Studying the Role and Impact of Mentoring on Undergraduate Research Experiences[1]

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Abstract

Despite the wide-spread belief that mentoring plays a critical role in the retention and success of researchers across the career spectrum, the actual evidence to support the claim is weak. This article addresses the primary issues impeding progress towards a common understanding of mentoring, its impact on undergraduate research experiences (UREs), and what needs to be done to advance research and target interventions which will ultimately improve the undergraduate research experience and the subsequent outcomes. A framework for these issues and recommended next steps are presented.

Introduction

> *At its best, mentoring can be a life-altering relationship that inspires mutual growth, learning, and development. Its effects can be remarkable, profound and enduring; mentoring relationships have the capacity to transform individual groups, organizations and communities.* (Ragins and Kram, 2007b)

The impact of the mentoring relationships in which one engages during their career have been the subject of considerable research for the past thirty years. This body of research, gathered across a broad range of professional domains, indicates mentoring has a positive impact on career success, career satisfaction, and career commitment (see Cox, 1997). Within the realm of higher education, mentoring has been associated with academic and career success across disciplines and career stages. At the junior faculty level, strong mentorship has been linked to enhanced mentee productivity, self-efficacy, career satisfaction and sense of support (Bland et al., 2009; Cho et al., 2011; Feldman et al., 2010; Fleming et al., 2012a; Garman et al., 2001; Laursen et al., 2010; McGee and Keller, 2007; Palepu et al., 1998; Ragins and Kram, 2007; Ramanan et al., 2002; Sambunjak et al., 2006; Shea et al., 2011; Steiner et al., 2004). Graduate students being mentored are more likely to persist in their academics decisions (McGee and Keller, 2007; Williams et al., 2015) with positive mentoring being cited as the most important factor in degree attainment (Solorzano, 1993). Moreover, mentored graduate students and junior faculty are more likely to publish their research than counterparts who are not mentored (Steiner and Lanphear, 2002; 2007; Wingard et al., 2004)

For undergraduates, engagement in mentored research experiences has been linked to self-reported gains in research skills and productivity as well as retention in science (see (Linn et al.,

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2015) for most recent review). Different mentoring functions, such as socioemotional (e.g., psychological support) and instrumental (e.g., research task support) mentoring, have been positively associated with both students' identity as a scientist, their sense of belonging, and their confidence to function as scientists (research self-efficacy) (Chemers et al., 2011; Paglis et al., 2006; Thiry and Laursen, 2011; Dolan and Johnson, 2009; Lopatto, 2007)). These factors have also been associated with increased interest in and commitment to research careers (Hunter et al., 2007). Undergraduate research experiences (UREs) have been shown to effectively increase undergraduate student interest, motivation, and preparedness for research careers, with a positive mentoring relationship often cited as a key element in these outcomes (Eagan et al., 2013; Lopatto, 2007; Russell, 2008; Seymour et al., 2011). The frequency and quality of mentee-mentor interactions has been associated with students' persistence in science, technology, engineering, and mathematics (STEM) degrees (Nagda et al., 1998) with mentoring directly or indirectly impacting grades and persistence in college (Bordes-Edgar et al., 2011; Campbell and Campbell, 1997)

For students from underrepresented racial and ethnic groups, mentorship has been shown to enhance recruitment into graduate school and research-related career pathways (Hathaway et al., 2002; Junge et al., 2010; Nagda et al., 1998; Thiry and Laursen, 2011). Interestingly, the effect of whether or not a student is matched with a mentor of the same race and gender is not clear ((Russell et al., 2007). In one study, students ranked having a mentor in their field with higher importance than race or gender concordance (Lee, 1999). However, some research suggests that underrepresented undergraduate and graduate students experience more positive attitudes toward research when they are mentored by female faculty or faculty of color (Frierson et al., 1994; Gandara and Maxwell-Jolly, 1999). Blake-Beard et al. (2011) found that female and racial/ethnic minority mentees in STEMM reported experiencing more psychosocial and instrumental help as well as more role model support when paired with a mentor with whom they had race or gender concordance (Blake-Beard et al., 2011). The value of concordant mentoring relationships across gender has also been shown (Johnson-Bailey and Cervero, 2004). However, the ability to match students with mentors who share cultural similarities and come from the same field would require a level of cultural diversity that does not yet exist. Recent research indicated that cultural diversity must be considered in mentoring relationships. For example, Byars-Winston et al. (2015) found that underrepresented minorities (URM) students were more likely than their non-URM mentors to agree that cultural diversity matters should be addressed in research mentoring relationships (Byars-Winston et al., unpublished). This is supported by research showing that mentors of URM mentees tended to espouse colorblind attitudes and the notion that cultural diversity is irrelevant to the research mentoring relationship (Prunuske, Wilson, Walls and Clark's 2013).

Though there is less research about the benefits of being a mentor, increased productivity among research mentees inevitably leads to increased productivity for research mentors (Campbell and Campbell, 2000; Dolan and Johnson, 2009b). Examples of other benefits to mentors include a sense of personal fulfillment through knowledge and skill sharing, sharpening of leadership skills, career preparation, and cognitive growth (Dolan and Johnson, 2009; Eagan et al., 2013; Laursen et al., 2010).

Despite the wide-spread belief that mentoring plays a critical role in the retention and success of researchers across the career spectrum, the actual evidence to support the claim is weak. Reviews of undergraduate research programs document significant shortcomings. Jacobi (1991) published the first review of undergraduate mentoring literature and found key deficiencies including the lack of a clear definition for mentoring, as well as theoretical and methodological weaknesses (Jacobi, 1991). A subsequent study of the mentoring literature

conducted by Cruz and Crisp described similar methodological concerns (Crisp and Cruz, 2009). Gershenfeld's more recent review reports some progress on the use of theoretical frameworks but still significant methodological shortcomings. Gershenfeld concluded that there was no conclusive evidence that mentoring programs impact desired outcomes for undergraduates, as not one of the 20 empirical studies identified included an experimental design with equivalent control or comparison groups (Gershenfeld, 2014). This conclusion has recently been supported by Linn et al who showed that of the 60 empirical studies published since 2010, half rely exclusively on self-reported data collected through surveys or interviews and fewer than 10% validate the self-reports with direct measures of research productivity, longitudinal evidence of persistence, or direct observation of skills (Linn et al., 2015).

One reason for the lack for empirical evidence may be the sheer complexity of studying mentoring. In particular, what makes the study of mentoring within the context of UREs even more difficult is that mentoring does not occur in isolation from the other support an undergraduate engaged in research receives. How do we determine the specific role(s) of the mentor and the impact of the mentoring relationship on the undergraduate mentee compared to the immersive undergraduate research experience itself? How do we make certain that we understand who mentees believe are serving as mentors for them, which roles their mentors are playing and in what context? Without these pieces of data, we cannot advance our understanding of mentoring and the roles mentors play in the undergraduate research experience.

Table 1. What Is Needed to Advance Research on Mentoring within Undergraduate Research Experiences

1. Clear, functional definition of mentoring
2. Definition of success for mentoring relationships
3. Detailed context for the mentoring relationship
4. Detailed list of the roles mentors are playing
5. Attributes for effective mentoring relationships
6. Account of who is doing the mentoring
7. Metrics for assessing knowledge, skills, and effectiveness of relationships
8. More methodologically rigorous studies

List derived from recommendations made in Gershenfeld (2014).

The goal of this article is to address the primary issues raised by Gershenfeld (see Table 1) in an attempt to expand our understanding of mentoring, its impact on UREs, and what needs to be done to advance research and target interventions which will ultimately improve the undergraduate research experience and the subsequent outcomes.

Clear, Functional Definition of Mentoring

The term mentor has been defined in many ways dating back to Greek mythology (Kram, 1985). In the simplest sense, mentorship, or the act of mentoring, describes an experienced person (mentor) guiding a less experienced person (mentee/protégé) (Eby et al., 2007). In her 1991 review, Jacobi listed a range of definitions found in the psychological research literature (Jacobi, 1991). The term mentoring has been used to describe many different types of relationships in the research training context. This includes academic advising, research or laboratory supervision, evaluation, informal support, and career coaching. In its most general sense, mentoring is "a reciprocal, dynamic relationship between mentor (or mentoring team) and mentee that promotes the satisfaction and development of both" (McGee, 2016; Pfund et al., 2016). A more functional definition is that *mentoring is a collaborative learning relationship that proceeds through purposeful stages over time and has the primary goal of helping mentees*

acquire the essential competencies needed for success in their chosen career. Thus a successful mentoring relationship is one in which 1) the mentee acquires research skills needed for productivity and career-related knowledge essential to advance; and 2) the mentor acquires a working knowledge of the mentee in order to effectively nurture academic and professional growth of the next generation (Pfund et al., 2016). This definition of mentoring is the one currently being used by the newly established National Research Mentoring Network (NRMN, www.nrmnet.net).

Ideally, mentees and mentors engage as partners through reciprocal activities such as planning, acting, reflecting, questioning, and problem solving (Pfund et al., 2016). Mentor success is then defined as having the skills and knowledge to effectively support mentee development and facilitate the attainment of the transferrable "competencies" necessary to meet individual mentees' goals. This requires the ability to come to a clear understanding of each mentee's unique needs and desires and the flexibility and humility to adjust one's approach to support a mentee's success. Thus, mentee success occurs when the mentee has gained 1) personal and professional competencies necessary to define his/her career goals; 2) experience needed for that career; and 3) the ability and opportunity to progress toward that chosen career goal (Pfund et al., 2016).

Definition of Success for Mentoring Relationships

In many URE programs, success is measured by persistence in the targeted field and advancement into an advanced degree in that field. As noted, however, successful mentoring relationships can be defined as those in which mentees reach the individual milestones that allow them to progress to the next stage along the trajectory for a sustainable career in their chosen area. Thus, for undergraduate researchers success is not defined by a single career choice and persistence on a given track is not the only successful outcome.

Longitudinal studies do show a correlation between a mentored URE and persistence indicators (Lopatto, 2007; Russell et al., 2007), although only a few exist and most track intent not actual behavioral outcomes, (see Linn et al., 2015 for recent review). However, participation in a URE might also result in a student making more informed/educated choices about their majors and ultimately their career path such as the decision to pursue a MD or PhD degree (Pacifici and Thomson, 2011) or a non-science degree. These outcomes would still fit with the above definition of a successful mentoring relationship and thus should not be disregarded. Importantly, the goal of each mentoring relationship must be defined by the mentor and mentee and aligned. The success of each relationship can then be defined as achieving these aligned goals towards a desired career outcome.

Detailed Context for the Mentoring Relationship

Mentoring does not happen in isolation. It occurs within the context of a larger program, making it a difficult factor to study. For example, an URE program may provide programmatic elements that support the student experience and fulfill some of the mentoring needs of the students. Other mentoring roles may be performed by a primary research mentor and yet others may be provided by peer mentors. Thus when student is asked about the overall mentoring they received during their URE experience, the response may reflect all of these components. This is further complicated by the fact that most UREs do not describe how mentoring relationships within the program are established, structured, and supported, making it even more difficult to isolate the variable and study it (Lunsford et al., 2017).

The types of UREs in which students participate can vary (See Linda Blockus' commissioned paper). Many undergraduates participate in summer research programs in which they engage in full-time research over several months. Others participate in research part-time during the academic year while taking courses. Most students conduct work on campus but some move off-campus to do internships or field work. Students may work individually or in a cohort. Some students do research at their home institution while others travel to different places. Importantly, the type of institution one attends can impact access to, experience in, and outcomes from undergraduate research (Laursen et al., 2010) .These contexts matter when it comes to understanding the experience of undergraduates and the role of mentoring in that experience.

As noted in Dolan et al (2017), most of the studies on undergraduate mentoring report on data collected at the programmatic or administrative level rather than on the undergraduates' assessment of their mentor or the mentoring relationship (Lunsford et al., 2017). Most studies have analyzed data collected from single institutions and individual programs and thus the generalizability of the findings is limited (Eagan et al., 2013). And as pointed out above, if a student is asked to assess the mentoring they received, it is difficult to interpret the results without a detailed understanding of the context of the mentoring experience, the various mentoring roles played by various individuals, and the frequency and quality of the interactions.

Detailed List of the Roles Mentors Are Playing

Mentors can play many roles, and as noted, a lack of understanding about these various roles and which are played within what context makes the study of mentoring challenging. In academe, roles have been described for faculty mentors which fall into the domains of career functions, psychosocial functions, and role-modeling. Career functions refer to the roles mentors play to prepare an individual for advancement within an organization or along a career path. Psychosocial functions include the emotional roles a mentor plays to build an interpersonal relationship with their mentee to help that mentee grow professionally and personally. Role-modeling is demonstrating effective attitudes and behaviors that can help a mentee succeed in a given context (Ragins and Kram, 2007).

For mentors working with undergraduates engaged in research, roles have been described across all three of these domains. Thiry and Laursen (2011) described three sets of roles which emerged from their qualitative studies: professional socialization, intellectual support, and personal/emotional support (Thiry and Laursen, 2011). Thiry and Laursen found that mentors provided professional socialization by helping mentees learn disciplinary knowledge and skills, setting and aligning expectations, and modeling behaviors and norms. They also reported that mentors provide intellectual support to their mentees on their research project, helping them learn the methods of research and applying those. Finally, Thiry and Laursen stated that undergraduates noted the importance of their mentor providing personal/emotional support and becoming a trusted advisor (Thiry and Laursen, 2011).

Research points to career functions and psychosocial functions as the two primary functional domains for mentor roles (see Kram, 1985; Ragins and Kram, 2007), and it has been shown that mentors fulfilling these two roles contributes to mentee career satisfaction (Allen et al., 2004). This list of domains has also been expanded. For example, in a review of mentoring roles for faculty in academic medicine, five domains of general research mentors' roles were identified and described in detail: 1) communication/ relationship management; 2) psychosocial support; 3) career and professional development; 4) professional enculturation/ science integrity; and 5) research development (Abedin et al., 2012).

Importantly, the need for mentors to play specific roles varies with each individual relationship and across the phases of the relationship (Kram, 1985). Yet, little is known about which specific roles have the greatest impact in mentoring relationships between undergraduate researchers and their mentors and which account for positive outcomes across student populations. Are there core roles that transcend the idiosyncratic nature of mentoring relationships? Or is alignment of roles and goals the most important element?

One approach is to focus on goals of the roles, not the roles themselves. This changes the focus away from what mentors do to how they achieve a certain goal and why they engage in certain actions. As mentors and mentees identify goals of their relationships and align these goals, then mentors can identify the goals they need to achieve and articulate the roles they can play which will be more beneficial to their mentee. Moreover, it also allows for focus on the role the mentee must play in the relationship.

Account of Who Is Doing the Mentoring

Many people may consider themselves mentors for undergraduates and may even be considered mentors by an undergraduate, but the individual or individuals who fulfill the roles described above for a given mentee may not be one of the mentee's "official" mentors or may not have sustained relationships with the mentee. They may in fact be an unofficial mentor engaged in a short "mentoring episode" (Ragins and Kram, 2007). The definition of mentoring embraced by the National Research Mentoring Network (NRMN) suggests that mentors are those who engage as partners with their mentees through reciprocal activities such as planning, acting, reflecting, questioning, and problem solving. Just because someone is a manager, advisor, or supervisor, does not mean they are a mentor, While these folks serve very important roles for the undergraduates with whom they interact and may in fact directly help them advance in their career in very meaningful ways, they do not necessarily engage in reciprocal activities and thus would not be considered mentors in the context of an undergraduate research experience. While these interactions can be very important for a mentee, they are not the focus of this paper.

So who do serve as mentors for undergraduates engaged in research? The answer differs across institutional type, programmatic context, and discipline. Undergraduates may be mentored directly by a professor, which is often the case at smaller liberal arts institutions, or by a senior researcher (e.g., a graduate student, postdoctoral fellow, or scientist), which is typically the case at Research 1 universities. Across institutional type, near-peers and peers serve as mentors for undergraduates. In the case of classroom-based undergraduate research experiences (CUREs), instructors may play the role of mentors (see Erin Dolan's commissioned paper). Finally, in many cases a single individual does not serve all the functions of a mentor. Mosaic mentoring or a network of mentors is becoming a focus of mentoring programs in order to provide a circle of support for undergraduates (Bartlett and others, 2012; Darling, 1986; Head et al., 1992; Mullen, 2007), however this approach is not always practical at a particular institution or in certain disciplines. In these cases, mentoring may be fulfilled in a variety of ways by individuals within and outside the institution.

Regardless of who is serving the role(s) of mentor, there currently exists a lack of criteria by which mentors are selected and evaluated. Nor is there any requirement for mentors to meet some minimum level of competency before engaging in mentoring, or participate in training to obtain a baseline of knowledge and skills in mentoring. Traditionally, the only experience required for being a mentor is having been mentored, regardless of whether the experience was negative or positive (Handelsman et al., 2005). This is in stark contrast to mentoring outside academe where much thought is put into how the relationships are formed, supported and

evaluated. And those playing the role of mentor are often required to participate in training and be regularly reviewed by their mentees. Ironically, peer mentoring and mentoring programs within the academy have more structured elements and more preparation of mentors than does traditional research mentoring in UREs (Lunsford et al., 2017). In recent years, there have been calls from funding agencies to improve mentoring relationships for trainees (i.e. NIGMS, NSF, HHMI, Sloan Foundation).

Attributes of Effective Mentoring Relationships

Development of "attributes" that contribute to successful research mentoring relationships are needed. These attributes take into account the factors which have been shown to lead to persistence, such as science identity, research self-efficacy, and cultural diversity (Byars-Winston et al., 2015; Chang et al., 2011; Chemers et al., 2011a; Estrada et al., 2011; Hurtado et al., 2009; McGee and Keller, 2007; Seymour et al., 2011). A list of proposed attributes of effective mentoring across five domains is offered in Table 1. This list is derived from Pfund et al (2016) building on the existing literature and proposed organizational frameworks (Abedin et al., 2012; Pfund et al., 2016; Ragins and Kram, 2007; NRMNet.net), and factors shown to impact academic persistence.

Table 2: Proposed Attributes of Effective Mentoring Relationships

RESEARCH SKILLS • Developing disciplinary research skills • Teaching and Learning disciplinary knowledge • Developing technical skills • Accurately assessing mentees' understanding of disciplinary knowledge and skills • Valuing and practicing ethical behavior and responsible conduct of research	DIVERSITY/CULTURALLY-FOCUSED SKILLS • Advancing equity and inclusion • Being culturally responsive • Reducing the impact of bias • Reducing the impact of stereotype threat
INTERPERSONAL SKILLS • Listening actively • Aligning mentor and mentee expectations • Building trusting relationships/ honesty	SPONSORSHIP SKILLS • Fostering mentees' independence • Promoting professional development • Establishing and fostering mentee professional networks • Actively advocating on behalf of mentees
PSYCHOSOCIAL SKILLS • Providing motivation • Developing mentee career self-efficacy • Developing mentee research self-efficacy • Developing science identity • Developing a sense of belonging	

Not all of these attributes need to be addressed in every mentoring relationship, nor do they need to be addressed at the same time. Moreover, it is unlikely that any single mentor can tackle all of these attributes within a given mentoring relationship; it is more likely that multiple mentors serve the roles needed to meet the targeted goals for a given individual in a given relationship. For example, a particular undergraduate applying for graduate school may need multiple mentors skilled in sponsorship who can help them network, advocate for them, and promote their professional development much more so than a first year undergraduate who may

need a mentor to help them develop a sense of science identity and belonging within their chosen STEM major. Importantly, the context in which these roles are fulfilled is critical.

By looking at a program, such as a URE, holistically, one can begin to see that these attributes can be provided for a given mentee by multiple mentors across time with the goal of helping that mentee acquire the research skills needed for productivity and the career-related knowledge essential to advance. Within the context of a URE, the classic apprenticeship model may create the optimal opportunity for a research mentor to address some of the research skill building and cultural factors while others in the URE program fulfill some of the psychosocial factors. This point must be underscored as the growing list of roles mentors are expected to play makes it impossible for any single person to fulfill them all for a given mentee at a given time. This requires consideration of what the mentee needs, which attributes need focus, and who across a mentoring network can fulfill those needs for the greatest impact on learning.

Metrics for Assessing Knowledge, Skills, and Effectiveness of Relationships

One benefit of a list of attributes of effective mentoring relationships is that is provides clear, targeted areas for study and intervention. However, in order to examine the complex nature of research mentoring relationships and their impact on undergraduates, theoretically-grounded, validated measures are needed to assess the quality and effectiveness of research mentoring relationships and to identify factors that shape a successful research mentoring experience (Byars-Winston et al., 2015; Pfund et al., 2016). Currently, there are few metrics available to assess the effectiveness of research mentoring relationships at various career stages, with diverse mentees, across varied types of research mentoring relationships and across career stages. A handful of scales have been developed. Some of these are designed to assess a mentor's self-reported knowledge and skills (e.g. (Fleming et al., 2012; Pfund et al., 2006, 2014a); others are designed to assess a mentor's skills, knowledge, and behaviors from the mentees' perspective (e.g. (Berk et al., 2005; Byars-Winston et al., 2015; Eagan et al., 2013; Hunter et al., 2009; Lopatto, 2004; Weston and Laursen, 2015); and finally, others were created to assess the effectiveness or quality of the mentoring relationship overall (e.g. Berk et al., 2005). However, only a few scales have been validated. While these scales hold some promise, there is much work to be done to develop and validate metrics which can be used to identify causal links between mentoring and the career outcomes of mentees.

In recent years, there has been much more investigation across many domains of attributes of effective mentoring relationships (Table 1). A compilation of available metrics for consideration across each attribute is available (Pfund et al., 2016). Some notable advancements using mixed methods have been made in the development and testing of scales to assess several specific attributes including the development of measures to assess 1) cultural attributes within research mentoring relationships (Byars-Winston et al., unpublished), 2) elements of career coaching (Williams et al., 2015), 3) sources of self-efficacy (Rogers et al., unpublished) and 4) integration into the scientific community (Estrada et al., unpublished).

Finally, metrics need to include parallel mentor and mentee measures so that alignment may be assessed as an indicator of mentoring effectiveness. Research suggests that mentor-mentee alignment is a critical determinant of effective mentoring relationships (Byars-Winston et al., 2015; Kardash, 2000; Pfund et al., 2006).

More Methodologically Rigorous Studies

As noted, one reason for the lack for empirical evidence is the sheer complexity of studying mentoring within the context of UREs, yet the need for more methodologically rigorous studies of mentoring are needed. As stated by NIH, "Two of the cornerstones of science advancement

are rigor in designing and performing scientific research and the ability to reproduce biomedical research findings" (https://www.nih.gov/research-training/rigor-reproducibility).

One issue undermining advancement in the study of mentoring within the context of UREs has been the inclination to examine too many variables at once. The large diffuse number of outcome variables impacts the statistical ability to detect the impact mentoring makes. If the research community is able to hone in on a refined set of common variables then there will be a better chance of generating reproducible results. Listed in table 3 are principles that can guide towards more methodologically rigorous and focused studies of mentoring within UREs. Many of the articulated ideas have been iterated for years and continue to be promoted by research communities focused on understanding interventions (http://understanding-interventions.org/reports/).

Table 3: Principles that will guide improved rigor

A. Shared view of the problem
B. Consensus on the research priorities
C. Validated measures
D. Theoretical framework to guide inquiry
E. Interdisciplinary teams conducting inquiry
F. Mixed method designs
G. Intentional focus on issues of culture and intersectionality
H. Feasible research designs

Shared view of the problem

Clearly articulating the problem that mentoring, in the context of UREs is hypothesized to solve is critical to advancing towards a solution. Some have proposed that the problem is one of quality; others state it is access for diverse groups; others claim the problem is one of unrealized potential and impact. While all of these problems are important, our community of researchers and practitioners must come to a common understanding of what problems are most critical at this point in time.

Consensus on research priorities

A shared view of the major problems that mentoring in the context of a URE may solve can drive research priorities. For example, if the most pressing problem is one of diversifying the scientific workforce and mentored UREs are considered a promising solution to this problem, then a research priority must be understanding the critical factors that contribute to the success of diverse groups engaged in UREs. In terms of mentoring, research focused on the impact of mentoring relationships on the persistence of diverse groups in science and how to maximize that impact would be a priority. Prioritizing research goals is crucial if the community is to move in a concerted fashion toward understanding and ultimately towards implementing interventions optimized for groups of interest.

Validated measures

Validated, theoretically-informed instruments are needed to better assess the effectiveness of UREs on undergraduate researchers, and to identify the most influential and beneficial factors in research mentoring relationships. The validation of such instruments will allow mentors, URE program directors, and institutions to assess the effectiveness of their efforts in this area and guide improvements (Byars-Winston et al., 2015; Lopatto, 2004; Rogers et al.). As noted above, few validated scales exist and of those that do exist few have been tested with undergraduates, let alone those from diverse groups. Moreover, very few scales for undergraduates have parallel mentor metrics thus limiting the ability to assess alignment within mentoring relationships. One priority is to identify, curate, develop, and test measures with diverse groups and then come to consensus regarding which ones to use across the community of researchers. Only then can comparative studies be conducted and generalizable, best practices be identified.

Theoretical frameworks to guide inquiry

Although the research is not very strong, it is fairly well-established that mentoring impacts UREs. Much less is understood about how and why mentoring matters and for whom. Further studies are needed to determine if there are core attributes that transcend the idiosyncratic nature of mentoring relationships or if alignment of goals between mentees and their mentors is the most critical factor of a successful relationships. Using theoretical models to understand the factors contributing to persistence is one promising approach providing some insights into how and why mentoring relationships contribute to success (Byars-Winston et al., 2015; Estrada et al., 2011; Hurtado et al., 2009). Identifying critical factors in persistence and targeting them for both further investigation and intervention should be a priority.

Interdisciplinary teams conducting inquiry

Over the past few years, there has been growing demand for more interdisciplinary work to advance science. This focus on interdisciplinary (or team science) has driven research agendas and funding priorities from agencies such as NSF and NIH and has been the focus of groups such as the Understanding Interventions (UI) community for years. UI promotes "dialogue among behavioral/social science and education researchers, evaluators, and faculty in STEM (science, technology, engineering, and mathematics) fields who participate in intervention programs (http://understanding-interventions.org/about/). Such efforts have significantly advanced the study of interventions, such as UREs and mentoring, and should continue.

Mixed method designs

Mixed method design calls for the integration of quantitative and qualitative approaches to research. The combination of these data can uncover "links between theory and empirical findings, challenge theoretical assumptions and develop new theory" (Östlund et al., 2011). Because social science phenomenon are so complex, mixed method designs can help to elucidate critical factors in the phenomenon of interest (Creswell et al., 2003; Greene et al., 1989). While there is still debate on the value of mixed method design, the community should consider it when designing studies aimed at understanding the role and impact of mentoring on the URE.

Intentional focus on issues of culture and intersectionality

Recent studies indicate that cultural diversity can influence how undergraduate researchers experience their mentoring relationships, what attributes they value in their mentor(s), their perceptions of science, their identity, and their sense of belonging (Blake-Beard et al., 2011; Byars-Winston et al., 2013; Carlone and Johnson, 2007; Hurtado et al., 2009; Ishiyama, 2007; Johnson et al., 2011; Laursen et al., 2010). Thus there needs to be attention to how theoretically-derived factors associated with student persistence, including self-efficacy and science identity, vary as a function of gender racial/ethnic group membership and their intersection (e.g. Rogers et al.). Such studies should be a priority and not an after-thought.

Feasible research design

How do we determine the specific role(s) of the mentor and the impact of the mentoring relationship on the undergraduate mentee compared to the immersive undergraduate research experience itself? While one might call for a rigorous randomized controlled trial to isolate mentoring and study it, implementation of such a study is almost impossible. It would require comparing mentees engaged in URE with and without a research mentor while controlling for any mentoring role that might be fulfilled by others in the URE program, department or classroom. As Lopatto states "Practical difficulties in the creation of the proper controls are legion. For example, one might select for the control group students who applied for, but were not selected for, an undergraduate research experience. The same selection process that

differentiated between these groups, however, may introduce confounds based on student ability or experience. A traditional method of creating a control group, such as random assignment of students to undergraduate research group and control group, would be unlikely to meet ethical and fairness concerns…….[However] In the field of clinical psychology, for example, a nonrandomly selected group of people experience a variety of therapeutic techniques in a variety of environments. The assessment of therapies has been undertaken by employing both effectiveness and efficacy studies" (Lopatto, 2007).

Thus one promising approach is studying interventions aimed at improving mentoring relationships such as mentor training. One of the most well-studied approaches to mentor training is based on the *Entering Mentoring* curricula (Handelsman et al., 2005; Pfund et al., 2014a; Sorkness et al., 2013). In recent years, this curriculum has been used to train thousands of mentors across the country (Pfund et al., 2015). The training uses a process-based approach to introduce core mentoring competencies, experiment with various mentoring strategies, and provide a forum to solve mentoring dilemmas with small peer groups. Qualitative and quantitative data indicate that compared to untrained mentors, mentors who participated in *Entering Mentoring* training assess their mentees' skills and communicate with them more effectively (Pfund et al., 2006). Undergraduate researchers indicated that they had a better experience with the trained mentors (Pfund et al., 2006). The curriculum has since been adapted for faculty mentors of junior faculty and post-docs engaged in clinical and translational research as part of a randomized controlled trial at 16 sites, including 15 NIH-Clinical and Translational Science Award (CTSA) institutions. Both mentors and their mentees reported a positive impact on participants' mentoring knowledge, skills, and behaviors (Pfund et al., 2013, 2014b). To our knowledge, this is the first randomized trial to show positive impact on both mentors and mentees from a research mentor training intervention. Follow-up studies are underway to understand why the intervention had the effect on mentor skills, knowledge, and behaviors, in particular on issues of diversity within mentoring relationships, as well as its long-term impacts.

Although *Entering Mentoring* and the parallel curriculum for undergraduate researchers, *Entering Research* (Balster et al., 2010; Branchaw et al., 2011), are now well-established, they were not initially designed with an explicit theoretical base in mind. Specifically, they did not capitalize on the extensive literature on career development, and thus did not focus on important cognitive and cultural factors. Moving forward, new mentor and mentee training modules will be built upon a strong theoretical base and will focus on training hypothesized to impact the persistence of undergraduates from underrepresented groups. For example, two selected theories, social cognitive career theory (Lent et al., 1994) and science identity development (Carlone and Johnson, 2007; Estrada et al., 2011; Laursen et al., 2010) are guiding the development of some training modules which are being tested through the NRMN.

Prioritizing Next Steps

This paper outlines the rationale behind and the arguments for many next steps toward a common understanding of mentoring, its impact on UREs, and what needs to be done to advance research and target interventions which will ultimately improve the undergraduate research experience and the subsequent outcomes. This author suggests a few initial priorities to begin addressing the significant gaps identified:

- A working group representative of the community of those doing research in this area should be assembled to come to consensus on prioritized outcomes of mentored UREs and the problems both UREs and mentoring in the context of UREs are trying to solve.
- Every funded URE program should be required to complete a profile about their program which identifies all of the programmatic and contextual elements including how mentoring relationships are formed, supported and evaluated. These elements should be selected from a common list so that programs can be compared. These profiles should be uploaded to a common national database shared across funding agencies.
- Researchers should continue interdisciplinary, mixed methods investigations to study mentoring within UREs, with a focus on interventions aimed at improving mentoring relationships and understanding how and why they have impact.
- Efforts should be made to continue and expand funding to support the activities described above by interdisciplinary teams of practitioners and social scientists. Support for this work can come from such programs as:
    - NIGMS Research on Interventions Program (https://www.nigms.nih.gov/training/pages/interventions.aspx)
    - NSF –WIDER program (www.nsf.gov/funding/pgm_summ.jsp?pims_id=504889&org=EHR&sel_org=EHR&from=fund)
    - NSF TUES program (www.nsf.gov/funding/pgm_summ.jsp?pims_id=5741&org=EHR&sel_org=EHR&from=fund);
    - NSF PRIME Program www.nsf.gov/funding/pgm_summ.jsp?pims_id=504995&org=EHR&sel_org=EHR&from=fund;
    - Sloan University Centers of Exemplary Mentoring Program (UCEMs) http://www.sloan.org/fileadmin/media/files/press_releases/UCEM_Press_Release_vF.pdf

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