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Toward a Holistic View of Undergraduate Research Experiences: An Exploratory Study of Impact on Graduate/Postdoctoral Mentors

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Abstract Involvement in research has become a fixture in undergraduate science education across the United States. Graduate and postdoctoral students are often called upon to mentor undergraduates at research universities, yet mentoring relationships in undergraduate—graduate/postdoctoral student dyads and undergraduate—graduate/postdoctoral student—faculty triads have been largely unexamined. Here, we present findings of an exploratory case study framed by relational theory that identifies the motives, gains, and challenges reported by graduate/postdoctoral students who mentored undergraduates in research. Graduate/postdoctoral mentors experienced a wide range of gains, including improved qualifications and career preparation, cognitive and socioemotional growth, improved teaching and communication skills, and greater enjoyment of their own apprenticeship experience. Notably, graduate/postdoctoral mentors reported twice as many gains as challenges, neither of which were limited by their motives for mentoring. Indeed, their motives were fairly narrow and immediate, focusing on how mentoring would serve as a means to an end, while the gains and challenges they reported indicated a longer-term vision of how mentoring influenced their personal, cognitive, and professional growth. We propose that understanding the impact of mentoring undergraduates on the education and training of graduate/postdoctoral students may uncover new ideas about the benefits reaped through undergraduate research experiences.

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Introduction

Involvement in research has become a fixture in undergraduate science education across the United States (Gonzalez 2001; Merkel 2003). The value of such experiences is noted in the Boyer Commission's call (1998) for the promotion of undergraduate learning "based on discovery guided by mentoring rather than on the transmission of information." A growing body of research documents the positive outcomes of research experiences for undergraduates (Bauer and Bennett 2003; Hathaway et al. 2002; Hunter et al. 2007; Kardash 2000; Kremer and Bringle 1990; Lopatto 2004; Rauckhorst et al. 2001; Russell et al. 2007; Seymour et al. 2004). Undergraduates have reported personal gains such as increased confidence in their ability to do science, professional gains such as establishing working relationships with peers and mentors, intellectual gains such as learning to "think and work like a scientist," improved skills in performing techniques or communicating scientific findings, and increased career clarification and preparation (Hunter et al. 2007; Seymour et al. 2004). These gains have been corroborated by faculty mentors, who have noted that involvement in research helps undergraduates "become scientists" through their cognitive and personal growth and development of their professional identity (Hunter et al. 2007).

The vast majority of these studies have characterized undergraduate research experiences (UREs) at predominantly undergraduate institutions. Individuals at research universities have noted the impracticality of one-on-one

mentoring of undergraduates by faculty because of insufficient numbers of faculty and competing demands for their time (e.g., Desai et al. 2008; Wood 2003). Thus, graduate and postdoctoral students are often called upon to mentor undergraduates (Dooley et al. 2004; Gonzalez 2001; Wood 2003). Yet, mentoring relationships in undergraduate—graduate/postdoctoral student dyads and undergraduate—graduate/postdoctoral student—faculty triads have been largely unexamined. The small body of literature draws attention to the logistical challenges of engaging undergraduates in research at large universities (Wood 2003) and consists of URE program descriptions and advice from experienced mentors and program developers (Dooley et al. 2004; Whiteside et al. 2007). These descriptions provide valuable information from experienced practitioners, especially in helping to improve program delivery, but generally the claims made are not supported by evidence gathered using methodologically sound research and evaluation approaches. Here, we present findings of an exploratory case study that begins to provide such evidence by investigating in-depth the experience of graduate/postdoctoral students who mentor undergraduates in research.

Given the widespread involvement of graduate/postdoctoral students in mentoring and the fact that these individuals are themselves students and protégés, we propose that mentorship research and theory-building should include examination of the undergraduate—graduate/postdoctoral student dyad as well as the triadic relationship that includes their faculty mentor. The stage of a mentor's career development is likely to influence critical mentoring relationship parameters (O'Neil and Wrightsman 2001). For example, peer relationships have been shown to prompt enhanced self-disclosure and trust and offer a greater sense of mutuality (i.e., both individuals take turns as the giver and receiver of particular functions; Kram and Isabella 1985). In addition, smaller differences in age and hierarchical levels have been correlated with relationships that move beyond complementarity, where both mentor and protégé contribute to and benefit from their relationship, to mutuality. Graduate/postdoctoral mentors may also have more immediate personal experience they can share with their undergraduate protégés. Although the influence of protégé developmental stage on mentoring relationships has been studied (Rose 2005), the influence of mentor developmental stage or "organizational distance" (i.e., difference in professional status or position) is largely unexplored, especially in academic settings (D'Abate et al. 2003).

Undergraduates may reap unique benefits when mentored by graduate/postdoctoral students. Johnson (2006) proposes that offering a safe environment for self-exploration is an important aspect of the construct of the mentoring. When measured against faculty, graduate/postdoctoral students may offer comparatively safer environments for undergraduates to grow as researchers in their skills and identities. Mentorship by graduate/postdoctoral students may offer higher relational quality as they may be better positioned to empathize with undergraduate students, engage with them more frequently, and offer them a more authentic perspective, having been undergraduates recently themselves (Liang et al. 2002). In addition to the instrumental and psychosocial functions of mentoring (Kram 1985), Tenenbaum et al. (2001) identified a "networking" function (i.e., the making of professional connections) that could be enhanced through the involvement of additional mentors, as in the undergraduate—graduate/postdoctoral student—faculty triad.

Graduate/postdoctoral students may also reap unique career development benefits from mentoring undergraduates in research (Kram 1985; Levinson 1978). Opportunities to mentor may enhance recruitment and retention of a more diverse pool of graduate-level scientists by offering opportunities for interpersonal and socioemotional gains (Good et al. 2000). Mentoring may also enhance graduate/postdoctoral students' self-awareness and meta-cognitive abilities (Ploetzner et al. 1999). Dooley et al. (2004) report benefits specific to the undergraduate—graduate student relationship, including enjoyment that comes through collaboration and enhanced research productivity for both students. The graduate student in this study attributed other gains to her mentoring of the undergraduate, including learning to be a better mentor, communicator, and researcher.

Just as undergraduate—graduate/postdoctoral student dyads and undergraduate—graduate/postdoctoral student—faculty triads may offer unique benefits to both mentors and protégés, they may present unique challenges. For example, negative experiences reported by protégés in corporate settings include lack of mentor expertise (Eby et al. 2004), which may be exacerbated in a relationship with a mentor who is early in their career development. Peer mentors report negative outcomes such as a lack of clarity regarding the degree to which they should be leaders versus equals to their protégés (French and Russell 2002; Haith-Cooper 2003; Solomon and Crowe 2001). Other negative outcomes of mentoring relationships include competition and jealousy (Eby and McManus 2004), which may occur more frequently between undergraduates and graduate students who may feel as though they are competing for the time, attention, and interest of their faculty mentor. Most importantly, negative experiences have been shown to have greater explanatory power than positive experiences in predicting protégé outcomes (Eby et al. 2004), possibly presenting a greater risk if graduate/postdoctoral students are not well-prepared or motivated to serve as mentors.

Theoretical Framework

A relational perspective on mentoring theory frames this study because it explores the outcomes realized for the mentor, in this case graduate/postdoctoral students, assuming that they engage in relationships that are reciprocal and mutual in nature as they mentor undergraduates in research (Fletcher and Ragins 2007). Traditionally, mentoring has been defined as a relationship between an older, more experienced mentor and a younger, less experienced protégé for the purpose of developing the protégé's career (Kram 1985; Levinson 1978; Ragins and Kram 2007). Much of the research on mentoring has focused on mentoring functions provided by the mentor to the protégé (Noe et al. 2002; Wanberg et al. 2003), neglecting the functions provided by the protégé to the mentor as well as socioemotional and interpersonal outcomes for mentor and protégé alike. Viewed from a relational perspective, mentor and protégé are engaged in an "interdependent and generative developmental relationship that promotes mutual growth, learning and development within the career context" (Ragins and Verbos 2006, p. 96).

The context of a research university offers a unique setting for viewing mentoring from a relational perspective. Specifically, this context involves a constellation of developmental relationships, most notably, the triad of undergraduate—graduate/postdoctoral student—faculty. Positive relationships are nested within and influenced by a network of other relationships, and the needs of members within one relationship are affected by the resources obtained from the other relationships (Higgins and Kram 2001; Higgins and Thomas 2001; Kram 1996; van Emmerik 2004). A natural extension of this idea is that the needs of graduate/postdoctoral mentors and their undergraduate protégés are affected by the resources offered by their faculty mentor.

The constellation of relationships within a research group at a university can further be considered a "mini-organization" with its own environmental factors (Allen et al. 1997; Kram 1985). The research group chosen for study was selected because it presented opportunities for mentoring, including frequent and numerous queries from undergraduates wanting to gain research experience in the group and the fact that the group's faculty head enabled the regular involvement of undergraduates in research by garnering funding to support UREs and setting an overall tone that undergraduates should be involved in the research endeavor. This tone setting by the faculty head served as a de facto reward structure because it was a "cue from management" that encouraged research group members to serve as mentors to undergraduates (Kram 1983; Young and Perrewé 2000). The combination of opportunities to mentor and an implicit reward structure helped create a "mini-organizational" climate within the research group that appeared to influence graduate/postdoctoral students' willingness to mentor.

Here, we present findings of an exploratory case study that begins to examine the impacts of mentoring undergraduates in research on graduate/postdoctoral mentors by addressing the following research questions: (1) What motivates graduate/postdoctoral students to mentor an undergraduate in research? (2) What do graduate/postdoctoral students report that they gain by mentoring an undergraduate in research? and (3) What challenges do graduate/postdoctoral students report that they face as mentors of undergraduates in research? By choosing to focus on graduate/postdoctoral student mentor experiences, we hope to begin to address the gap in the literature regarding mentor outcomes in academia, especially at research universities, and encourage a more holistic approach to the analysis of undergraduate research experiences.

Methodology

Participants

This exploratory study examines how seven graduate students and one postdoctoral student from a molecular life science research group at a large public research university in the Mid-Atlantic region in the United States viewed their experiences as mentors of undergraduates conducting research. This research group was chosen for study because: (1) it has a long history of involving undergraduates in research (over 35 students in 10 years), (2) graduate/postdoctoral students have mentored most of the undergraduates, and (3) the faculty head had an interest in understanding how her group benefits (or not) from UREs.

We defined a mentoring relationship between a graduate/postdoctoral student mentor and an undergraduate protégé as one where there was an explicit intention to form a relationship on the part of the mentor, protégé, and faculty head of the group and that the relationship was sustained over time (i.e., at least one semester and up to several years; Aagaard and Hauer 2003). In contrast, graduate/postdoctoral students who interacted with undergraduates during daily activities but did not play a direct, active, or intentional role in mentoring were not considered "mentors." Our intention was not to devalue these interactions, but rather to distinguish mentoring from more fleeting, serendipitous, or informal interpersonal interactions (e.g., providing limited or generic instruction, offering isolated advice, unintentional role modeling) that students may have as part of a research group.

Eleven past and present graduate and postdoctoral students who had mentored at least one undergraduate were invited to respond. Eight individuals (one postdoctoral and seven graduate students, six males and two females, five Caucasians and three minorities) responded and all agreed to participate in the study. One of the respondents had mentored just one undergraduate, but the others had mentored two to five undergraduates during their time in this research group. No formal mechanism was in place to pair undergraduates and graduate/postdoctoral students, but a number factors appeared to influence pairing, including interest that undergraduates expressed in particular projects and time that graduate/postdoctoral students had available to mentor, as well as the appropriateness of particular projects for involving undergraduates. In some cases, the graduate/postdoctoral student recruited an undergraduate to work with them, typically following interactions during a laboratory course for which the graduate/postdoctoral student was a teaching assistant. Of the eight respondents, one was still a member of the research group, four held faculty positions at research universities or predominantly undergraduate institutions, and three held positions at non-academic organizations (e.g., companies, private research institutes).

Data Collection

We chose to collect data using interviews to gain insight into the experiences of graduate/postdoctoral mentors. In addition, the timeframe of the mentors' experiences relative to the research group's history varied significantly, making real-time observation or documentation of mentoring unfeasible. Mentors were interviewed after completing their mentorship experience in person or by phone using a semi-structured protocol (interview questions are included in the Appendix) to explore as best as possible all of the avenues of each mentor's experience. We actively sought reports of both positive and negative outcomes so that data collection would not be lopsided in favor of either.

Interview questions were designed to explore the URE characteristics and structure as well as mentors' (1) motives, expectations, and interests in mentoring UREs and (2) their perceptions of the gains they made and the challenges they faced while mentoring. The semi-structured style of the interviews meant that these topics were approached at different times, yet all were addressed in each interview. Respondents were invited at the end of the interview to add any comments that they felt would help the researcher develop a more complete picture of their experience. Interviews typically lasted 60 min, and were audio-taped and transcribed for analysis.

Data Analysis

A constant comparative method of data analysis (Merriam 1998) was used to construct categories representative of recurring patterns in the mentors' responses. As such, the categories identified represent an initial interpretation of the data. Data from each interview were broken down into units (i.e., specific quotes) that revealed information about the mentors' experiences. Data units identified from analysis of the first transcript provided a tentative list of categories. As each transcript was analyzed, category construction continued through emergence of new categories or the reinforcement of existing categories. To establish internal validity and ensure correspondence of data units with the categories, three researchers (i.e., the authors and a graduate student in molecular life science who was otherwise uninvolved in the research) coded the transcripts. Each transcript was read and coded by each individual separately. Following each reading, a consensus-reaching discussion took place during which previously identified data units were (1) confirmed to fit a category (all three researchers coded it as such) or (2) were tagged as having a 'poor fit' (not considered further in the work we propose to present here). To ensure that no one researcher dominated the consensus building, each researcher was allotted time to 'make their case' if they disagreed with a category fit. During this process, new data units were identified and a few categories were merged, refined, or eliminated. With each category change, all of the transcripts were re-read by the three researchers and consensus was reached as described above.

Results

Here we present the motives, gains, and challenges reported by graduate/postdoctoral students who mentored undergraduates in research. Throughout the discussion, we group mentors' responses into themes that reflect their nature, for example, whether reported gains were cognitive, socioemotional, or instrumental (i.e., served as a means of accomplishing an end). We consider whether and how the motives mentors report influenced the gains they realized or challenges they faced, as well as how the developmental stage of the mentor may have shaped their views of mentoring.

Motives

Because we thought graduate/postdoctoral students' motives for mentoring might influence either the gains they made or the challenges they faced, or their reporting of positive and negative outcomes, we started by exploring

why they chose to mentor undergraduates in research. Mentors reported motives that were mostly instrumental or socioemotional in nature (Table 1), and all mentors reported two or more motives for mentoring, indicating the diverse nature of mentoring relationships even within the context of a single research group.

Graduate/postdoctoral students in this study primarily saw mentoring undergraduates in research as a means to two ends: improving their research productivity and meeting the implicit or explicit expectations of the research group. All but one mentor reported either that the faculty head had directly requested that they serve as a mentor (i.e., explicit expectation) or that their impression was that mentoring was a responsibility of being a member of the research group or the scientific community in general (i.e., implicit expectation). The fact that mentoring was either an implied or stated expectation was positive for most of the mentors. For example, several mentors reported that they expected the process of mentoring to reflect their further development as scientists and help them build skills that they would need in this new identity. Thus, they viewed the expectation that they would mentor undergraduates in research as both appropriate and beneficial. Their views of mentoring as an instrumental activity were intertwined, however, with their perceptions that agreeing to mentor would help them maintain good relations with the faculty head or that not agreeing to mentor would displease her:

> She [the faculty head] made it clear that it was important to do for various reasons… And it was as critical in her view as coursework or maybe not quite as critical to getting the research done, but very important. So it would have—if I refused to do it for whatever reason or if one would refuse to do those things, I think that initially could hinder the relationship with Carol*. Mentor 4 [*Names are pseudonyms.]

Less than half of the mentors reported that they were motivated by the prospect of enjoying their interactions with their protégés or of sharing their expertise, suggesting that they more often approached mentoring as a professional relationship that would either help them get more research done, maintain good relations with the faculty head, or help prepare them or their protégés to become scientists.

Gains

Mentors reported a range of instrumental, cognitive, interpersonal, socioemotional, and professional gains that outnumbered the challenges they reported two-to-one (Table 2). Mentors reported 14 distinct types of gains, indicating a greater diversity of mentoring functions than would be predicted by the motives they reported.

Instrumental Gains

The motives mentors reported reflected fairly narrow and immediate perspectives on how mentoring would be useful

Table 1 Motives reported by graduate/postdoctoral students for mentoring undergraduates in research

Motives		Mentors 1	2	3	4	5	6	7	8	Example Quotes
Instrumental	Expectation of improved productivity	●	●	●	●	◉	●	◉		I expected some return on productivity. I wanted to get something back for what I was putting into it… Frankly, I expected to – you know, four hands are better than two. [M1*]
	Implicit expectations	●	●		●		●	●		I guess it's assumed. It's not written in the job description. It's just something you do… I figure it's part of working your way through university. I mean you have got to train to work, mentoring the newer students, the incoming students. [M7]
	Explicit expectations	●		●	◉					She [Carol**] suggested it because I didn't know to what extent I had freedom to hire. So Carol just told me oh there's this person from your class who's interested in doing a research here. Would you like to talk, would you like to tell me more about her [the undergraduate]. One thing led to another and then finally she was in the lab. [M3]
Socio-emotional	Desire to share expertise			●		●	◉			I want to make sure they're learning the right way of doing it. Because some of the techniques they learn under me, they might end up doing the same thing for the rest of their life or for major research… [M5]
	Personal enjoyment	●		●	●					I liked working with the students. I mean even though I wasn't working directly with the other students, I was always kind of helping out. [M1]

● ◉

* Data from a single mentor are noted within each numbered column and illustrative quotes are provided in the rightmost column where [M1] is Mentor 1, [M2] is Mentor 2, and so on. A small circle indicates that one or two quotes within the category were identified within a mentor's interview. The large circle indicates that three or more supporting quotes were identified. Within each table, categories and themes are listed in order of most frequent reports. This organization is designed to maximize readability rather than to place value on any particular category or theme.

** Pseudonym

Table 2 Gains reported by graduate/postdoctoral students mentoring undergraduates in research

Gains		Mentors 1	2	3	4	5	6	7	8	Example Quotes
Instrumental	Improved qualifications	●	●		●	●		●	●	It's your ability to manage or mentor. It's like any other job. You should be able to manage your own task. And when you teach someone or you can mentor someone, it shows that you are capable of that much amount of knowledge and experience of mentoring someone. So it's got to be on your CV. [M5]
	Improved research productivity / quality		●	●	●		●	●		They [the undergraduates] contribute in small but important ways to the actual project I was working on. Having another set of hands to do things in the lab enabled me to do some other things… Most of the time when you're working in a lab, you're sort of multi tasking and doing lots and lots of different things at once. Having another set of hands there really helped. [M2]
	More interaction with faculty mentor	●						●		It gave us something else to talk about. If I was bothered with something or the way something was going, I would definitely model after her or go talk to her about it and she would make time to talk to me if I was having interpersonal problems with someone or didn't know how to explain something the right way. [M1]
Socio-emotional	More enjoyable work life			●	●	●	●	●		It just feels good. I like to interact with people. And it's just fun to interact with students you know. And maybe get a different perspective on things. [M7]
	Enhanced confidence			●	●	●	●			Because I had other people doing the job, I had hands, other hands doing replicates of an experiment, I had more confidence in telling Carol results… It's being shown by another person. In a way it was giving me confidence about my results and speaking to Carol about it. [M3]
	Personal satisfaction				●		●	●		I felt the feeling of, oh cool, this person has become autonomous. She [the undergraduate] can do it you know. She can do her own experiments. She can be left alone to do clone this or do this. And she could do it. [M6]
	Enhanced self-awareness					●	●			So as a person, I also came to know more about my communication skills. How I communicate better, in what size of group and all that. [M5]
Interpersonal	Improved mentoring skills	●		●		●		●		I would say that the managerial skills that I learned because of that mentoring program was very beneficial. Even now, I'm doing it. The way I'm delegating jobs to my crew here in the [farming business], it's there. But it's a different field. [M3]
	Improved teaching skills		●		●			●		How did it help my actual teaching? Like I said before about communicating effectively to a broad number of people and not taking it for granted that people are going to understand your way of communication. [M4]
	Improved communication skills			●	●					I think it helps in my communication skills of science, which I think can be difficult because for me all the times when I understand something, I have a hard time. I just I get it. Trying to get someone else to get it is difficult. I think that's where it really helps me out is in actually communicating ideas and techniques and why we do things that way. [M7]
Professional	Improved understanding of faculty head's job				●	●	●			I could look at things from Carol's eyes, how she had to manage all of us at that time. How she had to manage all her students, you know, with all our little wishes and our incompetencies. Because many times even with undergraduate students, things didn't go the right way because they forgot to do something or they dumped the reaction down the sink or whatever. I could understand from my education point of view the responsibility you carry with your dependence on your graduate students or your undergraduate students for delivering. [M6]
	Career clarification					●				It was helpful to decide my career path, what I want to do in general. [M5]
Cognitive	Intellectual growth	●			●	●	●			From a research perspective, I'll say that like when you teach someone and like some of the very good undergrad students, they ask us lots of questions and sometimes they force us to think why we're doing this. So from a research point of view, I must admit that most of them, they were helping me to understand the concept. [M5]

to them. When considering the gains they actually experienced, mentors reported instrumental outcomes that aligned with their motives (e.g., improved productivity) and took a longer-term view of the benefits (e.g., being able to note the experience in a job application or in their curricula vitae).

Although seven of the eight mentors reported that they anticipated improving their research productivity, only five of these individuals reported that they experienced gains in the amount, quality or diversity of the research they were able to accomplish:

> After a minimal investment, usually of time training, it really opened up my research to tackle slightly more risky or you know more interesting areas of research of various projects that I was working on… And having an undergraduate researcher that is competent, that I can trust to do those things, opened up time for me to really explore other things, which was the whole point, in my view, of graduate school. Mentor 4

One mentor noted that, even though she was not able to get more research done, she was more confident about the research that was conducted because "it's being shown by another person."

Two mentors saw the experience as presenting more opportunities to learn from the faculty head. The faculty head's approachability was rarely an issue, and the graduate/postdoctoral mentors did not seem concerned about improving their comfort with talking to her or their confidence in doing so. Thus, the URE did not appear to change the nature of the graduate/postdoctoral mentors' interactions with the faculty head. Rather, it served as impetus for them to interact more frequently and discuss a broader range of topics.

Socioemotional Gains

All but one mentor reported some type of socioemotional gain as a result of mentoring, including enjoyment and personal satisfaction as well as enhanced confidence, self-awareness, and empathy. Although less than half of the mentors reported that they became mentors because they expected to enjoy it, six of eight mentors noted that the process of mentoring made for a more enjoyable work life. Four of the mentors found personal satisfaction in process of mentoring and took pride in shaping their protégé's educational and career choices and in seeing their protégé succeed:

> Maybe hopefully have them go on and change their career path. Maybe they weren't sure of what they were doing and now they're going to—just from interacting with you and from the project, they got excited about it and then they want to do science. That's great. That's the biggest impact one could have as a scientist is to train other people 'cause it's exponential. The people you train will absolutely have a better chance at making serious scientific discoveries than I would just doing it, doing the work all by myself. Mentor 4

Half of the mentors reported gains in confidence that resulted either from their selection as mentors or the process of interacting with their protégés. For example, two mentors reported increased confidence as a result of feeling admired and respected by their protégés. Two others reported that they interpreted the faculty head's choice to make them mentors as an affirmation of their scientific credibility, skills, and abilities:

> It was a booster, a positive one—basically, I feel that ok, [Carol] believes or she has that trust in me that ok, I have that much knowledge and I can pass it to someone. I can teach. I have those kind of skills which I can pass it to someone else. So basically I really felt really good, like she has that much amount of trust and confidence in me that ok, she can give me a student and she can say ok, just go ahead and teach them protein purification and expression. Mentor 5

Interpersonal Gains

All but one mentor reported interpersonal gains that related to development of their teaching, mentoring, and/or communication skills. Mentors who made clear distinctions between these three types of skills noted how each presented unique challenges. For example, one mentor noted that by mentoring he learned to better gauge his audience when he was teaching so that he could recognize and respond to "a blank face."

One mentor distinguished his gains in mentoring skills from development of teaching skills by emphasizing the larger role that interpersonal factors play in the relationship. Two mentors focused more narrowly on how these skills would be relevant if they became faculty in the future, while others considered their improved mentoring skills more broadly, for example, how these skills would be relevant for any career path that involved teaching or management. The value each mentor placed on these skills varied, but most implied that their scientific training was enhanced by having the opportunity to develop their communication skills.

Professional Gains

Two mentors reported gains in their understanding of the diverse roles and responsibilities of being a scientist, especially in academia. One mentor went so far as to consider the experience of mentoring an undergraduate as a "low intensity" faculty experience that helped confirm interest, or lack thereof, in an academic career. Two

mentors discussed that they had grown in their self-awareness, developing a better understanding of their own skills, interests, and shortcomings as they related to possible career choices. One mentor noted that developing a better sense of her abilities helped her consider which career paths would be most appropriate. Another mentor explained that she could better empathize with the faculty head as a result of mentoring. She noted parallels between her activities as a mentor and the responsibilities of the faculty head as well as how mentoring an undergraduate provided a view of the challenges faced by faculty.

Undergraduates also report that research experiences help them clarify their career interests, primarily whether they want to pursue jobs or further education in research science (Hunter et al. 2007; Lopatto 2007; Seymour et al. 2004). Unlike most faculty mentors, graduate/postdoctoral students are still making decisions about further education and career paths, for example, whether to pursue an academic position or transition to industry. Thus, graduate/postdoctoral mentors may be better positioned to serve as a role model and advisor for an undergraduate protégé who is making similar decisions. In addition, the process of mentoring may allow graduate/postdoctoral students to "try on" the idea of being faculty in a scaled-down, lower-risk way and start developing the range of professional skills required by academic scientists.

Cognitive Gains

Although mentors did not appear to be motivated by an expectation that they would make intellectual gains themselves, seven of eight mentors noted how guiding an undergraduate in research deepened their understanding of their own work, including thinking through their experiments more carefully, recalling "forgotten" knowledge, reassessing completeness of their understanding, deepening understanding of their own research, and acquiring different perspectives and thinking differently. These cognitive gains echo those reported by undergraduates who are mentored in research (Hunter et al. 2007; Lopatto 2007; Seymour et al. 2004) and resemble cognitive benefits reported by peer mentors and graduate teaching assistants (Barker and Pitts 1997; French and Russell 2002; Good et al. 2000; Micari et al. 2006).

Challenges

As a group, the mentors reported half as many challenges as gains (Table 3). Some challenges arose when mentors' expectations of their protégés or the mentoring experience in general were not met. Other challenges reflected the mentors' beliefs that they had deficits in their mentoring skills that lessened over time as their skills developed. Instrumental and socioemotional challenges varied with time, becoming more significant in cases where mentors believed their protégés should be making more rapid progress and lessening in cases where mentoring took less time and energy as protégés grew in their skills and knowledge and thus were able to work more independently.

Interpersonal Challenges

Most mentors noted their struggle to gauge undergraduates' prior knowledge and to explain concepts and techniques in a way that would ensure the undergraduates' understanding as well as the quality of their work. Several mentors viewed this challenge as an opportunity to fine-tune their communication skills.

Socioemotional Challenges

Socioemotional challenges reported by the mentors were indicative of relationships that were ineffective or marginally effective rather than dysfunctional (Eby and McManus 2002). A few mentors were frustrated by their protégés' lack of ability, including their struggles to follow directions or work more independently after an initial period of training. Three mentors expanded on this concern, explaining that their own research was at risk because of their protégés' missteps. In these relationships, the mentors struggled to trust their protégés to be responsible and to be confident about their protégés' abilities to complete tasks accurately:

> For me [the most challenging part was] achieving the realization that the undergraduate researchers were at a point where they can be somewhat independent and didn't need my micromanaging. Establishing when I could just trust them to do things that I trained them to do. Mentor 4

During the trust-building phase, the benefits that could be realized by both the mentor and protégé were limited. For example, protégés who could not yet be trusted were micromanaged and thus perhaps less able to develop the ability to work independently.

Instrumental Costs

Most mentors expressed concerns about balancing their research and their role as mentor, including reconciling expectations about time commitment. One mentor suggested that the fragmented nature of undergraduates' schedules during the academic year exacerbated the issue. Typically, the first few weeks of the URE were considered the most time-consuming and resulted in reduced research productivity for some mentors. Once undergraduates were

Table 3 Challenges reported by graduate/postdoctoral students mentoring undergraduates in research

Challenges		Mentors 1	2	3	4	5	6	7	8	Example Quotes
Interpersonal	Balancing protégé's and own needs	●	●		●	●		●	●	You have to be able to put your own ego aside at times and grow within yourself in order to help other people grow too. Being positive and balancing my own studies and my own work with participating in someone else's learning about how to do this stuff themselves is challenging. [M8]
	Gauging protégé's knowledge and abilities	●		●	●	●		●		It did feel like I was repeating the same explanations everyday… It seemed like it wasn't working, at least in the beginning. But eventually what I did was I changed it and instead of treating him like a grad student, I decided ok, it would be like a recipe for what's to be done. Every day, it will be on this desk. There will be things to do and things that I needed for him to accomplish the job and that worked. [M3]
Socio-emotional	Emotional costs	●				●	●	●		There are times, especially in the early stages, you kind of wished that they would – you reach that point where it's like ok, I've told you once, just go off and do it. And I can't . . . every 5 minutes, I don't need you standing here and going, "What?" [M7]
	Establishing trust				●	●	●			Challenges would be the dependability of these people because they don't realize that they are perhaps – especially to make them part of your research. That you're depending on them to water the plants on these x days and if they don't, there's no way for you to know that you didn't and that the gene expression may be different. [M6]
Instrumental	Reduced research productivity	●		●			●			Of course the problem is that you don't want somebody to mess up your buffers. That's sort of a difficult task to depend on somebody because the experiments can all go wrong completely. [M6]
External	Ambiguous mentorship structure	●						●		She was recruited with the idea that she was gonna be helping both of us, but me and (other graduate mentor) tended to do things differently… There's two ways to pour a gel and both are perfectly fine but I wanted it done my way and (other graduate mentor) wanted it done her way. And then we would both be kind of driving (the undergraduate student) crazy because – it ended up being a problem with how we were getting our work done. [M1]
	Lack of recognition	●								It would have been nice to do something so that that shows on your CV... If you do mentor, it doesn't necessarily show up that you've done that later unless it's in your recommendations letters, unless you choose to put that in I guess. But there's not a convenient way to put that in without sounding pompous. [M1]

"trained," this challenge lessened and some mentors even reported an increase in productivity. In some cases, however, the mentors were unable to improve their research productivity because the anticipated "extra pair of hands" not only failed to make independent progress, but undermined the mentor's progress. One graduate/postdoctoral student avoided mentoring until he felt that he "was in a place to lose time" because he anticipated that his ability to remain productive in his research would be compromised. This view could be observed from a more holistic consideration of the mentors' thoughts on research productivity, specifically, that productivity was increased when they worked with certain protégés and decreased with others. This mentor resigned himself to the fact that it would not be beneficial research-wise to mentor an undergraduate, yet he chose to do so, implying that other gains he could realize would outweigh this challenge.

External Challenges

Two mentors reported challenges with aspects of their mentoring experiences that were beyond their control. For example, although most mentors reported one-on-one mentorship structures in which they were the primary mentors for their undergraduate students, there were instances of co-mentoring (e.g., mentorship by more than one graduate/postdoctoral mentor). One mentor expressed frustration with mentoring an undergraduate student who was also being directly mentored by the faculty head on a regular basis. The mentor would find that when he asked the student to "do it one way" the faculty head would "meet with the student later and turn around and do it to a totally different way." This challenge may be reflective of this particular research group. The pervasive expectation that individuals within the group would mentor undergraduates as well as the group's generally positive attitude towards mentoring may have created an environment where goals and responsibilities of a particular mentor and the undergraduate—graduate/postdoctoral dyad were never explicated. In addition, there was a general tone of admiration for the faculty head, which prompted one mentor to question her own mentoring choices when they contradicted those of the faculty:

> She's [Carol] has been doing it a lot longer. I'll do it one way and then she'll meet with the student later and turn around and do it to a totally different way. And

> then I'm kind of like oh… *[laughs]* I always try to think what did I want, how do the students handle it, how are they going to go about it. Because I don't want to be at odds or do it the wrong way I guess. Mentor 7

Other studies have revealed unclear or incompatible expectations as a source of interpersonal difficulties in mentoring relationships (Young and Perrewé 2000). Involving more individuals in a mentoring relationship, as in the undergraduate—graduate/postdoctoral student—faculty triad, may present greater risk of conflicting or ambiguous expectations.

For one mentor, the lack of a clear reward or recognition for his mentoring efforts made it personally challenging for him to appropriately "market" the mentoring skills he gained when searching for jobs. Yet, he also expressed concern that a reward system may result in graduate/postdoctoral students taking on mentoring roles "just to get a line on their CV."

Discussion and Implications

The number and diversity of gains reported by graduate/postdoctoral mentors in this study are indications of how mentorship experiences can provide critical opportunities for scientists-in-training to gain skills required for successful careers in the sciences. Furthermore, it appears that graduate/postdoctoral mentors view the gains they report as having value in other career paths. Several of the gains reported by mentors resembled those noted by undergraduate protégés in other studies, including improved understanding of science, improved communication skills, and enhanced confidence, as well as development of their identities as scientists (Hunter et al. 2007; Lopatto 2007; Seymour et al. 2004). Notably, some studies have shown that certain cognitive gains may be challenging for undergraduates to realize (Hunter et al. 2007; Kardash 2000; Rauckhorst et al. 2001) and that advanced epistemological development is more likely to occur in post-college years (Baxter Magolda 2001; 2004). Graduate/postdoctoral mentors may be better positioned than undergraduate protégés to shift from what Baxter Magolda calls "transitional/independent knowing" to "contextual knowing," a shift that may be facilitated by mentoring. Even though graduate/postdoctoral work is educational in nature, none of the mentors in this study appeared motivated by the opportunity to learn by mentoring undergraduates in research. Faculty mentors have the potential to emphasize the relational quality of the undergraduate—graduate/postdoctoral student dyad by guiding graduate/postdoctoral mentors in recognizing and reflecting on the gains they make while mentoring.

Communicating the benefits of mentoring to graduate/postdoctoral students, for example during orientation sessions and professional development courses, may lead to increased involvement in mentoring undergraduates and increased retention of these scientists-in-training. Industry mentors have reported greater job satisfaction, greater affective organizational commitment, and fewer intentions to turnover than those who did not serve as mentors (Lentz and Allen 2005). These factors have been correlated with more positive work attitudes in general. Similarly, mentoring undergraduates may increase graduate/postdoctoral students' personal satisfaction with their scientific apprenticeship and enhance their cognitive development and identities as scientists, in turn increasing their persistence in science research in general and academia in particular.

Mentors reported challenges that reflected shortcomings in their own skills as well as difficulties associated with marginally effective or ineffective mentoring relationships. With respect to skill development, gains appeared to be realized when mentors successfully grappled with challenges and viewed them as opportunities for their own or their protégés' growth. For example, two mentors noted that their research productivity both declined and improved as a result of mentoring an undergraduate in research. This finding highlights the developmental nature of mentor-protégé relationships (Chao 1997; Kram 1985). Perhaps the early stages of mentoring UREs are more time and energy consuming, hindering what mentors can accomplish in their own research. Then, as graduate/postdoctoral students' mentoring and communication skills develop and protégés' research skills improve, protégés are able to make substantive contributions that augment research productivity. Faculty mentors have the potential to enhance the quality of the undergraduate—graduate/postdoctoral student dyad by tailoring their own mentoring to the developmental stage of the dyad, framing challenges as learning opportunities, and rewarding graduate/postdoctoral mentors when they handle challenges successfully.

Mentors also reported frustrations associated with ambiguity of the mentorship structure. Further study is needed to determine whether this challenge is particular to this research group or a more general practice of neglecting to articulate expectations for mentors and protégés in UREs. Practical guides and training programs such as the Wisconsin Mentoring Seminar and its companion Entering Mentoring manual (Handelsman et al. 2005) make goal setting and communication about expectations an integral component of developing and maintaining a mentoring relationship in academic research. These resources can be tools in supporting a more intentional approach to establishing undergraduate-graduate/postdoctoral student mentoring relationships and in turn enhancing their capacity for success.

Even though mentors reported many more gains than challenges, negative experiences may have the potential for greater impact. For example, protégés who reported difficulty relating to their mentors because of mismatched personality or values also tended to report that they had less job satisfaction, higher stress levels, and stronger intentions to leave the organization (Eby and Allen 2002). Less clear is whether mentors' negative experiences have similar effects on their job satisfaction and career choices and how concurrent or successive relationships with several protégés might act in concert to mitigate or exacerbate these effects. For example, three graduate/postdoctoral students in this study reported that mentoring undergraduates made their work lives more enjoyable, but also generated emotional costs. Since all but one of the graduate/postdoctoral students mentored two or more protégés during their time in the research group, it is likely that each relationship yielded differing levels of enjoyment and frustration. Rather than being contradictory, these reports underscore the multi-faceted nature of mentor-protégé relationships, which can be satisfying and effective in some respects or at some points in time, and frustrating or dysfunctional in others (Kram 1985). An improved understanding of the ramifications of effective versus ineffective relationships between graduate/postdoctoral mentors and undergraduate protégés, as well as the developmental stages of these relationships, is needed and could provide useful guidelines for faculty seeking to develop more formal mentoring programs in their labs or departments.

Because our study was limited in size and scope, we did not explore the roles of ethnicity, race, and gender, which have been identified as factors that influence the success of mentoring relationships (Sosik and Godshalk 2005; Turban et al. 2002). Further research should focus on understanding how ethnic, racial, and gender alignment between mentors and protégés influences the success of mentoring relationships within the undergraduate—graduate/postdoctoral student—faculty triad. Although the duration of mentoring relationships appears to moderate the effects of differing mentor-protégé ethnicity, race, and gender, UREs range widely in duration, from 8 weeks to multiple years. Some relationships may not have the luxury of time for trust formation that enables productive mentoring (Sosik and Godshalk 2005). By opening the pool of potential mentors to include graduate/postdoctoral students, the diversity of available mentors is multiplied, which may in turn enhance the likelihood of establishing productive mentoring relationships.

Exploring the undergraduate—graduate/postdoctoral student dyad from a relational perspective offers a unique opportunity to gain insight into the constellation of relationships that influence undergraduate mentoring at research universities. Institutional support for faculty to involve graduate/postdoctoral students in mentoring undergraduates as well as direct support for, encouragement of, and rewards for graduate/postdoctoral mentors has the potential to significantly influence the outcomes of UREs for mentors and protégés alike. Support can come in the form of "carrots" for undergraduate protégés mentored by graduate/postdoctoral students, graduate/postdoctoral students who mentor undergraduates, or their faculty mentors who provide them guidance in doing so. Preparing and encouraging faculty to make intentional and informed decisions about when they involve graduate/postdoctoral students in mentoring may also help maximize the opportunity for mutual growth within the undergraduate—graduate/postdoctoral student—faculty triad.

These findings are exploratory in nature and intended to serve as the groundwork for a larger study to investigate how UREs impact the apprenticeship experience of graduate/postdoctoral students. Three interesting hypotheses have emerged from this work: (1) scientists-in-training can better understand the content and process of science through interactions with newer members of the scientific community, (2) through the process of mentoring, scientists-in-training can develop communication and teaching skills, and (3) through the process of mentoring, scientists-in-training derive personal satisfaction that enhances their enjoyment of their graduate/postdoctoral apprenticeship experience. Future studies can focus on determining the role that mentoring plays in integrating scientists-in-training into the professional practices of the scientific community, as well as the generalizability of these findings.

From an education policy point of view, this research can play a role in addressing the concern that "nowhere are the failures of graduate education more serious then in the skills of communication" (Boyer Commission on Educating Undergraduates in the Research University 1998). The Boyer Commission recognized that graduate students are directly involved in the education of many undergraduates at research universities. Thus, the teaching and learning of graduate/postdoctoral students should be part of the larger picture of "re-inventing undergraduate education." Understanding the extent to which UREs impact the education and training of graduate/postdoctoral mentors may uncover new ideas of how to maximize the educational benefits that can accrue from resources dedicated to promoting undergraduate research experiences (e.g., National Science Foundation 2008).

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Appendix

Interview Questions for Graduate/Postdoctoral Mentors

Characteristics of Undergraduate Research Experiences (UREs)

1. For how long were you a graduate/postdoctoral student in this research group?
2. At what point in your graduate/postdoctoral training in this group did you start mentoring undergraduates?
3. In the course of your time in the group, how many undergraduates did you mentor?
4. What kind of undergraduate research experience (URE) models were you involved with as a mentor (e.g., year-round research apprenticeship, summer only research apprenticeship, research as part of coursework, research as part of a career or retention program, etc.)?
5. Did you complete a URE when you were an undergraduate? How was it funded?
6. How were the undergraduates typically recruited into this group?
7. How did you contribute to the structure of the URE?

Mentorship Structure

1. Were you the primary mentor for your undergraduate during their research experience?

a. (If yes) How would you define your mentorship role during this experience? What was the faculty head's mentorship role for this URE?

b. (If no) Who was the primary mentor for your undergraduate?

2. How would you define your mentorship role for this URE?
3. Did you receive any formal or informal mentorship training prior to embarking on the URE?

a. (If yes) Please describe. In what ways did you find the mentorship training useful?

b. (If no) Why do you think you did not receive mentorship training? In what ways do you think mentorship training could be useful?

Motivation and Goals for Mentoring UREs

1. What is/was your motivation for mentoring an undergraduate researcher?
2. What did you expect your undergraduate to gain or accomplish after completion of a URE with you?

Impacts of Mentoring UREs

1. How did you, as a graduate or postdoctoral student, benefit from mentoring UREs? [Probe regarding research, education, career, and personal impacts.]
2. What were the negative aspects or difficulties of the URE for you as a mentor? [Probe regarding research, education, career, and personal impacts.]
3. How did the presence of undergraduate researchers in the group affect the overall group dynamic?

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