, 2000). EVT suggests that motivation is a function of the expectation of success (self-efficacy) and anticipated task value. Task value is further defined in terms of the intrinsic value of a task (i.e., the task is enjoyable or interesting), utility value (i.e., the task will be practically useful or help advance toward a goal), and attainment value (i.e., the task will provide a sense of self-affirmation or accomplishment). Furthermore, these positive values must outweigh anticipated costs (e.g., opportunity

TABLE 5. This theory alignment heat map illustrates which motivations and hesitations correspond to each motivation theory, with dark gray shading indicating alignment of our data (along the vertical) with a dimension of the corresponding theory (along the horizontal) and light gray shading indicating areas of ambiguity that are not resolvable from the current data set

		Self-determination theory			Social cognitive career theory		Expectancy-value theory			
		Autonomy	Competence	Relatedness	Self-efficacy expectations	Outcomes expectations	Utility value	Intrinsic value	Attainment value	Cost
Agentic	Research productivity									
	Technical knowledge and skills									
	Interpersonal skills									
	Mentoring self-efficacy									
	Enjoyment									
	Fulfillment									
Communal	Social norms									
	Scientific community development									
	Altruism									

cost, emotional cost) for the task to hold sufficient value. When applied to mentoring, EVT predicts that postgraduates would be motivated to mentor if they expected to find the experience enjoyable, satisfying, or fruitful in terms of knowledge or skill gains, research productivity, or other useful outcomes; if it allowed them to feel like an accomplished scientist; and if it was not associated with substantial costs, such as lost research productivity or excessive frustration.

EVT mapped well to agentic motivations articulated by postgraduates in our study, with all four elements of EVT relating to their agentic outcomes expectations (Table 5). However, it remains unclear how their communal motivations (i.e., social norm, developing scientific community, and altruism) relate to EVT, as indicated by the light gray shading in Table 5. One possibility is that altruistic motivations (benefiting other individuals) and developing the scientific community (benefiting the community as a whole) fulfill intrinsic value if people are motivated to mentor because it makes them feel good to benefit others and society. These questions relate to the larger debate about whether people are truly altruistically motivated or whether apparently altruistic motives are selfish in nature because they present opportunities to feel good or attain status in the community (Andreoni, 1990). Another possibility is that benefiting the scientific community and fulfilling a social norm could be considered either attainment value or a separate distinct communal motive. If aiding the scientific community or complying with social norms helps an individual feel like part of a community, it would fulfill an individual's need to belong and offer attainment value. However, it is also possible that benefiting the scientific community or complying with social norms are distinct communal motivations that cannot be described by the agentic nature of EVT. Future research should investigate whether these communal motivations can be distinguished empirically from intrinsic or attainment values.

Finally, we also considered our results in light of social exchange theory (SET; Emerson, 1976; Cropanzano and Mitchell, 2005). SET has been used to describe relationships that involve interactions that generate obligations contingent on the actions of individuals within the relationship. Relationships that involve some sort of interdependent reciprocation (i.e., quid pro quo) can be understood in terms of SET. In terms of mentoring, postgraduates might be motivated to offer their resources (e.g., time, expertise, guidance, advice) to undergraduates if they feel that they will receive resources in-kind (e.g., research productivity, new ideas, practice communicating, experience that can be noted on a job application). The postgraduates in our study did not conceive of mentoring as a primarily transactional or quid pro quo relationship. Thus, we opted not to pursue finer-grained analysis related to this theory.

LIMITATIONS

Our study was designed to qualitatively explore the experiences of postgraduates mentoring undergraduate researchers in the life sciences. Thus, we cannot make generalizations about the prevalence of particular motivations postgraduates have to mentor undergraduates or the frequency of outcomes they experience. Future research should build off our results by quantifying postgraduate motivations and relating their motivations to outcomes that postgraduates attribute to mentoring. Our results provide useful insights into which motivations and outcomes may be most fruitful to examine in larger, more nationally representative studies. Our results also add to the current, very limited body of knowledge about postgraduate mentoring in STEM (Dolan and Johnson, 2009; Hayward *et al.*, 2017) because the postgraduates in our study span multiple institutions, multiple life sciences disciplines, and multiple types of research.

Our study has multiple potential sources of bias, which we took steps to mitigate. First because our recruitment strategy relied on volunteers, our results may represent a skewed view of postgraduate mentors' experiences due to selection bias. To mitigate this bias, we strategically interviewed postgraduates who varied in their overall rating of their mentoring experience, not just postgraduates who had positive experiences. Future research should make use of a similar strategy to ensure the full range of postgraduate mentors' experiences are studied. Second, we interviewed postgraduates about their motivations to mentor *after* they completed their mentoring experiences, which may result in recall bias or issues related to post hoc justification. Future studies should be conducted longitudinally, with postgraduates' motivations to mentor being measured *before* they engage in mentoring. Finally, we relied on postgraduates to report their outcomes. These results provide insights into the range of outcomes postgraduates may experience. However, future studies should aim to quantify these outcomes using established measures in order to mitigate cognitive biases (i.e., the "Dunning-Kruger effect"). For instance, gains in mentoring skills could be measured using the Mentoring Competence Assessment (Fleming *et al.*, 2013). It is likely that new tools will need to be developed to measure key constructs that emerged in our study (e.g., postgraduate mentoring outcomes expectations) before additional research can be done.

DISCUSSION

Several results from our study yield new insights into how postgraduates experience mentoring undergraduate researchers. For example, several postgraduates reported developing new personal and professional perspectives as a result of working with undergraduate researchers who were different from them or who brought new ideas to the research. Postgraduates also expressed hesitations about mentoring, including concerns about the time and effort it takes to mentor undergraduates and their personal lack of interest in mentoring. International mentors expressed particular concern about their mentoring abilities, given their lack of knowledge about undergraduate education in the United States, including ambiguity about norms and lack of clarity about expectations. Additional research with a larger and more broadly representative sample of postgraduates is needed to determine the prevalence of the motivations and hesitations we observed. It would first be necessary to develop a more scalable way of measuring postgraduates' motivations to mentor undergraduates. The results of our study in concert with previous research (Dolan and Johnson, 2009; Hayward *et al.*, 2017) should be sufficient to define the content domain of postgraduate motivations to mentor undergraduates, which can be used to draft a survey measure of the construct (American Educational Research Association, American Psychological Association, National Council on Measurement in Education, Joint Committee on Standards for Educational and Psychological Testing [US], 2014; Bandalos, 2018).

A subset of the motivations and beneficial outcomes reported by mentors in our study recapitulate those identified in smaller studies with more limited samples (i.e., single lab or single program; Dolan and Johnson, 2009; Hayward *et al.*, 2017). For instance, postgraduates in our study reported being motivated to mentor undergraduate researchers to improve research productivity, develop mentoring and other interpersonal skills, experience enjoyment and fulfillment, and contribute to and become a part of the scientific community. The replicability of this subset of previous results provides further evidence that the content domain of postgraduate motivations to mentor undergraduates has been fully described, and the next step for research should be development of a quantitative measure.

The postgraduate mentors in our study also reported mentoring motivations and outcomes similar to those reported by faculty mentors. For example, both postgraduate and faculty mentors report communal motivations, such as helping others and benefiting the scientific community (Morales *et al.*, 2017). Both report agentic motivations, such as wanting to increase their research productivity (Dolan and Johnson, 2010; Baker *et al.*, 2015). Faculty and postgraduate mentors report similar outcomes from mentoring, including increased or decreased research productivity and positive and negative emotions (Dolan and Johnson, 2010; Lunsford, 2014). Yet our results show that some postgraduate motivations and outcomes are distinct from those of faculty mentors. For example, postgraduates in our study indicated that mentoring undergraduates was an opportunity to develop their technical and interpersonal skills, gain experience and confidence, and clarify their own career interests. These results suggest that postgraduates are viewing mentoring as a self-focused, developmental activity, which is consistent with their roles as scientists in training. These results also hint at postgraduates' status as members, rather than heads, of research groups and their developing identities as scientists. For instance, postgraduates expressed motivations related to mentoring norms within their research groups, programs, and disciplines, either adopting these norms or feeling obligated to comply with them. In contrast, faculty mentors report motivations and outcomes consistent with their more advanced career stage, such as mentoring to advance their institutions' missions and to build and maintain relationships with collaborators (Behar-Horenstein *et al.*, 2010; Baker *et al.*, 2015). These motivations and outcomes reflect faculty mentors' sense of responsibility not only for themselves but also for their research groups and perhaps even their departments, institutions, and disciplines. These results also reflect the greater autonomy faculty mentors have over how they structure their research groups, including whether and how to involve undergraduate researchers. Future research should investigate these differences more directly to determine how shifts in autonomy and identity associated with career stage relate to mentors' motivations and outcomes.

Prior research categorized postgraduates' motives to mentor undergraduate researchers as intrinsic (i.e., inherent to mentoring undergraduates in research) or socioemotional (i.e., relating to interpersonal or internal factors) and instrumental (Dolan and Johnson, 2009; Hayward *et al.*, 2017). We delineated motivations as agentic, communal, vocational, and psychosocial, terms more commonly used to describe mentoring in workplace settings (Kram, 1983; Schockett and Haring-Hidore, 1985). These new categorizations of postgraduate mentoring in the life sciences enable more direct comparison of the research mentoring relationship with workplace mentoring relationships, which have been the subject of much more extensive research (Eby *et al.*, 2013). These categorizations also lay a foundation for developing hypotheses about how postgraduates are affected by mentoring undergraduate researchers. For instance, postgraduates who realize psychosocial benefits of mentoring may experience higher satisfaction with their training experience and a greater sense of well-being and commitment to continue in science. Postgraduates who realize vocational benefits may experience greater scholarly productivity and more favorable career prospects. Testing these hypotheses may yield unique insights into how to address recognized shortcomings and problems with graduate and postdoctoral education in the United States, including concerns about graduate student well-being and how to prepare postgraduates to pursue diverse career paths (Gibbs and Griffin, 2013; Gibbs *et al.*, 2014; NASEM, 2018; Price *et al.*, 2018).

Our results also build on previous research by determining the extent to which empirically derived motivations align with various motivation-related theories. Although postgraduates in our study reported motivations that could be classified as "means to an end," they rarely discussed their motivations or experiences in transactional terms. In fact, when we attempted to interpret our results in terms of SET, which is the most transactionally oriented theory of motivation that we considered, we found few examples of quid pro quo language. Although SET did not reflect the experiences of the mentors in our sample, it may be more relevant to a larger, more heterogeneous population of postgraduate mentors not captured by our sampling method. A modest proportion of mentors in our study reported feeling pressured, assigned, or told to mentor, which was also observed by Hayward and colleagues (2017). All of these individuals also reported at least some motivations that held personal value for them, as depicted in Figure 1, suggesting that the postgraduates in our study are internalizing the value of mentoring undergraduate researchers at least to some extent. This internalization aligns well with how Deci and Ryan (2000) describe autonomy, stating that "by identifying with the value of the activity, internalization will be fuller, people will experience greater ownership of the behavior and feel less conflict about behaving in accord with the regulation, and the behavior will be more autonomous" (p. 237). Such internalization is desirable because, as noted earlier, mentors' motivations can affect the mentoring functions they perform and the outcomes they and their protégés experience (Noe, 1988; Allen, 2003; Wanberg *et al.*, 2006; Ghosh and Reio, 2013). These results raise practical questions, such as whether prompting postgraduates to reflect on their various reasons for mentoring might increase internalization and ultimately improve outcomes for them and their undergraduate protégés. Although it is premature to make firm, practical recommendations, faculty mentors and mentoring program directors could consider asking postgraduates to engage in this type of reflection before they start mentoring undergraduate researchers.

Collectively, our data align well with three of the four theories of motivation that we considered: SDT, SCCT, and EVT. We found substantial overlap among these theories in our data and propose a model that combines relevant elements from each

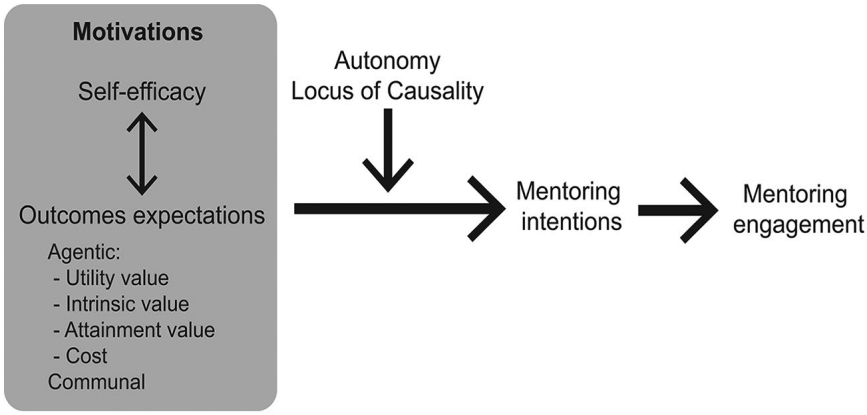

FIGURE 1. Integrated model of postgraduate mentoring motivations. We propose a model of postgraduate motivations to mentor undergraduate researchers that integrates elements of self-determination theory, social cognitive career theory, and expectancy-value theory. On the basis of our results, we hypothesize that mentoring self-efficacy (competence) and outcomes expectations influence whether postgraduates intend to mentor, which in turn influences whether they engage in mentoring. We further hypothesize that postgraduates expect to realize both communal and agentic outcomes from mentoring undergraduate researchers. We also propose that the relationship between motivations and intentions is moderated by the extent to which postgraduates' decisions to mentor are both within their control (locus of causality) and aligned with their personal interests (autonomy). In other words, if postgraduates do not perceive they have a choice to mentor or if mentoring does not align with their personal interests, their mentoring self-efficacy and outcomes expectations will have less influence on whether and how they engage in mentoring.

theory to describe postgraduates' experience with mentoring undergraduate researchers in the life sciences (Figure 1). This model captures key theoretical elements related to motivation and career development and reflects all of the major themes that emerged from our participants' responses. Specifically, the competence dimension of SDT corresponds to self-efficacy expectations in SCCT and EVT. The relatedness dimension of SDT corresponds to attainment value in EVT. EVT provides a finer-grained characterization of the outcome expectations, such that EVT is nested within SCCT.

The influence of autonomy as a dimension of SDT remains ambiguous because our results indicate that postgraduates' autonomy in mentoring undergraduate researchers is likely to have two facets: 1) freedom to initiate the mentoring relationship and 2) latitude during the experience of mentoring per se. Some postgraduates in our study felt obligated to initiate a mentoring relationship with an undergraduate researcher. However, no postgraduates in our study indicated that they were obliged to mentor in any particular way; thus, they had autonomy in how they went about mentoring. Some postgraduates in our study even expressed an interest in having *less* autonomy and more guidance on how to mentor effectively. Deci and Ryan (2000) described these two elements of intrinsic motivation as 1) perceived locus of causality, meaning whether a behavior is done out of free choice or because it is a requirement, and 2) autonomous regulation, meaning whether a behavior is characterized by goals that reflect personal interests and values. Future research should aim to empirically distinguish locus of causality and autonomy in postgraduates' decisions to mentor undergraduate researchers with the longer-term aim of determining whether and how each influences postgraduate or undergraduate outcomes. Future research comparing postgraduate and faculty mentors could also examine whether career stage moderates any relationships among autonomy, locus of causality, and mentoring motivations and outcomes.

Future research should also test the other relationships hypothesized in Figure 1. Specifically, studies should examine the extent to which postgraduates ascribe various forms of personal value (utility, intrinsic, attainment) to the experience of mentoring undergraduates and how these values relate to postgraduates' intentions to mentor and engagement in mentoring. This research should also examine how postgraduates weigh their personal values against anticipated costs of mentoring. If the relationships we hypothesize are observed in a larger and more broadly representative sample of postgraduates, further research should examine how external motivations such as feeling pressure or being assigned to mentor moderate any observed relationships. For instance, postgraduates who are motivated by expectations of positive outcomes and have sufficient mentoring self-efficacy are expected to have high intentions to mentor and to engage substantively in mentoring. In contrast, postgraduates who are not confident in their mentoring skills or who expect mentoring undergraduates to be too costly are likely to have low mentoring intentions and low engagement in mentoring. If the faculty supervisor or the graduate program sets expectations that everyone mentors undergraduates or, alternatively, prevents interested postgraduates from engaging in mentoring, then postgraduates' mentoring self-efficacy and outcomes expectations would be unrelated to their mentoring intentions and engagement.

The constructs and relationships depicted in Figure 1 may also be useful for faculty mentors and mentoring program directors to consider as they make decisions regarding when and how to involve postgraduates in mentoring. For instance, if postgraduates have concerns about their mentoring abilities (self-efficacy), they can be encouraged to participate in mentoring professional development, which has been shown to improve mentors' assessments of their own mentoring competence (Pfund *et al.*, 2014). Postgraduates could also be encouraged to reflect on the various ways that the experience of mentoring can offer them both personal (agentic) and communal value, which may motivate them to view mentoring as a career development opportunity rather than an obligation. Faculty mentors and mentoring program directors might consider matching postgraduate mentors with undergraduate researchers whose motivations and desired outcomes are aligned, although additional research is needed to determine whether such matching would improve outcomes for both postgraduate mentors and their undergraduate protégés. Finally, postgraduates should be given some level of choice in mentoring undergraduate researchers,

either the large-grained decision of whether to do so or the fine-grained decision about how to do so.

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