Undergraduate Research Experience Programs in Natural Resources, 2012-2016

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Academic Abstract

Undergraduate research education occurs in a variety of formats including co-curricular, summer internship, and course-based formats. Research on such programs historically focuses on undergraduate outcomes particularly in STEM disciplines. Situated learning theories such as cognitive apprenticeship and community of practice feature in exploratory research on how research is associated with participant learning. However, there is a lack of practical research on the role of undergraduate research experiences as situated learning and on the type and implementation of practices associated with undergraduate research program delivery, particularly in natural resources disciplines. Understanding the roles of such mechanisms in providing the broad range of benefits to undergraduate and mentor participants is an area of further exploration. This research describes undergraduate research experience programs, associated outcomes, and outcomes' relationships with situated learning elements. The first research chapter sampled program coordinators using researcher-led respondent driven sampling and describes the population of natural resources undergraduate research experience programs during 2012-2016 across 127 such programs. Two-step cluster analysis using program characteristics identified seven variables that distinguish between seven program types. Variables included pay amount, academic preparation activities, graduate student mentorship, highest student classification allowed, affirmative action statement presence, undergraduate cohort siting, and summer duration. Program types were underclass intensive traditional, extended graduate student mentored, professional development, distributed intensive, site-based traditional, shorter duration intensive, and larger long-term types. The next research chapter explores how undergraduate participants in a subset of natural resources research experiences viewed their programs as situated learning and outcomes attributed to their experience. Exploratory factor analysis identified six situated learning domains associated with the practice of undergraduate research in natural resources disciplines: effective mentorship methods, project and task sequencing, mutual engagement, broad repertoire, specific repertoire, and joint enterprise. Outcome factors indicated moderate to strong gains in the following areas: general skills, career trajectory, academic and career readiness, communication of science, cognitive skills, and researcher identity development. Effective mentorship methods, sequencing, broad repertoire, and specific repertoire were significant predictors of increased gains across all outcome factors. The final chapter is a mixed-methods case study evaluation of a postgraduate mentored research experience program titled PINEMAP Fellowship. Participant outcomes associated with the fellowship lend support to prior literature on how participants, particularly a set of demographic groups, benefit from participation. Findings offer empirically-based considerations for program developers and coordinators in promoting and adapting programs to undergraduates' needs and goals as well as provide suggestions for further analysis of causal relationships. Additional research is needed to explain how and to what degree undergraduate experiences in natural resources and other disciplines provide positive outcomes for a diversity of participants.

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General Audience Abstract

Undergraduates as part of their education may conduct research with faculty and graduate students, and students generally experience many different benefits from research participation. For example, a student may individually work with a research mentor during the academic year, or groups of students may work with several research mentors over the summer, and in some courses taken for credit students may conduct research-related activities. Research on summer-based programs varies greatly and typically focuses on undergraduate outcomes in science, technology, engineering, and mathematics disciplines. Studying these types of programs and their participants' outcomes is difficult and some areas have been understudied, particularly in natural resources disciplines. Further, there is a need to understand which kinds of training practices identified in theory provide the broad range of benefits to undergraduate and mentor participants. This research describes the variation in natural resources undergraduate research experience programs, and it suggests how undergraduates may benefit from participating in these programs. One chapter describes an estimate of the size and types of summer internship-style natural resources undergraduate research experience programs operating from 2012 to 2016. Surveys indicated 127 programs operated during that time and could be classified as either underclass intensive traditional, extended graduate student-mentored, professional development, distributed intensive, site-based traditional, shorter duration intensive, and larger long-term types. Program types were identified with seven important variables: pay amount, academic preparation activities, graduate student mentorship, highest student classification allowed, affirmative action statement presence, undergraduate cohort siting, and summer duration. Another chapter explores how undergraduate researchers in natural resources experienced a range of teaching and social learning practices including mentor's teaching practices, how learning activities were sequenced, engagement with others, general information and tools, project-specific information and tools, and research community purpose. Undergraduates also reported gains in general skills, career trajectory, academic and career readiness, communication of science, cognitive skills, and researcher identity development. Mentor teaching practices was an important factor in predicting how much students benefitted in each outcome, and most practices were associated with other outcomes. The last research chapter used different methods to evaluate the PINEMAP Fellowship program. Undergraduates experienced a variety of gains, particularly in communication skills, although generally their attitudes toward research did not change. Mentors in the program also experienced work-related, social and emotional, interpersonal, professional, and thinking skills gains. PINEMAP Fellowship participants' data supported other studies' findings on how participants, and particularly some demographic groups, benefit from participating in undergraduate research programs. Altogether, this study offers considerations for program developers and coordinators in promoting and adapting programs to undergraduates' needs and goals as well as provides suggestions for deeper analysis of how participants obtain their gains. Further research is needed to explain how and to what degree undergraduate experiences in natural resources and other disciplines provide positive outcomes for a diversity of participants.

Dedication

For my children: this work started before I knew you, and it may never have been completed otherwise.

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To my committee: words cannot express how grateful I am for your patience as I worked through this process. John Seiler, thank you for giving me an opportunity to join PINEMAP as a project associate and work on the fellowship program. John Munsell, I appreciate your willingness to take me on as a co-advisee and share your expertise and experience. I greatly appreciate the funding that allowed me to continue working on this project after PINEMAP funding ended. Marc Stern, thank you for sharing your expertise and perspectives on social science research. JP Gannon, thank you for joining the committee at the eleventh hour and for your interest in my research. Steve McMullin, I greatly appreciate the time you invested while a committee member and your encouraging me to think about the role of leadership and policy in our discipline. All of you acted as guides through my PhD program at Virginia Tech and functioned as brokers that facilitated interests and trajectories into different communities of practice.

I thank the administrative staff and others in the Forest Resources and Environmental Conservation department at Virginia Tech for the support they provided during my time there.

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Thank you to several individuals that mentored me, however formalized those relationships may have been, early in my education and professional career.

Becca, thank you for supporting in the ways that you have. I probably would not have been in position to continue my formal education without joining you along yours.

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Attribution

This work is primarily my own. John Seiler and John Munsell reviewed data collection instruments and provided comments and edits on drafts. John Munsell and Marc Stern contributed ideas for data analyses.

Chapter 1: Introduction

Background

The Council on Undergraduate Research defines undergraduate research as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" (Beckman & Hensel, 2009). Undergraduate research is deemed a critical component of undergraduate education (Boyer, 1998), its benefits have been reported widely, and consensus about these benefits to undergraduates is being established as research studies become more prevalent. However, similar consensus on critical undergraduate research elements or their frequency of implementation across the broad classifications of undergraduate research experiences (URE) has not been reached. Scant, if any, literature reports on the variation of URE programs (NASEM, 2017), particularly within the natural resources field. Also of note is the dearth of literature pertaining to, especially non-faculty, mentors in URE programs, including both benefits and challenges for postgraduate mentors (Dolan & Johnson, 2009; Foertsch et al., 1997). URE literature references cognitive apprenticeship and community of practice theories among other theoretical frameworks for establishing connections to outcomes (Kardash, 2000). However, these situated learning theories have not been well studied within this context. Examining programs within the natural resources field through the lens of situated learning theory, this research provides insights into natural resources URE programs' elements and their prevalence, establishes undergraduate outcomes, and explores outcomes' relationships to situated learning elements.

This work began as a mechanism for evaluating a single URE program, the Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) Fellowship, before expanding to include other natural resources URE programs operating from 2012 to2016. PINEMAP was one of three coordinated agriculture projects funded in 2011 by the United States Department of Agriculture's National Institute of Food and Agriculture (award 2011-68002-30185; Eigenbrode, Morton, & Martin, 2014). Educational and outreach projects were a significant part of PINEMAP, and the fellowship program provided undergraduate students opportunities to participate in authentic research across other disciplinary arms within the project. Evaluating the PINEMAP Fellowship led to a broader interest in examining other natural resources URE programs. Situating the fellowship within a large context seemed necessary, in part due to its apparent uniqueness in structure and its distributed nature and lengthier annual program that incorporated an online communications and outreach course component. For the purposes of this research, natural resources UREs were defined as programs that included multiple undergraduates as a cohort involved in authentic natural resources research and specifically involving summer months with research or other activities that may or may not extend into the previous or following academic year. The following disciplines were considered as natural resources: forestry, rangeland, fisheries, wildlife, agriculture, soils, hydrology, and geospatial information.

Research presented in this dissertation supports what is known about URE and addresses gaps regarding lesser-known facets of experiences and outcomes. First, there are widely held beliefs among experts and practitioners about URE best-practices, but the field lacks supporting data on the prevalence of such characteristics. Second, undergraduate gains are becoming well-established, but considerable room exists for assessment tools that also take into account mechanisms through which those gains are conferred. Third, reviews of URE literature identify needs for examining mentor outcomes and challenges, particularly for non-faculty mentors with whom the majority of undergraduate researchers may interact. This study asks the following overarching question: in what ways do natural resources URE programs function as situated learning, and what is the relationship between those situated learning elements and participant outcomes?

Objectives

The goal of this research was to examines the role of URE programs in natural resources disciplines to better understand program characteristics and their associated participant outcomes through the following research objectives:

1. Identify the scale of natural resources URE programs and describe those programs' similarities and differences;
2. Explore how undergraduate researchers in those programs viewed their experience as situated learning and the degree to which those components are related to participant outcomes; and
3. Evaluate the PINEMAP Fellowship's effectiveness in providing undergraduates with positive outcomes including attitude and communication skill gains, graduate students with positive mentoring experiences, and public secondary school students with educational outreach.

This dissertation is divided into four primary chapters: Chapter 2 - a literature review of UREs and associated prominent situated learning theories; Chapter 3 - a research chapter on the population estimation of natural resources URE programs during 2012-2016 and a typology of that population based on program characteristics; Chapter 4 - an examination of undergraduate outcomes and perceptions of URE as situated learning; and Chapter 5 - a case study evaluation of the PINEMAP Fellowship program. Altogether, this study provides an overview of the state of natural resources URE at program and participant levels while offering a case study of an extended, distributed URE in which mentors were primarily graduate students.

Research chapters are written as stand-alone manuscripts intended for publication in STEM and natural resources educational research journals. Each chapter presents relevant background, methods, findings and discussion, followed by limitations and recommendations for future study or practice. Chapter 3 contributes an exploratory quantitative examination of structural and functional program elements and a proposed typology of programs based on empirically identified features congruent with previous consideration by experts. This chapter is a "state of" paper that describes a systematic review and quantitative survey targeting directors and coordinators of natural resources URE programs operating during 2012-2016 to provide data for cluster analysis at the program level. Chapter 4 examines undergraduate outcomes and perceptions of URE as situated learning using a survey of participants across a subset of programs identified in Chapter 3. The PINEMAP Fellowship case study in Chapter 5 provides descriptions of undergraduate attitudes and communication outcomes, a comparison of faculty and graduate student mentors' outcomes, and metrics of outreach to public secondary schools. This case study of undergraduate and mentor participants used mixed-methods including pre-post format self-report surveys, pilot study retrospective self-report summative surveys, and content analysis of survey open-ended question responses and journals.

Findings from this research add value to existing literature by examining a cross section of URE programs within a specified interdisciplinary field of study (natural resources) that vary by model, institution, and purposes. Taking stock of current programs through the lens of

situated learning provides empirical support for the view that URE are situated learning experiences providing cognitive, personal, and professional benefits. This diversity of gains more aptly come from mentors who deliberately model research skills and processes and that provide meaningful and inclusive participation in authentic research projects that are well-sequenced as educational processes. Less-experienced mentors also realize gains in their ability to provide positive mentorship and experiences through guiding undergraduates into their own disciplines. Limitations of this research include difficulties of lack of a formal sampling frame for URE programs, small sample size data from enough observations to meet certain statistical assumptions without further variable reduction methods. Broad impacts for this study include suggestions for practitioners to consider situated learning practices in designing and managing programs. Research findings may be applicable to other programs within natural resources disciplines.

Chapter 2: Literature Review

Undergraduate research was defined by the Council on Undergraduate Research as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" (Beckman & Hensel, 2009). URE are a subset of this type of inquiry and can vary widely in the elements they contain for meeting programmatic goals that often include the convergence of theory and practice, career exploration, development of personal and professional skills, or research deliverables (Moore, 2010; Seymour, Hunter, Laursen, & DeAntoni, 2004). Internship models also vary by setting (e.g., departmental, interdisciplinary, community). Pedagogical practices are different throughout programs where internships may be purely performance based, require thoughtful consideration of the process, and/or result in outputs such as papers or seminars (Beckman & Hensel, 2009; Moore, 2010). Students targeted by URE programs also vary widely, with some uniquely structuring their programs for underrepresented populations such as racial or ethnic minorities or women (Barker, 2009; National Academies of Science, Engineering, and Medicine, 2017). Generally, college juniors and seniors are the primary group participating in URE programs, and some research findings conclude that more attention should be given to college freshmen and sophomores (Russell, Hancock & McCullough, 2007).

With the advent of distributed learning technologies and a shift toward interdisciplinary research, the traditional site-based model of internships and URE programs may be adapted to needs of research consortiums or institutional goals for greater access for students (Hubenthal & Judge, 2013; Wood, Oswalt, & SARA Collaboration, 2000). Course-based URE utilizes alternative instructional methods to provide research methods training to undergraduates enrolled in degree program-required or elective courses (Auchincloss et al., 2014, Buchanan & Fisher, 2022). Another adaptation includes distributed research experiences as an alternative model where students in a program are placed at different sites based on a mentor's location instead of models where students and mentors aggregate at a single site. Distributed URE was a relatively new format that had not been widely publicized in peer-reviewed literature, although the format possibly saw considerable utilization during the global COVID-19 pandemic (Erickson et al, 2022). Examples of distributed URE in the sciences include those conducted by the Computing Research Association's Committee on Status of Women in Computing Research (Barker, 2009), the Southeastern Association for Research in Astronomy (Rumstay, 1996), and Incorporated Research Institutions for Seismology (Braile, Hall-Wallace, Taber, & Aster, 2003). Distributed models may be most appropriate in situations where a research project integrates individual primary investigators from distinct disciplines or from separate universities or institutions. However, distributed URE may include arrangements where students are fully geographically separate or some students are co-located at separate institutions.

Outcomes associated with URE participation may vary just as widely as included elements depending on the degree of planning and process rigor (Moore, 2010), and research in this area typically describes gains or benefits with less attention to negative outcomes. Researchers and evaluators recently focus on the actual value of internships and URE programs in providing benefits to students in light of variety in goals and structures of past and current programs (Hunter, Laursen, & Seymour, 2007; Kardash, 2000; Seymour et al., 2004; Thiry & Laursen, 2011). Undergraduates, however, are not the only participants affected by participation in undergraduate research. Graduate students frequently are primary points of contact or mentors for undergraduates participating in undergraduate research. While benefits for undergraduate participants are becoming well studied, outcomes for mentors in URE, particularly postgraduates, have received less attention (Dolan & Johnson, 2009; Dolan & Johnson 2010; Faurot, Doe, Lederman, Brey, & Jacobs, 2013).

Benefits of Undergraduate Research

Benefits to undergraduates from URE participation have been well examined and documented, but emphases are typically on immediate benefits rather than long-term impacts, negative outcomes, outcomes for other participants, and program elements associated with outcomes. Data collected from undergraduates include individual-level outcomes identified in literature under personal, cognitive, and professional domains (see Appendix A; Hunter et al., 2007; Thiry & Laursen 2011). Latent variables under these domains consist of a number of specific indicator variables. An example of this would be "enhanced career preparation" in the professional domain having indicators of: networking with faculty and other scientists, enhanced resume, and real-world work experience. Other benefits are widely documented (Appendix A) with some studies reporting effects on student retention, persistence, and enrollment in graduate studies while others report on skill gains related to research (Hunter et al., 2007; Lopatto, 2004, 2007; Russell et al., 2007; Seymour et al., 2004). Benefits to students may include personal or professional gains (Hunter et al., 2007; Lopatto, 2004, 2007; Seymour et al., 2004), the increased ability to think and work as a researcher (Hunter et al. 2007; Kardash, 2000; Seymour et al. 2004), various practical lab or field skill improvements (Hunter et al., 2007; Kardash, 2000; Lopatto, 2004, 2007), clarification of career paths (Hunter et al. 2006, Lopatto, 2007; Seymour et al., 2004), and enhanced career preparation (Hunter et al., 2007, Junge et al., 2010). Less understood is the long-term relationship between participation and long-term impacts. Only recently have investigations into longer term benefits of URE been called for and implemented (Harsh, Maltese, & Tai, 2011).

Typically, promoting interest and matriculation into graduate programs or research positions has been a primary outcome tracked since before the 1998 Boyer Commission Report (NASEM, 2017). For example, outcomes as used by Alexander, Foertsch, and Daffinrud (1998) were identified as degree- or career-oriented, where students were tracked after participation in a summer program to determine rates of retention, completion, and successful employment. This education and career outcome is used extensively by URE programs, particularly those with missions of retention and training of women and minorities in STEM fields. Student interest in graduate studies also has been documented (Russell et al., 2007, Seymour et al., 2004). An evaluation by Junge et al. (2010) suggests that a summer URE program at Emory University positively impacted students' interest in, preparedness for, and pursuit of graduate studies or professional careers.

Germane to the context of this research, in forestry and other natural resource management fields are good communication skills that are critical for graduates entering the work force (Sample, Bixler, McDonough, Bullard, & Snieckus, 2015). Additionally, some undergraduate curricula are being arranged to support a greater emphasis on "society-ready" graduates (Bullard et al., 2014). Given the importance of sharing research outside the immediate scientific community, little attention in URE literature is given to elements of formal communication to peers or lay audiences. Faculty mentors note that opportunities for communication are an essential program feature (Lopatto, 2003). The culmination of URE programs often includes participation in an event where undergraduates share research through oral or poster presentations and, in some cases, a formal report. This final event is often the extent of a student's project communication and results to those outside the immediate research group. While authorship in a peer-reviewed journal article is touted as a criterion for program success (Beninson et al., 2011), the frequency of this outcome as a result of undergraduate research is not well publicized. Many URE participants may have successful experiences with smaller projects that contribute to larger work but would not typically merit co-authorship, particularly in professional academic journals. For example, a review of the USDA Scholars Program at Virginia Tech identified that five of 42 students participating in a summer URE were co-authors on peer-reviewed undergraduate publications (Good, McIntyre, & Marchant, 2013). However, student authorship rates may be higher in other disciplines (Dillner, Ferrante, Fitzgerald, & Schroeder, 2011).

Undergraduate research-associated benefits are routinely measured using self-report surveys, and prior systematic reviews identify a need for broad utilization of validated and reliable measures such as the Survey of Undergraduate Research Experiences (Lopatto, 2007) that may be used in a pre-post format, Undergraduate Scientists-Measuring Outcomes of Research Experiences Student Survey (Maltese, Harsh, & Jung, 2017), and retrospective self-assessments (Hunter, et al., 2011). To date, retrospective self-assessments may be most widely used due to its development process and association with the NSF Biology REU Sites program. Other studies add validity to self-report measures using mentors' evaluations of perceived undergraduate gains, or other data sources such as journals or interviews for triangulation (Linn et al., 2015). Some evaluation tools have been subjected to validation-related processes such as confirmatory factor analysis, although resulting models may still benefit from refinement to improve model fit for measured constructs (Weston & Laursen, 2015). Other survey evaluation tools may not account for the diversity of mechanisms by which benefits are accrued.

Mentor outcomes

Impacts on mentors resulting from training undergraduate researchers remains an area in need of study (Baker et al., 2015). While some immediate benefits to undergraduates are well documented, approximately 13% of reported research in the last decade examined impacts on faculty or graduate student mentors (Haeger et al., 2020). In an exploratory study Dolan & Johnson (2009) reported that graduate and postdoctoral students experienced a wide range of previously theorized gains in personal, cognitive, and professional domains. This work on outcomes is supported by a small number of additional exploratory reports that frequently use qualitative research methods (Dolan & Johnson, 2010; Laursen et al., 2012; Luchini-Colbri & Wawrzynski, 2014; Reddick et al., 2012).

Several questions exist regarding the role of mentorship in URE to further understand how mentors and, by extension, their departments and institutions benefit from providing and expanding URE offerings (Haeger et al., 2020; Linn et al., 2015). A study of faculty at higher education institutions identified that institutional context may be associated with greater involvement of faculty mentors for undergraduate researchers, with faculty in life sciences, at liberal arts, and at historically black colleges and universities having greater likelihood of undergraduate involvement (Eagan et al., 2010). For institutions with graduate programs and greater emphasis on research, the primary mentor for undergraduate researchers may vary between faculty, postgraduate, and other positions such as technicians or even advanced undergraduates. As a result, distinctions in outcomes may exist between graduate student mentors in URE and more established faculty. Younger scientists-in-training may benefit from mentoring in multiple domains of gains and other ways, and they may become established members of their communities of practice (Reddick et al., 2012).

Motivations for and challenges of mentoring undergraduates in research may be more well-identified than other mentor specific considerations. Some studies identify that faculty motivations are altruistic and include promoting interest in research and recruiting students, although motivations may just as frequently be instrumental in nature (Foertsch et al., 1997; Hayward et al., 2017; Reddick et al., 2012). Interviews with faculty mentoring undergraduate researchers as part of UW-Madison's summer URE programs identified motivations and barriers for their participation (Foertsch et al 1997). Interestingly and potentially in consideration of undergraduate-postgrad-faculty triad models (Dolan & Johnson, 2010), Foertsch et al. (1997) found the majority of interviewed faculty mentors attributed their participation to provision of opportunities for graduate students to gain experience mentoring. Lack of time and research funding for supporting projects and student workers are frequently identified barriers across multiple studies (Adedokun et al., 2010; Baker et al., 2015; Foertsch et al., 1997). Other challenges associated with providing mentoring are associated with ambiguity or lack of support at the institutional level, such as mechanisms for providing internal funding, course-release time, or consideration of mentored URE programs in tenure and promotion considerations (Haeger et al., 2020).

URE Elements

While undergraduate research is documented to produce numerous and varied benefits to undergraduate students, researchers have given less attention to sources of these benefits (Lopatto 2003, 2007; Laursen et al. 2010; Thiry & Laursen, 2011; Thiry, Laursen, & Hunter 2011). Elements or components of successful programs have some exposure in the literature, although there is little consensus on the categorization of these components. Alexander et al. (1998) document three broad elements, or roles, from a multi-year, minority focused, summer URE program at Rice University. Authors identified critical components for helping minority students become interested in engineering, mathematics, and computer science research and graduate school. These included the program director, the student community, and the research project. Additionally, Alexander et al. (1998) specify characteristics of research projects leading to student outcomes. Working on open-ended and real-world problems, increasing disciplinary knowledge and its application, defining and refining career and research interests, introductions to academia and graduate studies, and collegial interaction with mentors. Lopatto (2007) used multiple linear regression to link summer URE components to students' self-reported general sense of the program as a learning experience. Program components used in this study were: 1) preparing an application or writing a proposal, 2) research seminar participation, 3) lab safety seminars, 4) ethics instruction, 5) a social activities program, 6) on campus housing/food, and 7) final presentation of work. Of these program components, only the final presentation was statistically correlated to students' overall evaluation of the program. These findings build on Lopatto's (2003) prior work highlighting broad categories of program structure and mentor consideration.

In addition to general URE elements, programs focusing on recruiting and encouraging minority students may include other elements tailored to this group. Gates, Teller, Bernat, Delgado, & Della-Piana (1999) discuss components of the affinity research group model as a mechanism for undergraduates to participate in small and large research group activities. They include five essential elements for establishing effective research communities: 1) positive interdependence, 2) face-to-face “promotive” interaction, 3) individual accountability, 4) group and social skills, and 5) group processing. Each of these elements was incorporated into the five affinity group model components: 1) orientation, 2) research project framework, 3) defined deliverables, 4) weekly and monthly meetings, and 5) outreach involvement. Elements in the general affinity group model were loosely linked to attitude increases relative to personal, social, and professional skills (Gates et al., 1999). Laursen et al. (2010) identify features of URE programs, including specifically those that target minority students, as three broad categories: 1) general features of research that promote benefits and outcomes, 2) program features valuable for minority students, and 3) uncommon features that address minority student needs. Additionally, Laursen et al. (2010) included individualized mentoring by an experienced researcher, carefully selected projects matched to a student’s abilities, multiyear engagement, early entry (starting before junior or senior years), emphasis on formal profession communication, multiple mentors, peer mentoring, persons of color in visible leadership positions, and academic monitoring and support.

Understanding the mechanisms through which URE provide benefits is limited, and experts identify a need to relate URE features to participant benefits (NASEM, 2017). Perhaps the most critical and well-studied component of URE is the mentor’s role in guiding undergraduates through research and enculturating them into associated communities of practice (Shanahan et al., 2015). Organizations and other groups associated with URE have developed “best practices” based on expert opinion, observations, and limited research (Hensel 2012; NASEM, 2017). However, little is known about the frequency or degree to which these are implemented in practice.

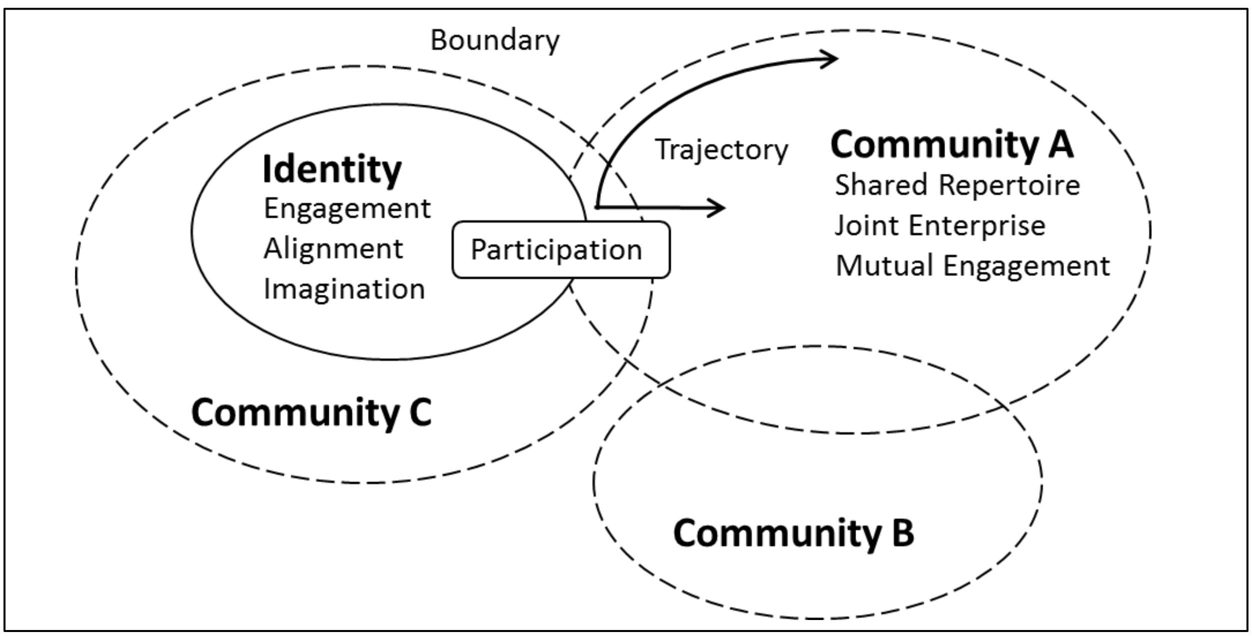


Figure 2.1. Conceptual model representing elements of community of practice theory including an individual’s learning through modes of identification (engagement, alignment, and imagination) relative to participation in a patchwork of communities. Individuals develop identity and display competence via community elements of participation (shared repertoire, joint enterprise, and mutual engagement) resulting in a trajectory.

Theoretical Framework

Community of Practice (COP) is a social learning theory developed by Lave and Wenger (1991) in an introductory text on the concept of situated learning (Figure 2.1, Table 2.1). Community of practice theory is implemented under other names at many corporations and organizations as the theory spreads and is studied (Neufeld, Fang, & Wan, 2013). Lave and Wenger's (1991) conceptual development of a COP is centered on a participant's "legitimate peripheral participation." This process involves a novice member actively participating in the community's authentic practice such that the novice gradually shifts from the periphery of a community boundary toward more knowledgeable full membership in the interior (Hunter et al., 2007). Learning in a COP relies on four components: 1) meaning as changing ability – individually and collectively – to experience our life and the world as meaningful; 2) practice as the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action; 3) community as social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence; and 4) identity as how learning changes who we are and creates personal histories of becoming in the context of our communities (Wenger, 2008, p. 5).

Through participation, novices are increasingly introduced to shared knowledge and skills of the practice. Full enculturation into COP requires more than just greater commitments of time, effort, and responsibility. Novice members must also develop a greater sense of identity as a member of the practice. Thus, in URE programs an undergraduate researcher's identity as a researcher in training is an essential element of effective learning (Thiry & Laursen, 2011).

COP as a social learning theory was further developed by Wenger (1998, 2000) into a formal framework for organizational and individual learning. COP as a social learning system hinges on a definition of learning as the tension between social competence (knowledge and skills the community deems important) and personal experience. Also critical to the theory are concepts of participatory modes of belonging: engagement, alignment, and imagination (Wenger, 2000). For increased accuracy, Wenger (2010) later termed these as modes of identification. Participation within the community and reflection on one's identity relative to the community leads to an interplay that shapes how the community's and an individual member's knowledge and identities change. Researchers also study COP in businesses and organizations to analyze how individuals form their identities and make meaning of the community. Neufeld et al. (2013) noted growing practical and academic interest in COP theory relative to organizational settings, but that limited academic research has been conducted on the theory. Situated learning and COP are also referenced in studies on undergraduate research (Hunter et al., 2007; Thiry & Laursen, 2011; Villa, Kephart, Gates, Thiry, & Hug, 2013) but are not otherwise heavily drawn on or examined within an undergraduate research context.

Learning is a social definition dependent on knowledge that individual members in a COP have come to establish, and knowledge is the display of competence as defined by the social community (Wenger, 2000). Although this display depends on an individual member's identity and the knowledge gained as a community member, these sources of knowing are harmonic. Competence becomes dynamic as the composition of the community alters as members participate in the practice of the community over time (Wenger, 2000). Communities often overlap, and individuals belong to and develop full identities through multimembership (Handley, Sturdy, Fincham, & Clark, 2006; Wenger, 1998). This concept also exists as "fabric of communities" or "networks of practice" (Brown & Duguid, 2001). Before an individual becomes a peripheral or inward member of a community, they bring to the community a prior identity based on membership and interaction with other communities. Competence is comprised of three elements of participation within COP: joint enterprise, mutual engagement, and shared repertoire. These dimensions are described as the "relation by which practice is the source of coherence of a community" (Wenger 1998, p. 72).

Negotiation of a joint enterprise holds a COP together by: the result of collective negotiation reflecting the complexity of mutual engagement, the negotiated response to the community's situation as they are in the process of pursuing it, and an integral form of mutual accountability among participants. Joint enterprise also includes the mutually agreed upon reactions to external and internal forces and influences as the community navigates through its position in the broader system of communities. A COP is not isolated and may require a community to negotiate responses to external influences (Wenger, 1998). Members' negotiation of the enterprise as a group implies the importance of mutual accountability and its role in a given member's authorship of their identity and meaning as an individual and as part of the community. Enterprise negotiation is a process that defines the boundaries of the community (Neufeld et al., 2013) and is a source of mutual engagement (Wenger, 1998).

Joint enterprise relative to URE settings is the common identity of what the community

Table 2.1. Important terms in the Community of Practice framework, from Wenger (1998).

Term	**Definition**
Practice	Development of a shared set of resources through time and interaction in pursuit of an interest
Community	A group of members engaging in joint activities and discussions, helping each other, and sharing information
Mutual engagement	Personal interaction among community members in negotiating meaning
Shared repertoire	Collection of resources (including objects, processes, and concepts) used in negotiating meaning
Joint enterprise	Pursuit of a collective, negotiated goal or situational response that implies mutual accountability
Identity	Negotiated experience of self, including membership in multiple communities and learning trajectory
Engagement	Work of active involvement in mutual processes of negotiation of meaning
Alignment	Work of coordinating energy and activities in order to fit within broader structures and contribute to broader enterprises
Imagination	Work of creating images of the world and seeing connections through time and space by extrapolating from our own experience
Trajectory	The constant, temporal process of constructing identity in social contexts relative to membership
Boundary	A fluid division between a community of practice and outsiders based on competence and experience
Participation	The process of being actively involved in the practice of social communities and constructing related identities

or research group aims to accomplish. Enterprise also acts as a form of accountability for the undergraduate researcher in setting and meeting goals during their internship or apprenticeship. From the undergraduate's point of view, understanding the current state of the community and being able to contribute in navigation toward the community's goals should affect their identity as an individual and as a member of the practice.

A COP exists due to the interactions of individuals that negotiate meanings amongst themselves, and the practice results from this shared meaning held by the members. Accordingly, membership in a community is the product of mutual engagement (Wenger, 1998). Sustained interactions of mutual engagement organized about the practice form and maintain the community's purpose. This maintenance requires work that may or may not be as visible as other "instrumental aspects" of the practice; work may be performed subtly and passively. Wenger provides the example of an experienced member of a claim's processing community setting out a dish of candies on her desk, and this act functions as a mechanism for positive engagement (Wenger, 1998). Mutuality within a COP reflects the interactions that establish a community's norms and relationships (Wenger, 2000). Inclusion in a community is important for passing on information about the practice and for fostering through engagement the social relationships that help smooth future interactions. Mutual engagement includes practical communication and sharing of knowledge that gets work done as well as interpersonal engagements that allow for problem solving (Neufeld et al., 2013). Wenger's (1998) theory also allows for constructive tensions, conflicts or competition in a community that can lead to greater degrees of cohesion among members.

Mutual engagement in a URE setting includes the interactions that contribute to achieving the research group's goals while also providing scaffolding to help an undergraduate understand and embrace the community's repertoire and enterprise. Engagement is also a critical function by which a student develops an identity as a contributing community member and also as a scientist or researcher. Mentors function as brokers to the community by helping enculturate undergraduates. This brokering leads to learning and to altering or confirming an undergraduate's trajectory as it relates to academic or career plans. Mutual engagement between novice undergraduates and more established members is important for contributing to professional socialization, intellectual support, and personal/emotional support.

The third element of participation, shared repertoire, includes the various resources that a community has taken up and/or adopted during its existence (Wenger 1998). These resources can include routines, procedures, terminology, roles, and physical tools that participants share to accomplish work and shape interactions (Brown & Duguid, 1991; Neufeld et al., 2013). Shared repertoire incorporates aspects of participation and reification, which Wenger uses to mean "the process of giving form to our experience by producing objects that congeal this experience into 'thingness'" (1998, p. 58) that creates a focal point for conveying meaning. A community's shared repertoire develops and accumulates over time through ongoing interpersonal engagement. These tools can be used to reflect the community's history and can also be used in negotiating new situations and making meaning. Shared repertoire's inherent ambiguity can make processes within the practice difficult as members may not have equal understanding of a given resource, but it does allow for further dynamic mutual engagement and development of shared meaning (Wenger, 1998). Boundaries form due to ambiguity and individual differences in meaning and competencies when members negotiate a shared practice (Wenger, 2000).

Shared repertoire relative to URE is the collection of procedures, tools, language, roles, and content knowledge of a participant's research community. These elements may function as boundaries, peripheries (a boundary with a door for entry to the community) or artifacts that give further access to the research community and greater understanding of its practice. As students learn more about the community's repertoire, they may become increasingly capable of interacting within the community and sharing its resources to further its goals.

Three modes of belonging in COP theory are the types of work an individual performs while developing an identity relative to a community (Wenger, 1998). Engagement encompasses productive personal interactions such as formal meetings, informal talks, or group activities. Imagination relates to one's self image, the community, and reflection on an individual's situation and possibilities relative to community membership(s). Alignment is participation where activities central to an individual's work are compatible with community processes such that they achieve higher goals than a given individual may achieve alone. Alignment also involves the concept of power where participation or non-participation of a given member is influenced by the community or individual members. Each mode of belonging provides a different element to the construction of the social learning system and personal identity. Additionally, each mode necessitates different kinds of work, like joint activity through formal or informal meetings, or active reflection on engagements, concepts or identity. These types of work are done to navigate across and within boundaries and to construct and regulate identities.

Communities of practice are not isolated from individuals or other communities, and this state is where the concept of boundaries comes into play. As communities arise from different enterprises, ways of engagement and various repertoires, boundaries between members and non-members are fluid (Wenger, 1998). Conceptually, individuals can and often do have membership in multiple communities. Participation and reification allow the crossing of boundaries into different practices through two types of connections: boundary objects and brokers. In addition to connecting communities, boundaries offer learning experiences due to the tendency for experience and competence to diverge. When these two attributes are in close tension during boundary interactions, learning can be increased for individuals and communities (Wenger, 2000). The degree of divergence between competence and experience determines how much learning is likely to take place. The practice itself may also become a connection between different communities, particularly in a larger organization. Through established boundary practices, overlaps between practices, and peripheries, individuals not on trajectories toward full membership may become members of a community. The idea of belonging or imagining the location occupied within a community is closely tied to participation and the location of an individual relative to the community's periphery (Handley et al., 2006).

Identity is an integral concept that expands the COP framework by including a focus on an individual person and by looking outward from the community through examining the processes of identification and social organization (Wenger, 1998). The community dimensions of mutual engagement, joint enterprise, and shared repertoire are applicable to identity. Wenger draws parallels between community and identity by characterizing identity as "a negotiated experience", "community membership", a "learning trajectory," the "nexus of multimembership," and a "relation between the local and the global" (Wenger, 1998, p. 150). Identity as a function of competence determines membership within a community and is a critical aspect of social learning. First, an identity is the convergence of personal experience and competence. Second, one's ability to engage and suspend an identity determines how well boundaries are negotiated or navigated. Third, identities are the realization of communities and boundaries that have been experienced by an individual. Furthermore, the three modes of belonging function as a means of negotiating identity, trajectory, and membership in a community. Each mode requires a different kind of work, and each may affect another. If tensions or conflicts arise that require an individual to negotiate their identity, they may change trajectories or choose to remain a marginal participant within a community (Handley et al., 2006; Wenger, 1998). Within the context of URE, students may alter or reinforce their inbound trajectories toward graduate studies as an insider. Students performing undergraduate research may bolster their identities as researchers in training or negotiate their trajectory toward peripheral or outbound paths.

Table 2.2. Principles for designing cognitive apprenticeship environments, borrowed from Collins (2006, p. 50).

Domain	**Principle**	**Definition**
Content		Types of knowledge required for expertise
	Domain knowledge	subject matter specific concepts, facts, and procedures
	Heuristic strategies	generally applicable techniques for accomplishing tasks
	Control strategies	general approaches for directing one's solution process
	Learning strategies	knowledge about how to learn new concepts, facts, and procedures
Method		Ways to promote the development of expertise
	Modeling	teacher performs a task so students can observe
	Coaching	teacher observes and facilitates while students perform a task
	Scaffolding	teacher provides supports to help the student perform a task
	Articulation	teacher encourages students to verbalize their knowledge and thinking
	Reflection	teacher enables students to compare their performance with others
	Exploration	teacher invites students to pose and solve their own problems
Sequencing		Keys to ordering learning activities
	Increasing complexity	meaningful tasks gradually increasing in difficulty
	Increasing diversity	practice in a variety of situations to emphasize broad application
	Global to local skills	focus on conceptualizing the whole task before executing the parts
Sociology		Social characteristics of learning environments
	Situated learning	students learn in the context of working on realistic tasks
	Community of practice	communication about different ways to accomplish meaningful tasks
	Intrinsic motivation	students set personal goals to seek skills and solutions
	Cooperation	students work together to accomplish their goals

Complementary Frameworks to Community of Practice: Cognitive Apprenticeship

Brown, Collins, and Duguid (1989) developed work on situated learning and an instructional model termed cognitive apprenticeship (CA) where, like COP, learning takes place in context. Theory includes content, method, sequencing, and sociology as four dimensions of a learning environment (Table 2.2). Similar to COP, CA makes use of content and sociology, where the content dimension includes domain knowledge and strategic knowledge required for establishing competence. Sociology as a dimension incorporates COP as well as situated learning, intrinsic motivation, and cooperation to drive active engagement and communication among participants. These two theories overlap, but each has a critical component of learning that is not explicitly focused on through the other. Where CA differs from COP is explicit incorporation of pedagogy through method (six teaching strategies) and sequencing of various learning activities (Collins, 2006). Additionally, this theory touches on but lacks the explicit focus on identity development as a result of participation through modes of belonging that COP incorporates.

Theoretical support for the implementation of URE comes from the CA instructional model. Brown et al. (1989) argue for the concept of CA as a means of situating learning. The term apprenticeship highlights the centrality of activity in learning and notes the "inherently context-dependent, situated, and enculturating nature of learning" (Brown et al., 1989). The authors explain apprenticeship's implied paradigm of modeling activities, coaching apprentices through them, and empowering apprentices to continue without support. Use of the term "cognitive" emphasizes the idea that apprenticeships go further than merely providing physical skills needed to carry out tasks (Brown et al., 1989).

Under the CA model, meaningful concept learning is best approached through apprenticeships where novices work intensively under the mentorship of experts to accomplish tasks relevant to the situation. These kinds of apprenticeships allow novices to learn and practice performance-related skills while also providing opportunities to consider tasks in ways similar to experts in the discipline (Kardash, 2000). The CA model rests on assumptions (Kardash, 2000; Shuell, 1997) that: 1) learning is a social process; 2) competence in a domain is defined in terms of expertise rather than innate ability; 3) meaningful learning is active, constructive, and self-regulating; and 4) learning activities should reflect the real-world rather than academic tasks performed without context. When these assumptions are met, apprentices completing the duration of the apprenticeship model should become masters of their practice and be capable of exploring other problems within the domain.

Dennen (2004) describes two of the necessary components of cognitive apprenticeships: modeling and scaffolding. Education in a CA relies on reifying processes into steps visible for learners to understand and practice. Modeling is the process of demonstrating thinking or action through a cognitive or behavioral activity. Undergraduate research experiences rely on modeling as a means of transferring process understanding from mentors to students. An active modeling experience for students engages them in observation followed by reflection and practice. Proper modeling including these steps strengthens the process and allows for application of knowledge to new situations (Dennen, 2004). Mentoring is a form of participation through mutual engagement where the student gains access to a community's shared repertoire.

Supporting students through handling tasks with gradually less support is known as scaffolding. Scaffolding is similar to the COP concept of tension and has roots in Vygotsky's (1987) zone of proximal development where task objectives are just out of reach of a student's current ability. With the mentor's supports, students learn the knowledge and skills required to attain goals. Consequently, new tasks are given and the zone shifts appropriately adjusting to the task and student's ability. Of note is that individuals develop awareness of cultural structures, norms, and tools through this process. Thus, scaffolding undergirds the notions of situated learning and social interaction as inherent parts of CA (Dennen, 2004). Intersubjectivity, the shared meaning derived from negotiating understanding from mentor and student perspectives, is a component of scaffolding. Intersubjectivity shares similarities with COP theory's negotiated meaning in that where divides in understanding occur during a learning situation, the mentor and apprentice engage in a negotiation of meaning to help the student comprehend the nature of the task and its purpose (Dennen, 2004).

Coaching is another critical CA component where mentors guide apprentices through the process of learning (Collins, Brown, & Holum, 1991). A mentor's coaching encompasses challenging the apprentice, providing encouragement and motivation, offering feedback, and strengthening weaknesses. Taking an interest in the student's well-being is important to effective coaching. Dennen (2004) notes that coaching and mentoring are often interrelated, but coaching includes support with concrete, goal-oriented tasks.

URE may function as CA by employing pedagogical practices associated with authentic experiential education. Kardash (2000) identifies features qualifying URE as CA. First, internships necessitate that participants have enough background knowledge on which to scaffold a learning experience. Second, skills taught by mentors include those from higher cognitive orders such as hypothesis formation and testing, information synthesis, and problem solving. Third, internships can be interdisciplinary and require participants to synthesize and integrate information from a variety of disciplines. Fourth, participants may be encouraged to "think outside the box" and apply new strategies or concepts while meeting high performance standards. Last, outcomes of UREs are complex and may not be predictable.

A CA may occur naturally within COP as newcomers are enculturated and develop a trajectory relative to that community. Apprentices engage in learning activities under community member mentorship that benefit both the apprentice and community. Apprentices gain access to the community's repertoire through a mentor's coaching and scaffolding through various tasks with authentic goals. Communities benefit from having new perspectives and abilities that contribute to their repertoire as mentors better understand their apprentices' abilities.

Table 2.3 is organized by relevant situated learning categories with priority placed on COP. For example, the CA "content" domain elements fit within the COP shared repertoire. These include components gleaned from situated learning writings (Collins, 2006; Wenger, 1998) and URE literature (John & Creighton, 2011; Laursen et al., 2010; Lopatto, 2003, 2007) where descriptions of URE program components (e.g., discussion on ethics) have been described by science faculty and / or students.

Situated Learning and URE Research

Situated learning and COP theory have not gone unnoticed by URE researchers, in particular relative to multiple publications from the Ethnography and Evaluation Research group at University of Colorado at Boulder. Hunter et al. (2007) set out to explore how student learning occurs in intensive, summer long URE at four liberal arts colleges with established programs. Multiple constructivist learning theories including situated learning were considered when evaluating data from this ethnographic study of faculty mentor and undergraduate mentee observations on undergraduate benefits. The authors conducted in-depth interviews 60-90 minutes in length with both undergraduate participants (n=76) and faculty mentors (n=80) among the four programs. Interviews were semi-structured and protocols focused on "the nature, value and career consequences of UR experiences, and the methods by which these were achieved" (Hunter et al., 2007, p. 7). Interview transcript analysis indicated that both faculty and undergraduates identified the same types of benefits to undergraduates. However, each group spoke about benefits differently. Mentors saw benefits as important developmental steps toward becoming professional scientists, while students spoke of benefits as contributing to personal growth and understanding of science as practice. Respondents' observations in the Hunter et al. (2007) study allowed the authors to make connections to constructivist learning theories, particularly the notion of situated learning as a mechanism for student movement further into the

COP. Participants identified intellectual, personal, and professional transition outcomes that the authors attributed to situated learning and, in the case of undergraduates, legitimate peripheral participation. Three categories of benefits — "thinking like a scientist," (growth in intellectual and practical understanding of how research is done and the nature of science) "becoming a scientist," (attributes of professional practices, attitudes, temperament and identity) and "personal-professional gains" (increased confidence and ability to form collegial relationships) — accounted for 62% and 61% of observations by faculty and students, respectively. Other benefits identified include clarifying a career path, preparation for careers, work-related skills, generalized benefits (e.g., work experience, financial income, and resume building), and working independently.

Table 2.3. Elements of URE practice identified in literature, community of practice, and cognitive apprenticeship theory as properties of situated learning (Collins, 2006; John & Creighton, 2011; Lopatto, 2007; Wenger, 1998).

Shared Repertoire	Joint Enterprise	Mutual Engagement
Vocabularies	Mutual accountability	One to one mentoring
Literature Review	Goal setting	Frequent small group meetings
Nature of science	Sense of belonging	Research seminars
Ethics training	Project ownership	Peer group structure
Roles in the community	Sense of achievement	Informal social activities
Procedural knowledge	Defined deliverables	Final research presentations
Equipment use	Identity as a researcher	Outreach beyond the group
Laboratory safety	Application process	Initial participant orientation
Heuristic strategies	Written proposal	Discussion on grad school
		Co-located participants
Pedagogical Method	**Sequencing Method**	**Physical Needs**
Modeling	Tasks increasing in difficulty	On campus / site housing
Coaching	Tasks in diversity of situations	Meals on campus
Scaffolding	Global to local skills	Access to equipment
Articulation		
Reflection		
Exploration		

Similar to Hunter et al. (2007), research on gains made by students in liberal arts college summer URE programs, Thiry and Laursen (2011) utilized situated learning theory for studying student-mentor interactions in four varied URE programs across two research institutions. In their study, a research mentor was defined per Guberman, Saks, Shapiro and Torchia (2006, p. 99-100) as an ''individual who helps another with one or more aspects of his or her personal or professional development'' including individuals functioning as advisors, supporters, tutors, masters, sponsors, and models of identity. The authors used a qualitative approach to identify students' perceptions of faculty and research group support on intellectual, professional, social, and personal levels and how support aided in constructing student identities as scientists. A comparative approach was also taken to examine differences in outcomes from novice and experienced URE student views. Thiry and Laursen (2011) found mentors were at various stages in their careers, and undergraduates were mostly advised by graduate students (42%) with the remainder advised by the PI (27%) or post-doctoral researchers (21%). Smaller percentages of students were advised by either other research faculty or advanced undergraduates. Frequent interactions with advisors helped novice researchers gain support and effective mentoring through the areas of professional socialization, intellectual support, and personal support. Professional socialization referred to transmission of values and norms in addition to critical disciplinary knowledge and skills. Intellectual support included help solving problems or identifying the next step for research. Personal support referenced a mentor's general condition of being seen as supportive, accessible, friendly, and taking a personal interest. While students identified a single advisor, these forms of support were rarely attributed to a single person in the research group. Proper mentoring that works to integrate an undergraduate is necessary, and both Thiry and Laursen (2011) and Hunter et al. (2007) provide cautionary anecdotes as approximately 10-15% of undergraduate researchers identified absent or uncaring advisors or being stuck in menial tasks for the duration of their experience. Such minimal practices are not likely conducive to enculturating undergraduates to the COP.

Researchers of URE outcomes focus work on positive outcomes and note the possibility of some negative or, at best, neutral outcomes for some undergraduate participants. Furthermore, much of the literature weights toward attention on undergraduates' outcomes over exploring how these communities of practice influence mentors, particularly relatively inexperienced graduate students that make up the majority of contact with undergraduates. Broader impacts of this dissertation include informing current and future URE program developers and coordinators with empirically-based practices on which to build programmatic elements and possibly how to tailor these to ensure that mentors also derive benefits.

Examining natural resources URE programs and their outcomes

Documenting the availability and variety of URE programs in STEM disciplines is challenging such that few reports rigorously collect or analyze data on their structures and functions outside of systematic reviews largely focusing on existing literature emphasizing assessment and evaluation (Crowe & Brakke, 2019; Linn et al., 2015; NASEM, 2017). Funding agencies, such as NSF, or other organizations, such as the Organization of Biological Field Stations, frequently maintain databases of active and/or historical URE programs and opportunities. Some collections are relatively well-maintained but other extant collections have not aged well. Individual URE programs market their availabilities or document cohort years on websites, although internet links may break over time as institutions update their webpages. Beninson et al. (2011) provide program-level characteristics of the NSF Biology REU Sites for 2006-2009. Further, funding cycles for programs sponsored through limited-time grants that do not receive continuation limit opportunities available to undergraduates and inhibit program level data collection as faculty or staff that function as program coordinators or directors shift to other projects. As a result, URE programs may function as hidden populations without formal sampling frames.

Salganik and Heckathorn (2004) describe a snowball type method known as respondent-driven sampling (RDS) for estimating proportions of hidden populations utilizing recruitment patterns and self-reported degree of association. This approach is useful in the proposed research due to the number and obscurity of URE programs, particularly those not funded by large governmental agencies such as the National Science Foundation. Program names, disciplines, coordinators and their contact information for individual URE and relevant programs from compilations of URE are typically available and can be used as an initial starting pool of potential respondents. Program information may be collected until a saturation point is reached and identification of additional programs becomes resource prohibitive. This process assumes personal networks exist, but modifications, such as researcher-led contact sampling, to standard RDS methods have been used in cases where this assumption does not hold (Platt, Luthra, & Frere-Smith, 2015).

Estimation of URE program population sizes may be conducted by implementing capture-recapture methods using at minimum two sampling periods or lists. This technique is frequently used by epidemiologists and wildlife biologists to estimate population sizes and can be applied to social science research (Berchenko & Frost, 2011; Dombrowski et al., 2012). The Lincoln-Petersen method of population estimation provides a population estimate if only two sampling events occur (Seber, 1982). This estimate's sampling events may also include independent lists on which individuals may appear only once or are "recaptured" when appearing on more than one list or sampling event. The Lincoln-Petersen method provides a "naïve estimate" based on the formula:

$$P = \frac{n * s}{t}$$

where P is the population estimate, n is a first sample size, s is the second sample size, and t is the number of recaptured individuals.

Program level data can be provided by coordinators and examined using cluster analyses. Two-step cluster analysis is a technique useful for segmenting populations and developing typologies based on clusters' similarities (Huberty Jordan, & Brandt, 2005). This clustering procedure allows for exploratory data analysis because it does not require a specified number of clusters and it allows both categorical and continuous data types (Norusis, 2012). Huberty et al., (2005) suggest sample sizes are not a limitation and provide no case-to-variable recommendations. However, Sarstedt & Mooi (2014) cite Formann (1984) and suggest a 2^m, where m is the number of clustering variables. Groupings of URE programs resulting from cluster analysis may be further described based on analysis of data that are important predictors of clustering.

Due to the large number of specific indicators and outcomes associated with undergraduate research participation, data reduction becomes an important consideration. Additionally, filtering variables associated with situated learning characteristics becomes necessary. Exploratory factor analysis (EFA) is a data reduction procedure useful for consolidating a large number of variables into latent variables (i.e., factors) manifested by indicators (Field, 2009; Tabachnick & Fidell, 2013). EFA is similar to principal components analysis except that EFA assumes indicators are correlated to some degree and that underlying constructs are related to individual variables that the constructs load. Further, EFA can be used for understanding the underlying structure of latent variables. Specifically, EFA is useful for identifying constructs relative to aforementioned situated learning theoretical considerations, and comparison of outcome domains. Some studies of undergraduate research outcomes used confirmatory factor analysis to support prior domains reported in prior research. However, those models were identified as not meeting thresholds for some fit indices (Maltese, Harsh, & Jung, 2017; Weston & Laursen, 2015). Further, any existing models of situated learning factors in URE contexts may not be available. Individual factors resulting from EFA may be quantitatively estimated through a variety of methods (e.g., sum scoring or averaging variables), but regression factor score estimation is a more sophisticated approach that preserves indicator loading weight and provides standardized data (Tabachnick & Fidell, 2013). Such scores may then be used in further analyses.

Given that prior research suggests multiple domains of gains associated with URE participation, multivariate data analyses may be useful in identifying the degree to which different outcomes are influenced by situated learning factors. Multivariate multiple regression is a technique capable of handling multiple independent, or predictor, variables and multiple dependent, or outcome, variables of continuous data types (e.g., regression factor scores) (Tabachnick & Fidell, 2013). Full model results may be further examined to evaluate predictor effects on individual outcomes. Educational research provides examples of this methodology (Allen & Eby, 2003; Bell, McCallum, & Cox, 2003). Allen and Eby (2003) examined mentorship using confirmatory factor analysis and incorporated factor scores into hierarchical regression models predicting mentorship quality and relationship-based learning. Bell et al., (2003) examined reading disabilities of 105 participants by incorporating cognitive assessment scores from principal components analysis into stepwise multiple regression models that predicted reading and writing skill.

Much published URE literature describes individual program evaluations and may use case study methods. One such natural resources URE program was contained within The Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP), a coordinated agriculture project funded by the US Department of Agriculture's National Institute of Food and Agriculture from 2011-2016 (award 2011-68002-30185; Eigenbrode, Morton, & Martin, 2014). The PINEMAP consortium consisted of 11 southeastern universities and institutions including the United States Forest Service and had research emphases in six disciplinary areas: silviculture, modeling, genetics, economics and policy, education, and extension. PINEMAP's goals included use of educational projects that integrated scientific disciplines and expanded science to public school students and educators. The PINEMAP Fellowship operated from 2012 to 2016 and was a URE that emphasized undergraduates conducting and communicating forestry research to different audiences. This program met criteria for being a program where evaluation would be useful, and a theory-driven, program-oriented evaluation approach by an internal evaluator was used (Fitzpatrick, Sanders, & Worthen, 2011). Evaluation research using quasi-experimental methods occurred throughout the PINEMAP Fellowship's operation and culminated with summative program evaluation arising from mixed-method analysis of undergraduate and mentor participants' survey responses and reflective journals (Babbie, 2010; Fitzpatrick et al., 2011).

Chapter 3: Toward a Typology: The state of natural resources undergraduate research experience programs 2012-2016

3.1 Abstract

Theory, existing research, published evaluations, and expert opinion suggest a broad diversity of structures and purposes of undergraduate research experiences. In practice, little is known about the extent or diversity of undergraduate research experience programs in operation at a given time. A systematic review of undergraduate research experience programs contributing to natural resources research during 2012-2016 was conducted for the purposes of gleaning data related to their structural and functional elements. Respondent-driven sampling in conjunction with a capture-recapture method was used to identify program coordinators of known and undiscovered natural resources URE programs, leading to an estimated population of 127 programs. Of these, 49 program coordinators provided program level data used in two-step cluster analysis. This analysis identified seven predictor variables important for distinguishing between clusters: student pay, summer duration in weeks, site-based co-location, student classification allowed, postgraduate mentors, diversity statements, and academic preparation activities. Cluster analysis indicated seven types of programs: underclass intensive traditional, extended graduate student mentored, professional development, distributed intensive, site-based traditional, shorter duration intensive, and larger long-term programs. Distinguishing among program types will assist program developers when considering how specific components may relate to student recruitment and interest as well as program objectives beyond conducting research.

3.2 Introduction

Outcomes of undergraduate participation in research is a subject of substantial attention among universities, scientific institutions, and funding agencies. However, variations in the structure (i.e., organization and scale) and function (i.e., activities, outcomes, and outputs) of undergraduate research experience (URE) programs are understudied. URE refers to a broad class of programs that provide undergraduate, and occasionally post-graduate and high school students, with opportunities to become researchers. The Council on Undergraduate Research defines undergraduate research as “an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline” (Beckman & Hensel, 2009). Theory, case studies, and individual program evaluations support the idea of substantial variation in the structure and function of URE in light of such a broad definition.

Among available URE opportunities, little research is conducted on the number and variation of available opportunities at national and institutional levels (NASEM, 2017), particularly in non-traditional STEM fields such as natural resources that span disciplinary boundaries. Approximating URE participation also is difficult, and few population estimates exist for both undergraduates and programs. One exception is an evaluation of the National Science Foundation’s (NSF) Research Experiences for Undergraduates (REU) Sites program (Beninson, Koski, Villa, Faram, & O’Connor, 2011). The authors estimated 1,239 acceptances out of 21,000 applications for 106 NSF BIO REU Site programs during 2009. While URE programs are frequently publicly visible, determining abundance of opportunities available to undergraduate students particularly within interdisciplinary fields like natural resources remains challenging due to the lack of a central record of URE programs offerings and marketing. Accordingly, sampling frame limitations qualify natural resources URE as hidden populations, and sampling approaches developed for social science research, such as respondent driven sampling (RDS), are appropriate for estimating opportunities and participation (Salganik & Heckathorn, 2004; Schonlau & Liebau, 2012).

Of the many types of curricular and co-curricular URE opportunities, faculty-mentored apprenticeships (Laursen, 2015) may be the most recognized. Coordinated URE programs based around specific research areas are an extension of the traditional apprenticeship and frequently include undergraduates as cohorts. In apprenticeship models, faculty and undergraduates form one-on-one dyads. Variations on apprenticeships include triads where graduate students or post-doctoral researchers are intermediately experienced researchers both learning and teaching. Other significant URE models include co-curricular research experiences that stem from traditional apprenticeship-styled undergraduate research for individuals and cohorts, and course-based undergraduate research experiences that are becoming more prominent (Auchincloss et al., 2014; Corwin, Graham, & Dolan, 2015; Dolan, 2016). Participation in course-based URE generally results from research-oriented coursework such as chemistry and biology lab courses, but recent growth and adaptation for other academic courses allows classes to address research questions or problems where the outcome or solution is unknown and is of interest to a broader community (Dolan, 2016).

Other URE models include community mentoring whereby pools of networked faculty, graduate students, postdoc researchers, and undergraduates function as communities of practice (Kobulnicky & Dale, 2016; Lave & Wenger, 1991; Villa, Kephart, Gates, Thiry, & Hug, 2013; Wenger, 1998). With the advent of distributed learning technologies and a shift toward interdisciplinary research, the traditional site-based or co-located URE model is also adapted as distributed research experiences become more available (Alford, Leaver-Fay, Gonzales, Dolan, & Gray, 2017; Hubenthal & Judge, 2013; Wood, Oswalt, & SARA Collaboration, 2000). Distributed research experiences occur where students in the same program are placed at different sites based on a mentor's location instead of a model where students and mentors are aggregated at a single site. Of the various formats, the coordinated URE program format, particularly where undergraduates are from institutions other than the hosting institution, allows for identification of individual programs from an external perspective through internet searches, job postings, and social media.

A need exists for identifying the prevalence of best practices utilized in the field by URE programs along with other characteristic information if researchers hope to better understand links between programmatic elements and systemic participant outcomes. Beckman and Hensel (2009) describe the different tensions surrounding URE based on their various functions and structures. While this work largely relates to a formal definition of undergraduate research, some of these tensions have links to URE operations. Sadler, Burgin, McKinney, and Ponjuan (2010) synthesized 53 published empirical studies of research apprenticeships for secondary students, undergraduate students, and pre-professional and in-service teachers. The authors focused primarily on outcomes but tracked program duration, numbers of student participants, and evaluation methods. That synthesis indicated that longer apprenticeship durations, inclusion of supplemental activities that explicitly target intended outcomes, and increased student involvement in the higher order cognitive aspects of research processes are likely to improve outcomes.

Hensel (2012) describes best practices and indicators of excellence in URE including aspects of individual programs identified by longstanding scholars based on experience, but the research lacked empirical support for practice prevalence. Economy, Martin, and Kennedy

(2013) examined whether factors of the NSF's REU Site programs affected student decisions to participate. The authors found that stipend was of primary importance, but project focus, offer date, extramural activities, housing/meal packages, and proximity to home also were important determinants. Blockus (2016) presented various models of URE and structural variations and enhancements based on anecdotes and professional experience. However, that work focused primarily on STEM disciplines and identified a need for greater attention to other disciplines, ways to identify URE (non)participants, and methods for characterizing positive outcomes.

Designing research to study gaps in understanding of the structure and function of URE programs is affected by the lack of a formal population frame, and RDS methods are potentially useful because they may be modified. For example, snowball sampling and other forms of RDS procedures are commonly used to identify and sample hidden populations (Handcock et al., 2015). Salganik & Heckathorn (2004) describe RDS as a sampling and estimation snowball-type technique providing unbiased estimates about hidden populations regardless of the number of initial respondents acting as recruits used in the survey. This technique is useful in accurately collecting information about the composition of particular social groups and can similarly be used in research on URE programs, particularly when selection probability is unknown. A researcher-led RDS approach is useful when populations are particularly fragmented or individuals are new to populations, as with immigrants (Platt et al., 2015). Furthermore, RDS can be used in conjunction with capture-recapture methods to estimate population sizes (Bouchard, 2007; Dombrowski et al., 2012; Platt et al., 2015). Field studies using capture-recapture sampling require a minimum of two independent samples or trapping sessions and effectively sample with replacement. This technique assumes closed populations such that the proportion of marked to unmarked individuals holds constant and all individuals in the population have an equal probability of capture. Effectively, it is sampling with replacement as captured individuals are marked and released back into the population. Recaptures are marked individuals subsequently captured in later sampling events. The second and subsequent sampling events may capture new individuals in addition to potential recaptures. The independence assumption applies also to techniques using multiple sources of information.

In addition to population proportion estimation, RDS allows researchers to collect other data of interest about the population. Many URE program evaluations (empirical and otherwise) exist, but few broad syntheses or reviews of program structure and function have been published (Auchincloss et al., 2014; Sadler, et al., 2010). For example, Linn et al. (2015) reviewed 60 empirical research studies of STEM (biology, chemistry, science, physics) URE programs to determine impacts on student participation and examine opportunities for additional research. However, this study lacked examination of program components other than site implementation, duration, and undergraduate participant rank. Knowledge of natural resources URE program structures, functions, and target populations may shed light on expected participant outcomes.

Objectives in this research were to: 1) estimate the population size of natural resources URE programs operating from 2012 to 2016 in the United States, 2) identify statistical groupings of natural resources URE programs using multiple structural and functional variables, and 3) propose a typology of natural resources URE programs. The variety of structural and functional components implemented in natural resources URE programs were hypothesized to lead to distinct types of programs that share structural and/or functional features. This research contributes to existing understanding of URE by quantifying the number of programs and participation in natural resources programs and by offering data regarding the prevalence of structural and functional characteristics among URE in a specific STEM discipline.

Understanding how similar URE programs are configured may offer models for future coordinators and undergraduate participants to identify types of programs that best represent formats for achieving desired outcomes.

3.3 Methods

This research focused on natural resources URE programs operating in the United States from 2012 to 2016. Programs included multiple undergraduates as a cohort involved in authentic natural resources research for some time and specifically involving the summer, with research or other activities that may or may not extend into the previous or following academic year. The following disciplines were considered as natural resources: forestry, rangeland, fisheries, wildlife, agriculture, soils, hydrology, and geospatial information.

An initial internet search for natural resources URE programs was conducted using combinations of the following search terms in online searches and available public databases (e.g., NSF REU): “undergraduate research”, “experience”, “internship”, “natural resources”, “forestry”, “range”, “fisheries”, “wildlife”, “agriculture”, “soils”, “hydrology”, “geospatial”. Where webpages with individual collections of URE programs were identified, programs under natural resources lists were recorded. Because of difficulty obtaining information for programs no longer in operation and program durations tied frequently to project funding cycles, data collection was limited to programs in operation from 2012 to 2016. Email, telephone, and physical contact information of coordinators and/or directors were collected where available on individual program webpages or other public marketing materials. One-hundred and thirty programs were screened to determine whether programs met established criteria for inclusion as natural resources URE, and 119 programs qualified.

The natural resources URE coordinator survey was developed to collect program level data on a wide variety of structural and functional variables identified in literature as important program components and where little to no data were available in meta-analyses. Initially, coordinators were asked to verify that their program met study criteria and, after confirmation, to complete the rest of the survey. Multiple variables (Table 3.1) were measured for each natural resources URE program in preparation for cluster analysis to identify important variables and to distinguish between different program types. Meta-information collected included methods of distributing URE advertisements and the number of other natural resources URE known to the coordinator (i.e., coordinators’ network sizes). Coordinators were asked at the end of the survey instrument to provide contact information for other natural resources URE programs known to them.

A draft survey was reviewed for coverage and clarity by a panel of four experts in URE program administration and research from three geographically distinct doctoral-granting institutions. Panel members were not associated with natural resources URE and were recruited through the Council on Undergraduate Research listserv. Panel members examined survey and recruitment documents prior to convening to share and discuss suggested changes and improvements. Instructions for respondents and individual survey items were edited for clarity and detail as suggested by the panel. The final version of the survey was administered to natural resources URE coordinators.

Survey administration followed the tailored design method (Dillman, Smyth, & Christian 2009). Initial contact with program contacts involved a personalized recruitment letter through postal mail where possible (57%) or email if postal addresses were unavailable. To incentivize participation, messages included a summary of preliminary data collected from publicly available information on programs collected through internet searches. Messages were followed by phone calls approximately one week later to verify receipt of the initial recruitment message and to clarify program contacts' potential concerns regarding the research. In some cases, individuals could not be reached through either method or contacts declined to participate. Approximately one week following the phone call, personalized automated email messages containing the survey link were sent through Qualtrics software (Qualtrics, Provo, UT) to program contacts. If program contacts did not complete the survey after two reminder messages, the recruitment process was reinitiated for that program with any advertised secondary contacts.

Table 3.1. Variables collected during surveys of natural resources undergraduate research experience program coordinators in 2017.

Variable	Measurement	Operationalization
Structural		
Location distributed*	Binary	Undergraduates distributed among research institutions
Mentor type graduate*	Binary	Graduate student or other type of primary mentor
Undergrad class max*	Ordinal	Highest level of undergraduate admitted
Summer duration*	Continuous	Length in weeks of only the summer components
Pay amount*	Continuous	Dollar value of direct financial compensation
Total program duration	Continuous	Length in weeks of the full program
Non-summer duration	Continuous	Duration in weeks of required time outside of summer
Collaborators	Continuous	Number of collaborating institutions
Funding sources	Nominal	Primary and secondary funding sources
Years operating	Continuous	Number of years in operation
Funding renewal	Binary	Whether program funding was renewed
Openness	Binary	Includes undergraduates external to the host institution
GPA requirement	Nominal	GPA requirement for admission (zero is none)
Pay method	Nominal	How financial compensation to undergraduates occurs
Housing provision	Binary	Whether housing was provided
Housing allowance	Continuous	Dollar amount of housing allowance provided
Meal provision	Binary	Whether meals were provided
Meal allowance	Continuous	Dollar amount of meal allowance provided
Cohort size	Continuous	Average number of undergraduates per year
Mentor size	Continuous	Average number of mentors per year
Applications	Continuous	Average number of applications per year
Application:Size ratio	Continuous	Ratio of applications received to cohort size
Rejections	Continuous	Average number of rejections per year
Incompletes	Continuous	Average number of students not finishing the program
Undergraduate total	Continuous	Total undergraduates completing the program
Functional		
Minority statement*	Binary	Affirmative action / equal opportunity statement
Academic preparation*	Binary	Academic support or intervention activities (e.g., GRE prep, graduate application process workshops)
Seminars	Continuous	Number of planned seminars, lectures, or workshops

Orientation	Binary	Requirement of a formal orientation or 'boot camp'
Ethics training	Nominal	Training in ethics, responsible research, or both
Proposal requirement	Binary	Requirement of a research proposal by undergraduates
Mentor training	Binary	Inclusion of formal training for mentors
Pre-post activities	Nominal	Types of required pre- or post-summer components
Academic credit	Binary	Requirement of academic course credit
Academic credit pay	Nominal	How payment for required credits occurs
Outreach requirement	Binary	Requirement of outreach components
Final reporting	Nominal	Types of required final outputs or reporting

* denotes variable important for clustering

A modified RDS approach in conjunction with capture-recapture methods was used to census the natural resources URE programs with program coordinators as the unit of observation (Dombrowski et al., 2012; Platt et al., 2005). The modified approach, termed 'researcher-led' referral (Platt et al. 2015), was used because natural resources URE are not vulnerable populations where anonymity is critical. This modification served two purposes: obtaining valid network sizes of coordinators and tracking connections between coordinators. During pre-survey recruitment, seven coordinators reported their programs did not meet study criteria because they ended prior to 2012 (n = 1), did not fall within natural resources disciplines (n = 4), were not focused on undergraduates (n = 1), or were not cohort-based (n = 1). One program coordinator declined outright to participate in the survey during pre-survey recruitment.

Respondent-reported personal network sizes often are viewed with skepticism in terms of accuracy (Li, et al., 2018; Wejnert, 2009). Furthermore, a modified RDS approach stays true to the concept of peer-referral while meeting the assumption of sampling with replacement, where in traditional RDS a "coupon" (a tool linking recruiters and recruits) that is offered to, but not taken by, an existing participant is not useful. In other words, a respondent in the first sample would thus be excluded from a second sample. Instead of using coupon codes to mark individual respondents, individuals' names and/or programs they coordinated were used.

Capture-recapture methods using at minimum two sampling periods or lists are frequently used by epidemiologists and wildlife biologists to estimate population sizes and can be applied to social science research (Dombrowski et al., 2012). Respondents to the initial survey distribution described above functioned as the initial sample, and screened reports by program coordinators responding to the survey function as the second sample. Programs identified in both samples were considered recaptures. RDS modifications included screening of programs identified in the second sample and use of capture-recapture estimates. In keeping with RDS methods, sampling continued by contacting new, screened and reported coordinators until no new referrals occurred.

The Lincoln-Petersen method of estimation (Seber, 1982) provides a population estimate if only two sampling events occur through the following formula:

$$P = \frac{n * s}{t}$$

where *P* is the population estimate, *n* is the number of natural resources URE, *s* is the number of screened reports multiplied by the proportion of reported respondents self-identified as natural resources URE, and *t* is the number of recaptured individuals. Cases where respondents self-identified as meeting natural resources URE criteria and were mentioned in the personal network of someone who did not coordinate both programs (i.e., coordinators of multiple programs would not contribute to their programs' recapture) were considered recaptures.

Statistical analyses were conducted using IBM SPSS Statistics (IBM Corp., Armonk, NY). Two-step cluster analysis identified groupings within natural resources URE programs for purposes of constructing a typology. The two-step clustering procedure allows for exploratory data analysis because it does not require a specified number of clusters. Additionally, the two-step procedure is useful due to simultaneous allowance of both continuous and categorical data types (Norusis, 2012; Sarstedt & Mooi, 2014). Standardization of variables is required prior to the analysis, but SPSS performs this natively during the procedure. Because continuous and categorical data were included in this analysis, intercluster distances were determined with log-likelihood measures. The two-step procedure is named for the algorithm's two major steps with the first step preclustering individual cases, which are then entered into a standard hierarchical clustering algorithm using an agglomerative method in a second step (Norusis, 2012). Given the formula 2^m, where m is the number of clustering variables, the clustering procedure was limited to five to seven predictor variables because the sample size was small. Variables entered into the clustering algorithm included both categorical and continuous data types and were selected based on theoretical impact to program structure or function and on previous research identifying distinguishing characteristics of URE programs.

Bivariate correlations and variance inflation factors were examined to verify that multicollinearity issues were not present for clustering variables. Categorical input variables included location (whether the program was site-based), mentor type (whether mentors were graduate students), undergraduate classification, minority statement presence, and academic preparation activities. Continuous variables were automatically standardized during the procedure and included pay amount (US dollars, unadjusted for inflation) and summer program duration (weeks). The statistical software determined the optimal number of clusters based on Akaike's Information Criterion (AIC). Cluster solution validity was assessed through the mean silhouette measure of cohesion and separation. Cluster solution stability was assessed through reordering cases, repeating the analysis, and confirming individual cases were repeatedly assigned to the same clusters.

3.4 Results

The online survey was distributed to coordinators of 119 potential URE programs, and 68 surveys were returned (57% response rate). Eleven respondents noted that their program did not meet criteria. Five coordinators provided no data other than self-identification. Based on 49 usable responses from natural resources URE coordinator respondents, an adjusted response rate of 41% was estimated. Researcher-led RDS provided a sample of 53 natural resources URE programs and 49 program names or contact information ("reports"). Other research implementing researcher-led RDS highlighted benefits to recruitment rates including longer referral chains than traditional RDS without negatively influencing bias associated with referrals (Platt et al., 2015). Further, researcher-led RDS may provide network size estimates smaller than those self-reported, and possibly upwardly biased, in traditional RDS. Non-responses may include programs no longer operating or whose coordinators had changed or considered programs as not natural resources-related.

Twenty-two respondents reported 49 unscreened natural resources URE programs that respondents either coordinated themselves (i.e., coordinators of multiple natural resources URE) or knew the coordinator. Many respondents (46%; n = 31) did not report specific knowledge of another natural resources URE, thus implying personal network sizes of zero. Given 11 respondents (16%) self-reported their programs were not natural resources URE, an estimated 16% error rate was identified when classifying the 119 programs based on their publicly available advertisements. The Lincoln-Petersen formula yielded a population estimate P = 127 natural resources URE programs operating from 2012 to 2016 calculated from initial survey respondents (n = 53), s = 12 nonduplicate, verified respondent reports, and t = 5 duplicate programs.

Two-step cluster analysis using AIC for model selection and six input variables identified a seven-cluster solution for n = 49 natural resources URE programs. A final, fixed cluster number model including program summer duration as an additional clustering variable decreased the clustering algorithm's mean silhouette measure from 0.58 to 0.52 and cluster size ratio from 6.5 to 3.25 while increasing the relative importance for each predictor variable. Mean silhouette measure for the final model solution indicated good separation between clusters using 0.5 as a threshold for good separation (Sartstedt & Mooi, 2014; Figure 3.1). Cluster sizes ranged from four (8.2%) to 13 (26.5%) programs (Figure 3.2). Variable predictor importance for all input variables was greater than 0.47 (Figure 3.3).

Model Summary

Algorithm	TwoStep
Inputs	7
Clusters	7

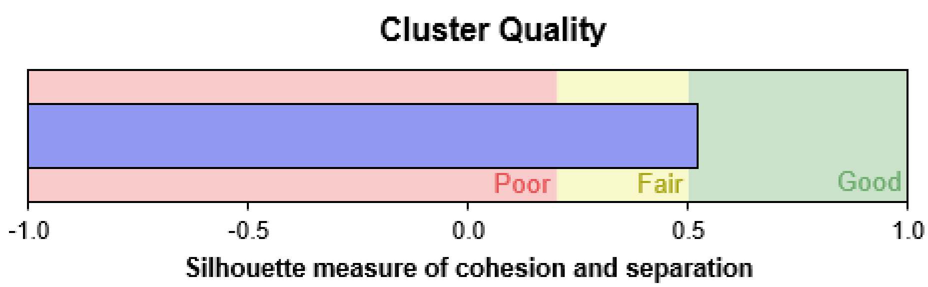
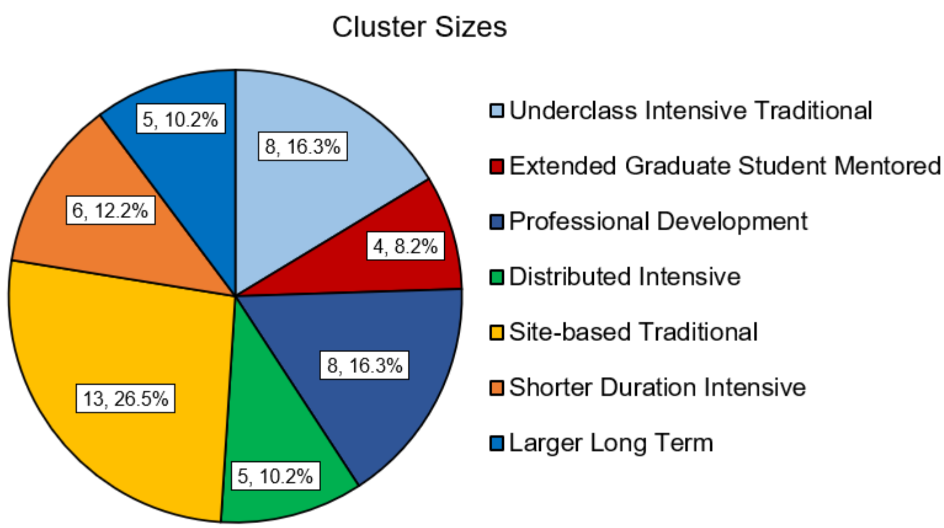


Figure 3.1. Model summary of two-step cluster analysis indicating a good measure of separation between clusters of natural resources URE in operation from 2012 to 2016.

Descriptive statistics of all surveyed natural resources URE programs are identified in Table 3.2, and general descriptions of clusters are provided in Table 3.3. Programs were mostly collaborations between multiple (71%; n=35) institutions and were predominantly site-based (78%; n=38). Most programs occurred only during summer, but six programs required additional time beyond summer. Programs averaged about nine mentor and 11 undergraduate positions per year. Primary mentors were generally tenure-track faculty (49%; n = 24) followed by other professionals in the field or mixed mentorship (25%; n= 12), graduate students (10%; n = 5), non-tenure-track faculty (10%; n = 5), post-doctoral researchers (4%; n = 2), and upper-class undergraduates (2%; n = 1). Most programs (90%; n = 44) admitted only students that completed at least freshman year, and 31% (n = 15) of programs were limited to students beyond sophomore status.

Minority or affirmative action statements were reportedly on 78% (n = 38) of programs' recruitment information. However, only one program was exclusively for minority students, and no programs included only females or students with disabilities. Programs with GPA requirements had minimums of 2.0, 2.5, 3.0, or 3.5 on a 4.0 scale. Ninety percent of all programs expected that undergraduate participants work full-time. With one exception admitting only institutional students, all other programs were open to students from external institutions. Programs received a large range in applications, and averaged 12 applications per position each year. A majority (84%; n = 41) of programs reported annual rejections of offers by one to 15, or about three on average, undergraduates.



Size of Smallest Cluster	4 (8.2%)
Size of Largest Cluster	13 (26.5%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	3.25

Figure 3.2. Cluster sizes and percentages obtained through two-step cluster analysis of data collected about natural resources URE programs operating from 2012 to 2016.

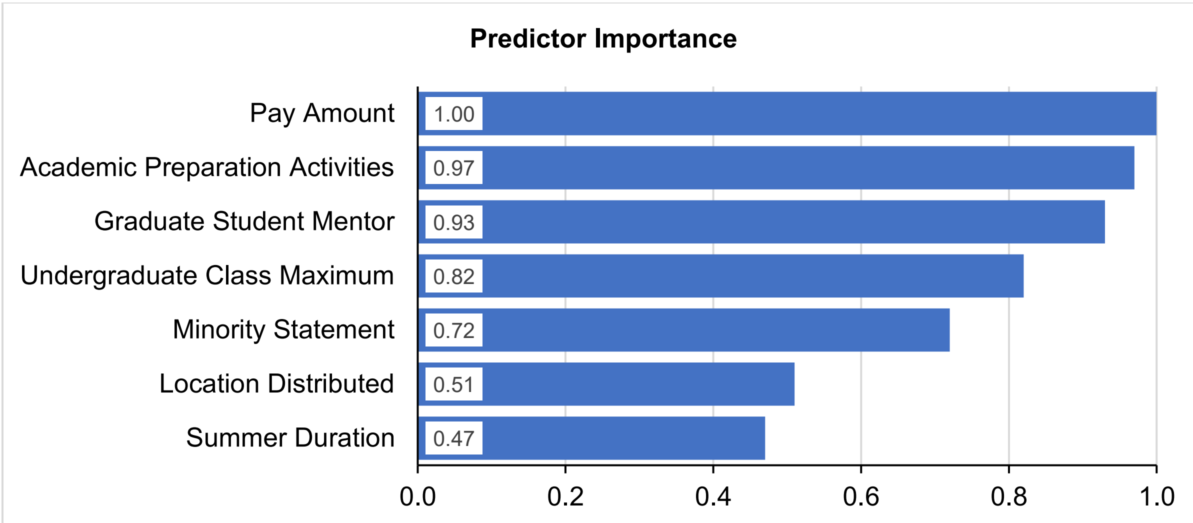


Figure 3.3. Relative predictor importance output from the SPSS two-step clustering procedure for natural resources URE programs operating during 2012 to 2016.

Table 3.2. Continuous and binary variable descriptive statistics of all program (N=49) data collected from natural resources URE programs during 2012-2016. Percentages of continuous and binary variables are proportions of programs offering or requiring a listed feature.

Continuous Variable	**%**	**Mean**	**SD**	**Min**	**Max**	**Binary Variable**	**%**
Pay amount*	0.96	4773.6	1657.0	160	7000	Academic preparation*	0.20
Summer duration*	-	9.8	1.5	4	12	Mentor type graduate*	0.10
Undergrad class max*	-	4.8	0.7	3	6	Minority statement*	0.78
Years operated	-	11.3	10.1	1	45	Openness	0.98
Collaborators	-	3.9	3.2	1	15	Location distributed*	0.22
Mentor cohort size	-	9.1	4.7	1	25	Funding renewal	0.76
UG cohort size	-	11.6	6.0	3	40	Meal provision	0.39
Mentor:UG ratio	-	0.8	0.3	0.05	1.3	Housing provision	0.88
Applications	-	132.4	109.2	12	600	GPA requirement	0.35
Application:Size ratio	-	11.8	8.6	2	34	Pre-experience activity	0.31
Rejections	-	2.9	3.1	1	15	Post-experience activity	0.31
Undergrad total	-	131.9	132.7	10	680	Orientation	0.86
Total program duration	-	11.0	5.2	4	39	Proposal requirement	0.51
Non-summer duration	0.12	1.2	5.0	1	30	Mentor training	0.31
Work hours per week	-	39.6	5.4	20	56	Outreach requirement	0.24
Meal allowance	0.47	409.7	549.7	400	2000	Ethics training	0.82
Transportation allowance	0.73	401.0	368.2	200	2000	Responsible conduct training	0.82
Housing allowance	0.35	451.6	727.9	500	2500	Ethics and conduct training	0.73
Social activities	0.94	7.3	6.4	1	35	Academic credit	0.10
Seminars	0.9	10.6	6.8	1	31		

*denotes variable important for clustering

Table 3.3. General descriptions of natural resources URE program types identified through cluster analysis.

Type	General Characteristics
Underclass Intensive	Traditional-styled research-focused programs favoring rising sophomore or juniors likely including more individualized mentorship by established researchers.
Extended Graduate Student Mentored	Longer duration research-emphasis programs with mentorship exclusively by graduate students likely tending toward an individualized mentorship structure.
Professional Development	More holistic programs providing academic preparation activities and additional opportunities for interaction through seminars, social activities, and tending toward group mentorship structure.
Distributed Intensive	Research-focused programs where undergraduates are geographically distanced at mentor institutions and tending toward group mentorship by individual faculty researchers.
Site-based Traditional	A "classic" style of intensive summer duration research, with individualized mentorship by faculty at a single institution that frequently offers seminars for broader exposure to undergraduates.
Shorter Duration Intensive	Research-driven programs lasting fewer weeks and with lower student pay than typical summer programs where structure likely favors one faculty member mentoring multiple undergraduates.
Larger Long Term	Programs with longer histories of operation as traditional undergraduate research opportunities tending toward individualized, faculty-led mentorship, frequently offering seminars and social activities, and additional requirements after summer.

Natural resources URE programs funding typically (62%) came from a single source, and federal agencies or programs provided primary funding for 82% of programs in this study. Financial compensation methods included hourly wages (27%), payroll assistantships (17%), financial aid grants or scholarships (6%), or other methods (47%) such as direct payments, installments, or non-employee payroll. All but three programs provided housing for undergraduates at no cost (59%; n = 29), through stipends only (n = 14), or some combination (n = 14). However, 33% (n = 16) of programs did not provide meals or stipends while others provided meals at no cost to students 20% (n = 10), provided food subsidies (n = 14), or some combination (n = 9). Allowances for transportation to the URE were provided by most (73%; n = 35) programs. Some (61%; n = 30) provided other amenities that included: field trips or recreation (n = 9), local transportation (n = 8), research material costs compensation (n = 6), facilities access (e.g., library, computer lab, or gymnasium) (n = 3), research conference fees (n = 2), and health insurance (n = 1).

Activities surrounding summer research experiences varied (Table 3.4). During summer sessions, formal orientations occurred for 86% (n = 42) of programs, but mentorship training occurred in only 31% (n = 15) of programs. Research proposals were required by 49% (n = 24) of programs. Academic preparation activities included career options information; resume development; graduate school, fellowship, and job application processes; GRE (graduate record examination) preparation; and academic progress and career goal checks. Social events during the experience occurred for 94% (n = 46) of programs, and 90% (n = 44) of programs incorporated seminars. Programs incorporated training in both ethics and responsible conduct of research (74%; n = 36), one of the two (16%; n = 8), or neither (10%; n = 5). Academic coursework was required by 10% of programs (n = 5), where students paid through home institutions (n = 2), the URE institution (n = 1), or the URE covered the course at its institution (n = 2). Outreach activities targeting non-scientific groups were required (25%; n = 12), optional opportunities (27%; n = 13), or not incorporated (48%; n = 24). All programs required final reporting, but required formats varied across programs and by cluster (Figure 3.4). Other reporting types included abstracts (n = 4), exit or post-experience surveys (n = 6), data records (n = 1), and video (n = 1).

Table 3.4. Pre- and post-summer session activity requirements for natural resources URE programs operating from 2012 to 2016.

Pre-summer Requirement	**n**	**Post-summer Requirement**	**n**
Review literature / lab procedures	9	Other	11
Non-coursework training	8	Presentation delivery	9
Other	7	Professional internship	1
Communication with mentors	3	Seminar	1
Orientation	2	Publication preparation	5
Pre-experience survey	1	Post-experience survey	5
CPR or safety training	1	Extended research	3
Publication preparation	2	Specialized coursework	3
Specialized coursework	2	Exit interviews	2
Outreach	2	Outreach	1
Extended research	1		

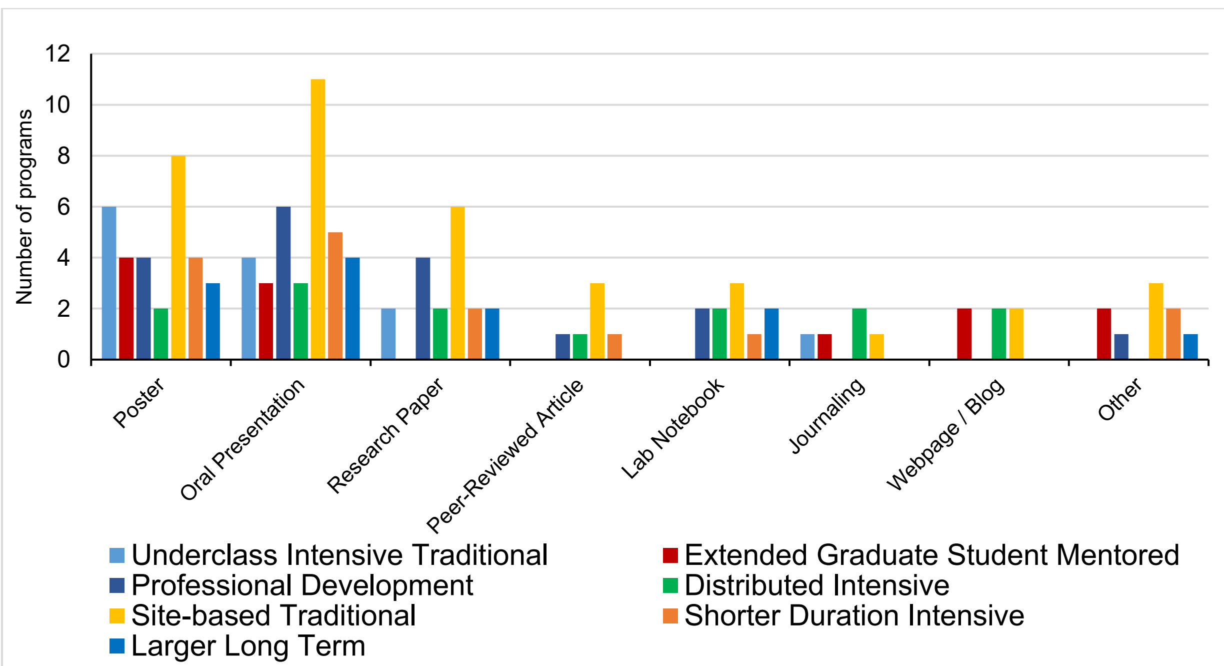


Figure 3.4. Types of final reporting required of undergraduate participants by program clusters.

Cluster analysis of program data allowed between cluster comparison (Table 3.5; Table 3.6). "*Underclass Intensive Traditional*" programs were characterized by moderate pay and duration advertising themselves to less-experienced, mostly underrepresented students equally likely to be a site-based cohort or distributed across research sites focused only on research with non-graduate student mentors. Undergraduate participants were limited to rising seniors and below. Primary mentors in this cluster were faculty and close to a 1:1 ratio with undergraduate participants, but this cluster contained the only program that utilized advanced upperclass students as the primary mentor. This is a research-focused model for underclass and minority students.

"*Extended Graduate Student Mentored*" programs were characterized primarily through mentorship completely by graduate students. Most programs targeted non-graduating seniors, but all had statements targeting underrepresented students. Pay was the second greatest at mean $5,690 over the longest summer program duration mean between 10 and 11 weeks. Academic preparation activities were not part of these programs.

"*Professional Development*" programs emphasized academic preparation and offers a mean $5,000 pay over 10 weeks for recent and current undergraduates. Three quarters of programs in this cluster were sited-based, but all advertised non-graduate student mentorship. Similar to cluster one, all programs advertised interest in recruiting underrepresented students. This cluster contains student-focused and research-driven programs.

"*Distributed Intensive*" programs were characterized chiefly by inclusion of only distributed cohorts targeting underrepresented students with all levels of undergraduate or recently graduated status. These programs focused only on research with no academic preparation under non-graduate student mentorship for shorter durations than most other programs and offering the second lowest pay ($4,500).

"*Site-based Traditional*" programs were the largest cluster and characterized by targeting underrepresented students for site-based research, moderate pay amounts over an average 10-week period, lack of offering academic preparation, advertises non-graduate student mentorship near 1:1 with undergraduates, and allows all levels of currently enrolled undergraduates. This cluster is a purely research-focused group identifying desire for underrepresented participants.

"*Shorter Duration Intensive*" programs were chiefly characterized as allowing postgraduates (66% of this cluster), lowest mean pay ($1,475) and shortest duration (mean = 7.5 weeks). These programs targeted all levels of undergraduates and recent graduates, most lacked a statement of targeting underrepresented students, and students worked only under non-graduate mentors and conducted research without academic preparation programming. This cluster also had the smallest mentor and undergraduate cohort sizes of about five mentors to eight undergraduates, respectively. Social activities and seminars occurred in small amounts.

"*Larger Long Term*" programs offered the greatest and most variable pay over longer summer durations. This cluster also contained programs operating up to 30 and 45 years. Mentorship in this cluster is heavily weighted toward non-graduate mentors with cohorts of non-graduating undergraduates researching mostly at a specific site. One of these programs limited itself to underclass that had not completed their junior year. Some programs offered academic preparation, but none emphasized themselves as opportunities for underrepresented students.

Table 3.5. Means and standard deviations in parentheses of program clusters displaying characteristics of continuous variables for cluster analysis of program data collected from natural resources URE programs during 2012-2016.

Variable	**Underclass Intensive**	**Extended Graduate Student Mentored**	**Professional Development**	**Distributed Intensive**	**Site-based Traditional**	**Shorter Duration Intensive**	**Larger Long Term**
Pay amount*	5062.5 (944.4)	5693.8 (399.3)	5315.6 (500)	4500 (500)	5110 (693.7)	1475 (1419.1)	6065 (2533.9)
Summer duration*	9.9 (1)	10.8 (0.5)	10 (0.9)	9.4 (0.9)	10 (0.8)	7.5 (2.5)	10.8 (1.3)
Undergrad class max*	3.8 (0.5)	4.8 (0.5)	4.8 (0.5)	5.4 (0.5)	5 (0)	5.7 (0.5)	4.6 (0.9)
Years operated	5.4 (5.3)	5.8 (8.2)	11.5 (6.8)	10.2 (6.8)	10.2 (7.8)	16.6 (12.8)	23.8 (16.8)
Collaborators	2.8 (1.9)	4.8 (2)	3.1 (3.7)	4 (3.7)	4.7 (3.4)	3.5 (4.3)	4.8 (3.3)
Mentor cohort size	11.1 (6.2)	11.5 (3.3)	8.4 (6.8)	10 (6.8)	7.8 (2.4)	4.7 (2.8)	13.2 (5.8)
UG cohort size	10.9 (4.2)	15 (2.1)	10.4 (12.1)	20 (12.1)	8.6 (2.7)	8.3 (2.3)	15 (5)
Mentor:UG ratio	0.97 (0.18)	0.86 (0.26)	0.79 (0.43)	0.67 (0.43)	0.96 (0.25)	0.54 (0.3)	0.86 (0.22)
Applications	98.6 (42.2)	160.8 (113.1)	163.4 (68.4)	134 (68.4)	121.4 (87.3)	50 (35.1)	233 (225.5)
Application:Size ratio	9.1 (2.3)	12.3 (10.3)	15.5 (3.2)	7.6 (3.2)	13.7 (9.3)	6.1 (4.3)	15.8 (13.1)
Rejections	3.7 (3.5)	5 (1.5)	2.1 (1.6)	2.2 (1.6)	2.9 (3.9)	1.3 (2)	4.2 (3.6)
Undergrad total	53 (58.9)	87.5 (94.4)	115.4 (157.7)	198.6 (157.7)	89.2 (82.3)	163.2 (122.5)	311.4 (234.3)
Total program duration	11.5 (2.6)	14.8 (0.5)	10 (0.9)	9.4 (0.9)	10.2 (0.7)	7.5 (2.5)	16.8 (12.4)
Non-summer duration	1.6 (3.3)	4 (0)	0 (0)	0 (0)	0.2 (0.4)	0 (0)	6 (13.4)
Work hours per week	41.4 (0)	40 (0.4)	40.1 (7.1)	43.4 (7.1)	39 (6.2)	35 (8.7)	38.2 (4.6)
Meal allowance	400 (489.9)	250 (558)	577.6 (273.9)	200 (273.9)	604 (684.1)	250 (612.4)	180 (402.5)
Transportation allowance	381.3 (299.9)	250 (261.9)	600 (210.2)	575 (210.2)	415.4 (218.3)	333.3 (816.5)	140 (219.1)
Housing allowance	550 (897.6)	775 (439)	312.5 (1134.3)	1200 (1134.3)	359.6 (587.9)	200 (489.9)	200 (447.2)
Social activities	8.4 (5.5)	5 (9.8)	12 (3.3)	4.2 (3.3)	7.1 (5.9)	1.8 (2.1)	10 (3.8)
Seminars	14.9 (7.8)	6.5 (5.6)	12.4 (5.2)	3.8 (5.2)	13.5 (6)	4.3 (3.4)	10.8 (3.8)

* denotes variable important for clustering

Table 3.6. Proportions of programs displaying characteristics of binary variables for cluster analysis of program data collected from natural resources URE programs operating from 2012 to 2016.

Variable	**Underclass Intensive**	**Extended Graduate Student Mentored**	**Professional Development**	**Distributed Intensive**	**Site-based Traditional**	**Shorter Duration Intensive**	**Larger Long Term**
Academic preparation*	0.00	0.00	1.00	0.00	0.00	0.00	0.40
Mentor graduate*	0.00	1.00	0.00	0.00	0.00	0.00	0.20
Minority statement*	0.75	1.00	1.00	1.00	1.00	0.33	0.00
Location distributed*	0.00	0.50	0.25	1.00	0.00	0.17	0.20
Funding renewal	0.50	0.50	0.88	1.00	0.85	0.50	1.00
Housing provision	0.88	0.50	0.88	1.00	1.00	0.67	1.00
Meal provision	0.50	0.50	0.13	0.60	0.38	0.33	0.40
GPA requirement	0.38	0.25	0.38	0.60	0.38	0.17	0.20
Pre-experience activity	0.13	0.25	0.50	0.20	0.31	0.33	0.40
Post-experience activity	0.13	0.50	0.38	0.00	0.31	0.33	0.40
Orientation	1.00	0.75	1.00	0.80	1.00	0.50	0.60
Proposal requirement	0.25	0.25	0.50	0.60	0.77	0.17	0.60
Mentor training	0.25	0.75	0.50	0.40	0.23	0.00	0.20
Outreach requirement	0.13	0.25	0.25	0.20	0.15	0.33	0.60
Ethics training	0.88	0.75	0.88	0.80	0.92	0.50	0.80
Responsible conduct training	1.00	0.50	0.88	0.80	0.85	0.67	0.80
Ethics and conduct training	0.88	0.50	0.75	0.80	0.85	0.33	0.80
Academic credit	0.00	0.25	0.00	0.00	0.08	0.33	0.20

* denotes important variable for clustering

3.5 Discussion

Using a researcher-led RDS approach, the population size of natural resources URE programs was estimated at 127 programs. Although this study's number of RDS seeds (i.e., respondents functioning as recruiters for additional respondents) was relatively high compared to most RDS studies, this number was appropriate particularly given coordinators' personal network sizes. When personal social networks are small and/or fragmented, it may be necessary to obtain a larger number of seeds than in traditionally studied networks (Mühlau, Kaliszewska, & Röder, 2011; Platt, et al., 2015). Personal network sizes of program coordinators appear to be minimal, suggesting this subset of URE programs is fragmented unlike highly organized subsets (e.g., NSF REU Sites) where coordinators or directors may be more connected with formalized networks. Traditional RDS approaches assume seeds have a limited number of tokens to randomly provide to members of respondents' networks that are often reported to be relatively large, but this was not a limitation in this study.

Studies utilizing RDS approaches frequently include descriptors of the target population for respondents to filter their social networks down to the population of interest. Despite such guides, respondents may still inaccurately report their personal network sizes. This study's estimation that 16% of researcher-screened respondents self-identified their programs did not meet criteria for natural resources URE. This may indicate selection bias and contribute error in estimating population size of natural resources URE programs. Furthermore, even natural resources URE program coordinators reported other URE programs for this study as prospective natural resources URE programs that did not meet study criteria. For most cases, misidentification resulted from inconsistency in use of "natural resources" instead of other criteria such as individualized versus cohort programs. Platt et al. (2015) identified that 58% of referred persons completed interviews resulting from researcher-led RDS. The Lincoln-Petersen population estimate calculation did not include misidentified programs and should be relatively accurate. Ultimately, this estimate may be viewed as a minimum given the possibility that URE programs closed to external students may not be publicly advertised. However, evaluating the estimate's accuracy is beyond the scope of this study.

Two-step cluster analysis identified multiple variables specified in literature as critical considerations for undergraduate research programs in addition to other variables participants and researchers may deem important. This includes pay or financial compensation, academic preparation activities, mentorship, undergraduate classes allowed, minority statements, geographic distribution of cohorts, and summer duration. These variables were important in determining a clustering solution resulting in distinctive groups of programs with shared qualities. However, a low sample size and inclusion of various data types could limit the clustering solution. Additional research using current natural resources and other STEM discipline URE programs to better understand distinctions between types of summer-based URE programs is warranted.

Natural resources URE program types resulting from cluster analysis indicate some programs are attentive to aspects of undergraduate education other than traditional research participation. *Site-based Traditional* programs may be viewed as a reference category due to its size and relatively standard structure and function with respect to general URE programming over the last few decades. Additionally, these programs are funded primarily by the NSF, and in one case the US Department of Education, and may explain some consistency within the cluster. Mentors were, with one exception of research scientists, exclusively tenure-track faculty. Each program in this cluster provided housing for students, indicating some institutional or collaborating partner support for the URE. Non-graduating senior was the highest level of student accepted by all programs in this cluster, combined with lack of alternative programming such as academic preparation activities or outreach requirements and with the greatest proportion of research proposal requirements, suggests an intensive research focus for these programs. However, research intensity may come at the cost of providing opportunities to underclass students and a holistic apprenticeship.

Underclass Intensive Traditional programs focused on providing opportunities for students earlier in their undergraduate curricula. Summer sessions of about 10 weeks were comparable to the overall average for all programs, but this cluster contained a program spanning two summer segments focusing first on research and then professional practice. Programs did not require extra time before or after summer sessions other than one program reporting engagement with mentors outside of summer. Similar to the *Site-based Traditional* cluster, this cluster had mostly faculty mentors and approached a one-to-one mentor to undergraduate ratio. It also contained the only undergraduate-mentored program, possibly indicating a two- or three-tiered hierarchy focusing on developing undergraduates' research and mentoring abilities if faculty were involved. However, explicit mentor training was not prevalent in this cluster or for the undergraduate-mentored program. Like *Site-based Traditional, Distributed Intensive, and Shorter Duration Intensive* programs, this cluster did not include academic preparation activities. It had the greatest proportion of programs including both ethics and responsible research conduct training. *Underclass Intensive Traditional* programs may represent the best opportunities for answering calls by practitioners and researchers to begin incorporating students into research earlier in their degree programs.

Of the five programs implementing graduate students as explicit mentors, four were exclusively clustered as *Extended Graduate Student Mentored* programs. This distinction may be important given the opportunities and challenges associated with having less-experienced mentors. This cluster had the greatest proportion of mentor training, and such training may reduce the challenges associated with less-experienced mentors. As in *Underclass Intensive Traditional* programs, these programs were relatively new with a mean 5.8 years in operation but like other clusters generally targeted more experienced undergraduates. Summer sessions in this cluster ranged from 10 to 12 weeks with an average similar to *Larger Long Term* programs, and this extra time may allow for a stronger development of a mentor-mentee relationship in addition to extra time for research activities. Only one program in this cluster had a non-summer duration-16 weeks in a course for academic credit. Half of *Extended Graduate Student Mentored* programs directly provided housing and meals; this proportion was lower than any other cluster, although a subsidy was used to offset housing in one case and the second highest average pay of any cluster may offset no direct provisions. Research reporting requirements in all cases included posters and in two cases either development or posting of weblogs. There was no emphasis on academic preparation activities and less emphasis on ethics and responsible conduct of research than in *Underclass Intensive Traditional, Distributed Intensive, and Site-based Traditional* programs.

Professional Development programs all included some type of academic preparation activities. Tenure-track and non-tenure track faculty, with one program indicating mixed types, were primary mentors in Professional Development programs like other clusters with non-graduate student mentors. The mentor:undergraduate ratio was equivalent to the average of all programs. Like *Extended Graduate Student Mentored*, *Distributed Intensive*, and *Site-based Traditional* clusters, these programs all had minority statements. For programs targeting underrepresented students or prospective first-generation graduate students, academic preparation activities may be an effective inclusion to traditional research activities. Direct provision of housing was similar to most other clusters and occurred in all programs except one where a $1000 stipend was available. However, the proportion of programs directly providing meals was lower than any other cluster, but this was offset by the greatest frequency of meal subsidies. All *Professional Development* programs provided transportation programs- the greatest proportion and greatest average amount. These three factors indicate *Professional Development* programs may pay particular attention to assuaging extrinsic challenges undergraduate may face. Summer durations were similar to *Site-based Traditional* programs, and no program in this cluster required time outside of summer sessions. reporting requirements for *Professional Development* potentially indicate greater emphasis on technical and scientific writing. This cluster included the second lowest rate of posters, the highest rate of research papers, and one of the six programs requiring manuscripts for publication.

Distributed Intensive programs all provided research experiences at different sites for cohort members. This suggests geographic isolation of undergraduates was likely unless multiple students were co-located as sub-groups at separate sites. Mentorship was either faculty, professional scientists, or a mix of the two, and was similar to clusters other than *Extended Graduate Student Mentored* programs. The mentor to undergraduate ratio was the second lowest after *Shorter Duration Intensive* programs. This cluster and the *Shorter Duration Intensive* cluster had the greatest allowed undergraduate class maximums and included the only programs where recent graduates were able to participate in research. Like half of other clusters, all *Distributed Intensive* programs included minority statements on recruiting materials. All programs in this cluster directly housed undergraduates, but providing or subsidizing meals occurred less frequently. The transportation subsidy rate was comparable to *Professional Development*, *Site-based Intensive*, and *Extended Graduate Student Mentored* clusters. Mentor training and social activities occurred less frequently than in other clusters. However, like other intensive research clusters, most *Distributed Intensive* programs required an orientation, and included explicit training in both ethics and responsible research conduct. Research reporting included all types and was more evenly distributed across types than any other cluster.

Shorter Duration Intensive programs shared many similarities with the *Distributed Intensive* cluster. Programs in this cluster were also the smallest in terms of mentor and undergraduate size, and also had more undergraduates per mentor than any other cluster. Like most clusters, mentors were faculty members, although one program had professional scientists with graduate degrees. Undergraduate classes allowed were higher than other clusters with most programs allowing recent graduates. Other aspects of research training were less frequent in this cluster compared to other clusters. No *Shorter Duration Intensive* program had mentor training, and this cluster had the lowest rates of orientations and of trainings in both ethics and responsible research conduct except for *Extended Graduate Mentored* programs' proportion of research conduct training. Program developers or mentors may feel that the brief nature of such programs does not lend itself to time away from the research process, or these topics may be implicitly addressed during research activities instead of explicitly incorporated. Given that this cluster also had the lowest average of social activities, lack of supporting activities also suggests focused emphases on the research process. Research reporting requirements were more comparable to *Site-based Traditional* and *Larger Long-term* clusters than to other clusters and emphasized poster and oral presentations, presumably limited by time constraints. Housing and meal providence or subsidies rates for this cluster were also among the lowest of clusters, although two thirds of programs provided housing. Lower rates could be attributed to the potential difficulties of housing individual participants on campus for short periods or short-term summer rental availabilities at off-campus properties. Only one *Shorter Duration Intensive* program provided transportation allowance. One potentially critical benefit of shorter duration URE programs is that they may accommodate undergraduate personal schedules better than longer programs. Students may frequently have other plans for summers, such as summer coursework, vacations, or family visits, where shorter programs would align better than programs consuming most of or all the summer months.

Some of the longest programs were in the *Larger Long Term* cluster, including one of the three programs having considerable post-summer durations. Of these, 60% had been operating for at least 30 years. The average mentor cohort size was also the greatest of all clusters, but undergraduate cohort size was relatively high and comparable to *Extended Graduate Student Mentored* programs but was less than the *Distributed Intensive* cluster. The maximum undergraduate class allowed average was lower than most other clusters, but this was driven by a two-summer program that began with rising juniors; other programs in this cluster allowed up to non-graduating seniors. No programs in this cluster reportedly included minority statements on recruitment materials. All *Larger Long Term* programs directly provided housing, but meal benefits were fewer and comparable to *Shorter Duration Intensive* and *Extended Graduate Student Mentored* clusters. Travel benefits were the second least frequently offered after *Shorter Duration Intensive* programs, and these were limited to \$200 and \$500 dollars and averaged the lowest of any cluster. Orientations occurred less commonly than all other clusters except *Shorter Duration Intensive* programs, but 80% *of Larger Long Term* programs required both ethics and responsible research conduct training. Final reporting outputs were similar to *Site-based Traditional* and *Shorter Duration Intensive* clusters. *Larger Long Term* programs also had the greatest proportion of programs requiring an outreach component.

Pay and other financial compensation are frequently important factors in undergraduate research program planning and participation, particularly when targeting underrepresented students. Minority and other underrepresented students particularly may evaluate URE participation based on financial compensation due to inequities other undergraduates may not experience, especially when volunteer opportunities are not feasible (Economy et al., 2013; Fuchs, Kouyate, Kroboth, & McFarland, 2016). All but two programs surveyed offered some form of direct financial compensation frequently supplemented with stipends for housing, food, and/or travel where these amenities were not directly provided for undergraduates. Average pay amount was at least \$4,500 for all clusters except for the *Shorter Duration Intensive* cluster that contained the two programs without direct compensation. *Shorter Duration Intensive* programs also had the lowest pay per summer duration ratios of any cluster even discounting the unpaid programs. Pay in natural resources URE was similar to previous general characterizations of URE stipends (Hensel, 2012). Financial compensation and its delivery mechanisms are important considerations with additional financial implications such as tax liability and federal financial aid assistance. Direct financial compensation was distributed as wages through payroll or by direct installments at periodic intervals by more than half of programs, while fewer programs used mechanisms such as non-employee payroll, smaller numbers (e.g., two or three installments) of payments, or scholarships. The specific frequency at which payments occurred was not assessed, and no particular method was specific to a type of program. However, 80% of *Larger Long Term* programs used wages, and this may be due to the lengthier durations where infrequent disbursements may be particularly challenging for some undergraduates or to the ease of using an institutional payroll system for longer periods. Classifying undergraduates as an employee may confer some benefits or restrictions to both the student and the institution, but this survey did not assess whether undergraduates were hired as employees of the institutions.

Seymour et al. (2004) identified four common models of summer URE: retention, career promotion, research apprenticeships, and research-based learning models. Study results suggest some nuance to such models and indicate URE programs implement academic preparation, socializing, leadership, and outreach opportunities in varying degrees. Incorporating these activities, particularly opportunities for presenting research, is a best practice, and they are considerations in undergraduates' decisions to participate (Economy et al., 2013; Hensel, 2012; NASEM, 2017). Only 10 programs across two program clusters (*Professional Development* and *Larger Long Term*) incorporated explicit professional development activities. Activities were mostly related to graduate school preparation, but some related more broadly to career-oriented professional development. Other clusters may implicitly include profession-related content informally during private discussion, but how or if such discussions occur would not be considered part of overall program function. Reporting and other outputs were required by all natural resources URE programs, but outputs widely varied with heavy reliance on poster and oral research presentations. Outputs may be linked to programmatic goals or targeted undergraduate classifications. For example, scientific peer-reviewed manuscript preparation was required only by some programs in *Professional Development*, *Distributed Intensive*, *Site-based Traditional*, and *Shorter Duration Intensive* clusters characterized by a traditional or intensive research emphasis and allowing advanced undergraduates that may be better prepared for academic research reporting.

Mentorship in URE may be complex with undergraduates being part of a senior researcher's lab but more frequently in direct contact with graduate students or other researchers than with their associated faculty mentor. Only one cluster, *Extended Graduate Student Mentored* programs, utilized the same mentorship type in all its programs, and graduate students were specified mentors in only one other *Larger Long Term* program. The finding of graduate students as primary mentors in 10% of programs is congruent with reports of 12% and 11% graduate student mentor rates (Lopatto, 2010; Luchini-Colbry & Wawrzynski, 2014, respectively). Graduate students and post-doctoral researchers are frequently the most accessible researchers to undergraduate participants, although they may not be considered the intended primary mentor (Linn et al., 2015; NASEM, 2017) and exposure to multiple and diverse mentors is theorized to lead to improved outcomes for all, not just underrepresented, students (Russell et al., 2007). Mentor to undergraduate ratios varied, but 21 programs with 1.0 ratios suggests explicit mentorship dyads. About half of programs in this study utilized tenure-track faculty as primary mentors. The large number of programs identifying primary mentors as faculty or advanced researchers or programs intending on dyadic relationships may not accurately reflect actual practice in those programs (NASEM, 2017; Russell et al., 2009). Institutions without graduate programs may not use graduate students as URE mentors unless there is external graduate student involvement, as in a triad model, explicitly built into program design. Only one program, in the *Underclass Intensive Traditional* cluster, in the study specified that advanced undergraduates were primary mentors. Incorporating undergraduates as explicit mentors and potential peer mentors in programs that target lower classifications of undergraduate participants may confer benefits to both mentees and mentors. Given that 31% percent of surveyed programs implemented mentorship training, additional work is needed to incorporate such training that may improve mentorship abilities of graduate students and outcomes of undergraduate participants (Aikens, Sadselia, Watkins, Evans, Eby, & Dolan, 2016).

At 567 undergraduate UR positions per year reported by respondents, extrapolating this amount to the estimated number of natural resources URE programs suggests 1,469 positions annually for this UR format. Sharik, Lilieholm, Lindquist, and Richardson (2015) identified enrollment of 24,551 students in natural resources undergraduate programs for 2012. Combining the estimation in this study with these data indicates that 6% of all natural resources undergraduates may participate in related URE programs, not including individual opportunities or course-based URE, each year. Previous estimates indicate 3% of undergraduate researchers studied “natural sciences” (Lopatto, 2003; Lopatto, 2004). Opportunities for early undergraduate and pre-college involvement are identified as a best practice (Hensel, 2012), but disentangling the proportion of undergraduates involved in internship-styled research prior to senior year is difficult. Beninson et al. (2011) found in a study of NSF REU Sites that 10% of undergraduate researchers completed only freshman year and 57% completed junior year prior to REU participation. About 5% of STEM URE programs may be limited to lower division students (Linn et al., 2015). The maximum classification allowed variable was an indicator of programs’ intention to include undergraduates at lower classifications. In this study, 10 % of respondents indicated their programs included incoming freshman in their target pools, and 70 % included rising sophomores. Results indicate 76% of programs surveyed did not exclude undergraduates in their senior year; most programs excluding rising seniors were in the *Underclass Intensive Traditional* cluster. Programs not exclusively recruiting underclass students may be more likely to pass them over in favor of advanced students with stronger applications or educational backgrounds, particularly when large numbers of well-qualified applicants are received. However, the burgeoning number of course-based URE opportunities may provide additional qualifications to less-experienced students prior to summer internship-styled URE (Linn et al., 2015).

Demographic data of program participants were not requested due to the potentially sensitive nature of the data and time involved on the part of respondents. Thus, a proxy measure, presence of a minority statement, identified programs’ perceived commitments to participant diversity. Nine programs indicated lacking a diversity statement, and one cluster, *Larger Long Term*, contained no programs that indicated having one on promotional materials. Programs receiving federal funding may be required to provide such statements on recruitment materials (e.g., the National Science Foundation REU Sites), but intended recruitment for natural resources URE programs may not reflect realized participant demography. Additionally, prospective applicants may or may not use such statements as an indicator, particularly if visuals of past participants are included. Over three quarters of natural resources URE programs indicated such statements were on advertisements, but a limited number of programs were solely devoted to underrepresented students. Minority participation in URE is associated with reduced attrition in obtaining a STEM degree (Nagda et al., 1998; NASEM 2017) that is a longstanding concern for increasing diversity in graduate programs and in the work force (NAS, NAE, & IM, 2011; Sharik, 2015). Without widespread demographic data, identifying progress toward diversifying the future workforce remains limited.

Distributed URE programs comprised 22% of natural resources programs, but most of these were spread through other clusters except for *Distributed Intensive* programs. Apart from individual program evaluations or reports, scant research exists on programs and participant outcomes where participants are a geographically separated cohort. While other variables were more important predictors in clustering, this feature may be an important distinguishing characteristic despite the spread of most distributed programs among clusters. As team science becomes an increasingly common mechanism for researching interdisciplinary and transdisciplinary problems (Hall et al., 2018), the distributed nature of collaborative work may require that research projects involving undergraduate researchers work more to address the deficiency of research on this aspect of URE and the potential limitations of *Distributed Intensive* URE types. Alford et al., (2017) described the NSF REU funded "cyber-linked" Rosetta REU program and found that undergraduate outcomes were similar to traditional site-based URE programs.

Duration was likely a critical factor in planning and delivering URE programs. Additionally, program duration is frequently linked to participant outcomes, and subsequent participation in URE is expected to improve outcomes (Adedokun et al., 2014; Linn et al., 2015; Thiry et al., 2012). *Shorter Duration Intensive* programs contained four of the six shortest (eight weeks or less) programs. Few programs in this study were structured outside of a traditional summer-only experience and supplemented summer research with additional requirements. For example, one atypical program utilized two summers (a traditional research experience followed by a professional internship), and another program required a post-summer course for academic credit. *Larger Long Term* programs were mostly 11- or 12-week programs that likely were constrained by academic semester considerations. This cluster also included a nine-week summer program that participating during the academic year followed by a required second summer professional internship.

Enumerating URE programs operating in a given discipline at any given time is difficult, particularly due to lack of explicit sampling frames and established coordinator networks. Modified RDS approaches are likely necessary to estimate population sizes of URE programs. This research contributes to the literature by empirically supporting the generalized understanding that URE programs are structurally and functionally diverse. Considerations for designing and implementing URE programs are also important for distinguishing programs. The proposed typology suggests some URE programs are better suited for meeting needs of certain participants than others, and no ideal singular program will meet all needs of higher education institutions and the work force. Additional work is needed to quantify programs' structural and functional diversity, particularly given recent calls for examination of causal links between programmatic elements and participant outcomes (Haeger, Banks, Smith, & Armstrong-Land, 2020; NASEM, 2017).

3.6 Conclusion

This study used researcher-led RDS involving natural resources discipline URE program coordinators to estimate 127 programs in operation during a 2012 to 2016 period. Seven structural and functional program variables theorized in literature and established statistically as important through cluster analysis were used to develop a typology of natural resources URE programs. Additionally, this research provided empirical evidence of the frequency at which many program elements occur. The traditional, site-based URE model was most commonly identified, but six other types may better cater to other needs and goals of diverse and, potentially, underrepresented participants. The variation of structures and functions present in all program types suggests that needed collaborative planning and buy-in from administrators and researchers occur and is funded at the federal level, with some funding from non-governmental organizations, to provide opportunities for undergraduates and their mentors.

Findings of this research suggest implications for URE researchers and practitioners. First, additional research confirming or refining the typology will be useful because this study was an initial exploration of URE program characteristics that are typically not the focus of UR studies. Variables identified as important for clustering are typically publicized on programs' webpages and promotional materials, thus allowing additional research in recent years or in other disciplines. Second, research programs incorporating undergraduate researchers should carefully consider programmatic target demographics and goals during the development phase to provide the structural, educational, and social opportunities needed to attract and train a diverse population for careers in natural resources research. Additional deliberate consideration may be needed by some program types (e.g., *Shorter Duration Intensive* and *Distributed Intensive*) with relatively unique structures. However, such considerations will need to be evaluated against available institutional and collaborator support and with mentor personnel involvement and research needs. Third, given 1) the relative importance and frequency of marketing presence of equal opportunity or affirmative action statements for clustering and 2) a lack of programs specifically recruiting underrepresented or less-experienced (i.e., freshmen and sophomore) students, then developing programs for these populations may be an important emphasis if natural resources institutions are to increase diversity and reflect general societal trends. Additional opportunities funded by more diverse patrons may be needed to support such programs, as student pay was an important predictor and may be a strong consideration by prospective undergraduate researchers particularly when they may consider offsetting other financial costs of participation associated with some program types. Finally, program operators may use the proposed typology when considering how to evaluate programs and participant outcomes. For example, programs types more aligned with long-term or traditional research activities (e.g., *Distributed Intensive* and *Site-based Traditional*) more frequently included proposal development as requirements; including undergraduate researchers at the foundation of the project may lead to better outcomes. Explicit training in mentorship practices was more frequently associated with nontraditional program types such as *Extended Graduate Student Mentored* and *Professional Development.* Linking participant outcomes to URE program elements remains a persistent task for researchers, and this work represents a first step toward quantifying structural and functional program components present in URE programs, notwithstanding pedagogical practices specific to the apprenticeship relationship between mentors and undergraduate researchers.

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Chapter 4: Relationships Between Situated Learning Elements and Participant Outcomes in Natural Resources Undergraduate Research Experience Programs

4.1 Abstract

Undergraduate research experiences are generally referred to as situated learning or cognitive apprenticeships and are associated with diverse outcomes. This study explored natural resources URE programs in operation from 2012 to 2016 with an emphasis on undergraduate participants' perceptions of their programs' incorporation of situated learning theory elements and their self-reported outcomes associated with participation. Exploratory factor analysis identified underlying concepts associated with situated learning theory encountered in undergraduates' UREs and consolidated a wide variety of specific outcomes into categories similar to those established in prior literature. Natural resources URE function as situated learning by having: 1) effective mentorship methods, 2) sequencing, 3) specific repertoire, 4) mutual engagement, 5) joint enterprise, and 6) broad repertoire. Outcome related factors were 1) general skills gains, 2) career trajectory, 3) academic and career readiness, 4) communication of science, 5) cognitive skills, and 6) researcher identity development. Correlations between all situated learning and outcome factors were significant with the exception of specific repertoire and career trajectory. Multivariate general linear modeling identified effective mentorship methods, sequencing, specific repertoire, and broad repertoire were significant predictors of outcomes. Further analysis indicated effective mentorship methods was an important significant predictor of increased gains for all outcome factors, suggesting the critical role of a research mentor. Joint enterprise was not significantly associated with any outcome type. Findings support the need for greater emphasis on mentorship training and consideration for other aspects of research experiences associated with novice researcher outcomes.

4.2 Introduction

Undergraduate research experience (URE) programs' structural (i.e., organization and scale) and functional elements (i.e., activities, intended pathways for outcomes, and outputs) may vary just as widely as the myriad benefits attributed to participation in them (NASEM, 2017; Moore, 2010). While literature and research on program characteristics exists, this emphasis generally is limited to individual programs, small numbers of programs, or mentor-mentee relationships (Blockus, 2016; Economy, Martin, & Kennedy, 2013; Hensel, 2012; Millspaugh & Millenbah, 2004). Past research on URE references theoretical underpinnings of expected and realized outcomes of participation (Kardash, 2000; Kardash & Edwards, 2015), but many reports are program evaluations that may not be informed by theory. Situated learning theories such as cognitive apprenticeship (CA; Brown, Collins, & Duguid, 1989) and community of practice (COP; Lave & Wenger 1991; Wenger, 1998) are referenced (Hunter, Laursen, & Seymour, 2007; Thiry & Laursen, 2011; Villa, Kephart, Gates, Thiry, & Hug, 2013) but may not otherwise be explicitly examined within contexts such as undergraduate research (Feldman, Divoll, & Rogan-Klyve, 2013; Neufeld, Fang, & Wan, 2013). Researchers and evaluators focus on the actual value of internships and URE programs in providing benefits to students in light of variety in goals and structures of past and current programs (Hunter, Laursen, & Seymour, 2007; Kardash, 2000; Seymour, Hunter, Laursen, & DeAntoni, 2004; Thiry & Laursen, 2011). However, associations between URE participation, elements, and attributed outcomes are frequently made qualitatively such as through interviews, but rigorous examination of these relationships remains underperformed (Haeger, Banks, Smith, and Armstrong-Land, 2020; Linn, Palmer, Baranger, Gerard, & Stone, 2015; NASEM, 2017; Palmer, Hunt, Neal, & Wuetherick, 2015). This study identifies relationships between situated learning elements and participant outcomes of URE programs in natural resources disciplines, an understudied interdisciplinary population.

Theoretical Framework

Brown, Collins, and Duguid (1989) developed work on situated learning and an instructional model termed cognitive apprenticeship (CA; where learning takes place in context). Within CA theory, method, sequencing, content, and sociology are four dimensions of a learning environment (Table 4.1). The authors (Brown et al., 1989) explain cognitive apprenticeship's implied paradigm of modeling activities, coaching apprentices through them, and empowering apprentices to continue without support. Method relates to pedagogical practices applied by mentors and includes modeling and scaffolding as necessary components and are useful constructs in considering URE (Dennen, 2004; Feldman et al., 2013). Scaffolding and the related dimension of sequencing have roots in Vygotsky's (1987) zone of proximal development where task objectives are just out of reach of a student's current ability allowing for application of knowledge to new situations (Dennen, 2004). Thus, scaffolding undergirds the notions of situated learning and social interaction as inherent parts of CA (Dennen, 2004). With the mentor's supports, students learn the knowledge and skills required to attain goals, and, consequently, new tasks are given and the zone shifts appropriately to the task and student's ability. In addition to knowledge and skills, individuals also develop awareness of cultural structures, norms, and tools through method-related processes. Coaching is another critical CA component where mentors guide apprentices through the process of learning by challenging the apprentice, providing encouragement and motivation, offering feedback, and strengthening weaknesses (Collins, Brown, & Holum, 1991). CA makes use of content and sociology, where the content dimension includes domain knowledge and strategic knowledge required for establishing competence. Sociology as a dimension incorporates other situated learning theory constructs, intrinsic motivation and cooperation to drive active engagement and communication among participants.

Wenger (1998, 2000) refined theory into a formal framework for organizational and individual learning. Community of practice (COP) defines learning as the tension between social competence (knowledge, skills, and abilities the community deems important) and personal experience. Within COP, competence is a community-based measure of learning and is comprised of three participatory dimensions: joint enterprise, mutual engagement, and shared repertoire. These dimensions are described as the "relation by which practice is the source of coherence of a community" (Wenger 1998, p. 72). Negotiation of a joint enterprise holds a COP together by: the result of collective negotiation reflecting the complexity of mutual engagement, the negotiated response to the community's situation as they are in the process of pursuing goals, and an integral form of mutual accountability among participants (Wenger, 1998). This process defines the community's boundaries and peripheries and can be a source of mutual engagement (Neufeld et al., 2013; Wenger, 1998). Members' negotiation of the enterprise as a group implies the importance of mutual accountability and its role in a given member's authorship of their identity and meaning as an individual and as part of the community.

Table 4.1. Principles for designing cognitive apprenticeship environments, from Collins (2006, p. 50).

Domain	Principle	Definition
Content		Types of knowledge required for expertise
	Domain knowledge	Subject matter specific concepts, facts, and procedures
	Heuristic strategies	Generally applicable techniques for accomplishing tasks
	Control strategies	General approaches for directing one's solution process
	Learning strategies	Knowledge about how to learn new concepts, facts, and procedures
Method		Ways to promote the development of expertise
	Modeling	Teacher performs a task so students can observe
	Coaching	Teacher observes and facilitates while students perform a task
	Scaffolding	Teacher provides supports to help the student perform a task
	Articulation	Teacher encourages students to verbalize their knowledge and thinking
	Reflection	Teacher enables students to compare their performance with others
	Exploration	Teacher invites students to pose and solve their own problems
Sequencing		Keys to ordering learning activities
	Increasing complexity	Meaningful tasks gradually increasing in difficulty
	Increasing diversity	Practice in a variety of situations to emphasize broad application
	Global to local skills	Focus on conceptualizing the whole task before executing the parts
Sociology		Social characteristics of learning environments
	Situated learning	Students learn in the context of working on realistic tasks
	Community of practice	Communication about different ways to accomplish meaningful tasks
	Intrinsic motivation	Students set personal goals to seek skills and solutions
	Cooperation	Students work together to accomplish their goals

Joint enterprise relative to URE settings is the common identity pertaining to community or research group objectives. Enterprise acts as a form of accountability for the undergraduate researcher in setting and meeting goals during their internship or apprenticeship. From the undergraduate perspective, understanding the current state of the community and being able to contribute in navigation toward community goals should affect their identities as individuals and as community members. Mutual engagement in UR settings includes interactions that contribute to achieving the research group's goals while also providing scaffolding to help an undergraduate understand and align with the community's repertoire and enterprise. Mutual engagement between novice undergraduates and more established members is important for contributing to professional socialization, intellectual support, and personal/emotional support that assist in developing an identity as a community member. Shared repertoire includes various resources, such as formal and informal routines, procedures, language, roles, and physical tools, that communities adopt (Wenger 1998) to accomplish work and shape interactions (Brown &

Duguid, 1991; Neufeld et al., 2013). These elements may function as boundaries, peripheries (a permeable boundary for entry to the community) or artifacts that give further access to the research community and greater understanding of its practice. As undergraduates learn more about the community's repertoire, they may become increasingly capable of interacting within the community and sharing its resources to further its goals. Within URE contexts, undergraduates may alter or reinforce their inbound trajectories toward graduate studies as an insider and may bolster identities as researchers in training during this process. Through participation, novices are increasingly introduced to shared knowledge and skills of the practice through commitments of time, effort, and responsibility. Full enculturation requires that novice members also develop a greater sense of identity as members of the practice. Tensions or conflicts may arise that require an individual to negotiate their identity, and individuals may change trajectories or choose to remain a marginal participant within a community (Handley, Sturdy, Fincham, & Clark, 2006; Wenger, 1998). Thus, in URE an undergraduate researcher's identity as a researcher in training is an essential consideration for effective learning (Thiry & Laursen, 2011).

Situated learning theoretical frameworks may be used when examining URE program development and outcomes (Hunter et al., 2007; John & Creighton, 2013; Kardash, 2000). Theoretical support for the implementation of URE comes from the CA instructional model where undergraduates participate in authentic experiential education under direction of an experienced research mentor. Use of the term "cognitive" emphasizes the idea that apprenticeships go further than merely providing physical skills needed to carry out tasks (Brown et al., 1989). The term "apprenticeship" highlights the centrality of activity in learning from a mentor and notes the "inherently context-dependent, situated, and enculturating nature of learning" (Brown et al., 1989). Kardash (2000) identified features qualifying URE as CA, including tasks associated with higher cognitive orders scaffolded on background knowledge and opportunities to consider how disciplinary experts may accomplish those tasks. The CA model rests on assumptions that: meaningful learning is active, constructive, and self-regulating; learning is a social process; competence in a domain is defined in terms of expertise rather than innate ability; and learning activities should reflect the real-world rather than academic tasks performed without context (Kardash, 2000; Shuell, 1997). Lave and Wenger's (1991) legitimate peripheral participation and community of practice encompass these assumptions that, when met after completing training, apprentices should shift along a trajectory from the community's periphery toward full membership, negotiate their identities, and be capable of exploring other problems within the domain (Hunter et al., 2007; Wenger, 1998). John and Creighton (2013) supported this idea of trajectory through qualitatively describing undergraduate views of their research as legitimate participation and engagement while learning about the enterprise and repertoire of research. In short, CA and COP learning theories may be complementary to one another and propose mechanisms by which undergraduates and their mentors may benefit from URE participation.

Benefits of Undergraduate Research

Benefits to undergraduates from URE participation have been well-examined and documented (Appendix A), but emphases are typically on immediate benefits rather than long-term impacts, negative outcomes, outcomes for other participants such as mentors, and program elements associated with outcomes. Outcomes as used by Alexander, Foertsch, and Daffinrud (1998) were identified as degree- or career-oriented, where students were tracked after participation in a summer program to determine rates of retention, completion, and successful employment. Such outcomes are used extensively by URE programs and researchers, particularly those with missions of attracting, training, and retaining underrepresented groups in science, technology, engineering, and mathematics (STEM) fields (Haeger & Fresquez, 2016, McGill et al., 2021; Moghe, Baumgart, Shaffer, & Carlson, 2021), but additional work is needed to determine levels of participation particularly with respect to broader populations. Student interest in and preparedness for graduate studies also have been heavily documented (Junge, Quinones, Kakietek, Teodorescu, & Marsteller, 2010; Russell, Hancock, & McCullough, 2007; Seymour et al., 2004). Other benefits associated with URE are widely documented with some studies reporting effects on student retention, persistence, and enrollment in graduate studies while others report on skill gains related to research (Hunter et al., 2007; Lopatto, 2004, 2007; Russell et al., 2007; Seymour et al., 2004). Benefits to students may include personal or professional gains (Hunter et al., 2007; Lopatto, 2004, 2007; Seymour et al., 2004), the increased ability to think and work as a researcher (Hunter et al. 2007; Kardash, 2000; Seymour et al. 2004), various practical lab or field skill improvements (Hunter et al., 2007; Kardash, 2000; Lopatto, 2004, 2007), clarification of career paths (Hunter et al. 2006, Lopatto, 2007; Seymour et al., 2004), and enhanced career preparation (Hunter et al., 2007, Junge et al., 2010). Research on undergraduates' professional identity construction and development is noted as relatively nascent (Palmer et al., 2015; Russell et al., 2007). Despite much work on benefits associated with undergraduate research, both Thiry and Laursen (2011) and Hunter et al. (2007) provide cautionary anecdotes as approximately 10-15% of undergraduate researchers identified absent or uncaring advisors or being stuck in menial tasks for the duration of their experience. Such minimal practices are not likely conducive to enculturating undergraduates to COP and future research work. Clarification of participants' negative, neutral, and positive outcomes and mechanisms through which outcomes occur are important considerations.

This study's guiding question was how do undergraduates benefit from situated learning participation in natural resources URE programs? The goal of this research was to examine extents to which natural resources URE function as situated learning and the relationships between situated learning elements and outcomes reported by undergraduate researchers. Undergraduate research participants in programs in operation from 2012 to 2016 in the United States responded to a survey developed to assess both elements and outcomes described in theory and prior research on URE. Research objectives of this study were to: 1) describe undergraduate participant perceptions of natural resources URE programs as situated learning experiences, 2) quantify the strength of undergraduate outcomes associated with participation in natural resources URE programs, and 3) identify relationships between undergraduate researchers' perceptions of natural resources URE as situated learning and their outcomes.

4.3 Methods

Survey Development

An online self-report retrospective survey was developed for collecting information from undergraduate participants of summer URE programs in natural resources disciplines in operation in the United States from 2012 to 2016. A retrospective approach was used due to lack of a formal sampling frame and the need to incorporate annual cohorts from multiple URE programs during this period in attempt to increase the number of responses. To mitigate sampling frame lack, a snowball-type sampling technique respondent-driven sampling (RDS), and modifications to such methods, was used to identify and request information from individuals in the target population (Platt et al., 2015; Salganik & Heckathorn, 1997). The survey was designed to collect information on situated learning variables describing the degree to which respondents considered their specific URE and to assess outcome variables based on previously theorized and reported benefits associated with undergraduate participation. This work was approved prior to data collection by the Virginia Tech Institutional Review Board under protocol 14-283.

The survey contained 154 items across 18 blocks (Appendix E). Introductory questions were used to identify the URE associated with the survey and to determine whether respondents were students enrolled at institutions hosting the URE, the last year of participation, and the type of primary mentor in the URE. Situated learning variables were organized by hypothetical structure into five blocks of COP and CA items related to knowledge and tools used (shared repertoire), collaboration and objectives (joint enterprise), personal interactions (mutual engagement), instructional methods (pedagogy), and task ordering (sequencing). Blocks were prefaced with, "Please identify the extent to which you experienced from your perspective each of the following." Situated learning variables were 5-point Likert-type items with the following response categories: 1 = not at all, 2 = slightly, 3 = moderately, 4 = a good deal, 5 = a great deal. A not applicable (NA) option was included for shared repertoire items; occurrences were later treated as non-random missing data. Undergraduate survey outcome variables were assessed through batteries of items categorized based on hypothetical structure from literature into personal and professional outcomes, application of knowledge and skills, knowledge and understanding of science and research, general skills, and graduate school and career preparation. Outcome blocks were prefaced with the text, "Please identify the level of change you experienced as a result of your participation in this URE for the following." Unipolar Likert-type ratings included: 1 = decrease, 2 = no change, 3 = slight increase, 4 = moderate increase, 5 = good increase, and 6 = strong increase. A negative rating was included due to previous research suggesting that some individuals have mixed or negative outcomes resulting from URE participation (Thiry, Laursen, & Hunter, 2011). Career and education plan items were assessed on 7-point ratings where 1 = strongly decreased, 2 = decreased, 3 = slightly decreased, 4 = no change, 5 = slightly increased, 6 = moderately increased, 7 = strongly increased. Demographic data requested included gender, ethnicity, race, undergraduate rank at the time of participation, first generation college student status, and need-based financial aid status. Two open-ended questions allowed respondents to provide qualitative feedback on personal experiences during the program and on potential improvements.

The survey was pilot tested in June 2016 with 31 undergraduate respondents from a natural resources URE program operating during 2012-2016 at a southeastern region doctoral granting institution. Participants were provided a recruitment email asking them to complete the survey. Reminder messages were sent approximately one and two weeks after the initial email. The survey remained open for four weeks. Respondents were instructed at the end of each block to provide feedback on wording and inclusion or exclusion of individual items within respective blocks. Pilot testing resulted in minor revisions to survey item wording and inclusion or removal based on respondent feedback. The pilot survey had a smaller number of rating choices for outcome-related items (5-point scale) and for education and career plan items (5-point scale).

Sampling

Program coordinators of 49 natural resources URE that responded to a separate survey in a related study about program level data were potential intermediaries for data collection from their URE program's participants. Sampling of program coordinators was conducted through a modified RDS approach due to lack of a formal sampling frame for URE programs that may be classified as hidden populations (Salganik & Heckathorn, 2004). Because some programs may be unwilling or unable to provide participant contact information to a third party, URE program coordinators were asked about willingness to distribute internet links to online surveys (Qualtrics, Provo, UT, 2017) to their programs' past undergraduate participants. Coordinator respondents of 12 programs agreed to provide a brief introductory recruitment message and survey link for the undergraduate survey through their programs' established communication channels that included email lists and social media pages. Reminder messages were provided to coordinators for distribution one week after the initial message, and final reminder messages were provided two weeks after the initial message. Survey links were valid from May through August 2017. Coordinators were asked to provide estimated numbers of undergraduate participants for years 2012-2016 to calculate approximate response rates at the program level.

Data Cleaning

Analyses were conducted with SPSS (version 28.0; IBM, 2021), and the SPSS-R Menu package (version 2.4.3; Basto & Pereira, 2012) and R (version 4.2.0; R Core Team, 2022) were used for procedures and estimates not available in the base SPSS version. Surveys with less than 50% completion were removed from further analyses (Tabachnick and Fidell, 2013). These exclusions resulted in a sample of 103 out of a total 118 undergraduate responses from 12 programs. Data were examined for missing values and for multicollinearity. For shared repertoire situated learning items, the NA option was removed from 15 instances across 11 cases and treated as non-random missing data. Six partial responses missing data on outcome variables were retained for use in exploratory factor analysis (EFA) of situated learning variables. Multiple methods were used to evaluate presence of multivariate outliers including Mahalanobis Distances, for which $p = 0.001$ is a significance threshold, and examination of residual scatter plots (Tabachnick & Fidell, 2013); no case met criteria for exclusion based on distances at or above significance values. Situated learning variables were examined for meeting linearity and residual normality assumptions prior to further statistical analysis. Skewness and kurtosis statistics were examined for variables exceeding commonly noted thresholds of 2 and 7, respectively, for situated learning elements and for outcomes (Fabrigar, Wegener, MacCallum & Strahan, 1999). Histograms and residual plots were visually inspected to evaluate normality, and data were determined to be approximately normal.

Likert-type response data are frequently not normally distributed, but factor analysis is considered to be fairly robust to such data and their distributional properties (Watkins, 2018; Hair, Black, Babin, & Anderson, 2010). Because data were Likert-type ratings with five to seven options per item, a comparison of Pearson, Spearman, and polychoric correlation matrices was conducted prior to further use of the Pearson correlation matrix (Watkins, 2018; Fabrigar et al., 1999). The Pearson correlation matrix assumes interval data but was used due to having ordinal variables with five or more ratings approximating latent intervals, and because polychoric matrices may be less tolerant of non-normally distributed data (Coenders & Saris, 1995; Lorenzo-Seva & Ferrando, 2021). The Pearson matrix indicated acceptable to good levels of correlation ($\geq .3$) between variables without suggesting presence of multicollinearity or singularity issues. Condition indices and shared variances were also examined to confirm lack of multicollinearity. Undergraduate participants may be considered as nested within programs but were from a limited number of programs ($n = 12$) that prevented testing and use of multi-level modeling. However, intraclass correlation coefficients of outcome factor scores were all less than 0.124 (mean ICC = 0.053) and suggested lack of a considerable grouping effect at the program level.

Factor score estimates from EFA were then screened for outliers and for meeting normality and linearity assumptions. Normality was visually assessed using histograms, scatterplots, and descriptive statistics. Multiple methods were used to evaluate presence of multivariate outliers including Mahalanobis distance, Cook's distance, tolerances, and examination of residual plots. Diagnostics suggested that 18 cases were suspected outliers. However, no case was consistently identified as an extreme outlier or influential point, and these 18 observations were left in the sample.

Exploratory Factor Analysis

Two separate common factor analyses were conducted on undergraduate responses and served the following purposes: blending of theoretical frameworks that may be competing or complementary, considering lack of consistency of domains identified in prior literature, examination for latent factors present in the data, and variable reduction for other statistical analyses. The first EFA was conducted on variables associated with situated learning theories as independent variables representing undergraduates' perceptions of their immediate research communities as part of their URE. The second factor analysis examined participants' reported outcomes. Bartlett's test of sphericity (Bartlett, 1950) evaluated the factorability of the Pearson correlation matrix, and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy statistic was required to be above 0.50 (Field, 2009; Kaiser, 1974).

Thirty-nine situated learning variables were presented for factor analysis. Initial EFA was conducted using iterated principal axis factoring (PAF) with a direct oblimin rotation with Kaiser normalization and delta = 0. All factors with eigenvalues > 1 were accepted. Maximum likelihood, a commonly used extraction method, can be sensitive to small data sets, but PAF is relatively common with small (≤ 300) samples, when assuming latent factors are correlated, and when data may not meet normality assumptions (Fabrigar, et al., 1999; Osborne, 2014; Watkins, 2018). Oblimin rotation is a commonly used oblique rotation method when items are assumed to be correlated (Osborne, 2014). Missing data from the not applicable option for shared repertoire situated learning items were treated as nonrandom missing and by excluding cases pairwise to conserve the greatest amount of useable data (McNeish, 2017). During the iterative process, variables with loadings less than |.3| on any factor and variables cross-loading more than 75% of the greatest loading on a single factor were excluded from further analyses (Samuels, 2017; Tabachnick & Fidell, 2013). If all variables loaded greater than |.3| on at least one factor, variables that cross-loaded on one or more factors were then removed. The individual item with the greatest cross-loading was removed first. The iterative process continued until a stable factor solution emerged.

Researchers of factor analysis procedures generally recommend evaluating solutions based on a number of criteria including factor overdetermination (three or more indicators loaded by a factor), salience of loadings (e. g., ≥ .3 or more or loading highly, ≥ .7), on only one factor without cross-loadings, high Cronbach alpha reliability (≥ 0.7 is considered acceptable, ≥ 0.8 is good; Osborne, 2014; Field, 2009), and theoretical foundation (Fabrigar et al., 1999; Hair et al., 2010; Samuels, 2017; Watkins, 2018). Factor score estimates were calculated using the regression method due to conservation of indicator variable weights, maintaining factor correlations, use of different numeric scales on some items, and standardization of scores

(DiStefano, Zhu, & Mindrila, 2009; Grice, 2001). Regression scores with PAF provides factor score estimates with a mean of zero and a variance of squared multiple correlation between factors and variables (DiStefano et al., 2009; Tabachnick & Fidell, 2013). Factor score estimate coefficients of determinacy (a measure of validity) and reliabilities were determined through SPSS syntax scripts estimating reliabilities (Beauducel & Hilger, 2022; Beauducel et al., 2016; Ferrando & Lorenzo-Seva, 2018).

A second EFA procedure was separately conducted on 79 outcome variables from 103 partial and complete responses. Five variables were removed prior to EFA due to strong (> 0.8) bivariate correlations with one or more remaining variables and with consideration of conceptual overlap with a remaining variable (e.g., applying general critical thinking skills and applying research critical thinking; Field, 2009). Common factor analysis was performed using PAF with direct oblimin rotation Kaiser normalization and delta = 0, excluding cases listwise, and initially accepting all factors with eigenvalues > 1. The maximum number of iterations for convergence of rotation was increased to 50 to allow convergence. Listwise deletion was used due to six incomplete surveys missing data for outcome variables; all other responses (n = 97) were considered complete. Variables with loadings < |.4| across any factor were removed (Samuels, 2017; Tabachnick & Fidell, 2013), and EFA was repeated. If all variables loaded > |.4| on at least one factor, variables that cross-loaded on one or more factors were then removed. For variable reduction purposes, a cutoff greater than the value used for situated learning variables was used. Items were removed individually with items having greater cross-loadings removed first. The iterative process continued until a stable factor solution emerged. In the present study, outcome related factors were considered retainable if they loaded at least three items with salient pattern matrix coefficients (≥ |0.40|), met recommended reliability thresholds (Cronbach's alpha ≥.70; Field, 2009; Osborne, 2014), and were theoretically meaningful (Osborne, 2014; Velicer & Fava, 1998). Factor score estimates were calculated using the regression method as described above with situated learning variables.

To determine the nature of relationships between situated learning elements of undergraduates' research experiences and their self-reported outcomes, bivariate correlations were analyzed. Pearson correlation coefficients of factor score estimates from the situated learning scale and undergraduate outcomes scale allowed the strength and significance of relationships to be examined. Additionally, factor scores may be used in further statistical analyses, such as multivariate regression, to examine relationships (Bell, McCallum, & Cox, 2003; DiStefano, Zhu, & Mindrila, 2009). Thus, situated learning and outcome factor scores were examined for meeting assumptions of multiple regression, including linearity, independence, normality of dependent residuals as a proxy for multivariate normality, homogeneity of variances, and multicollinearity. A multivariate multiple regression analysis was conducted using situated learning factor scores as independent variables and outcome factor scores as dependent variables. This analysis examined the main effects of situated learning factors in predicting outcomes. The general linear model (GLM) procedure with multiple dependent variables in SPSS is effectively a multiple analysis of variance.

4.4 Results

Respondents across 12 URE programs provided 103 usable partial and complete responses. Estimated approximate response rates ranged from 4% for the largest program to 80% (mean of 33%) where 10 coordinators reported URE populations within the sampling frame ranging from "approximately 250" to 10 undergraduates. Undergraduate respondents providing demographic information (n = 97; Table 4.2) were predominantly female (74%), white or Caucasian (65%), not of Hispanic or Latinx ethnicity (79%), not first-generation college (62%), and eligible for need-based financial aid (63%).

Table 4.2. Demographics reported by natural resources URE undergraduate participants of programs operating from 2012 to 2016.

Demographic	#	Percent	Demographic	#	Percent
Race			*Undergraduate Classification*		
White or Caucasian	67	65	Freshman/rising sophomore	10	9.7
Black or African American	9	8.7	Sophomore/ rising junior	31	30.1
American Indian or Native American	4	3.9	Junior/ rising senior	41	39.8
Other	5	4.9	Senior	10	9.7
Asian	4	3.9	Other	5	4.9
Native Hawaiian or Pacific Islander	1	1	Total	97	94.2
Prefer to not answer	3	2.9	Missing data	6	5.8
Multiple Races	3	2.9	Total	103	100
Missing data	7	6.8	*First Generation Student*		
Total	103	100	No	63	61.2
Ethnicity			Yes	34	33
Not Hispanic or Latinx	81	78.6	Missing data	6	5.8
Hispanic or Latinx	16	15.5	Total	103	100
Missing data	6	5.9	*Need-based Financial Aid Eligibility*		
Total	103	100	Yes	65	63.1
Gender			No	30	29.1
Female	72	70	Not sure	2	1.9
Male	24	23	Total	97	94.2
Other	1	1	Missing data	6	5.8
Missing data	6	6		103	100
Total	103	100			

Six incomplete surveys lacked responses to outcome variables and some demographic information. However, these contained responses for situated learning variables and thus were included for EFA of situated learning items. The remaining 97 responses were utilized for all other analyses. Univariate skewness and kurtosis were within acceptable limits for factor analysis for situated learning variables and outcome variables (see Appendix B and Appendix C). However, Mardia's multivariate skew and kurtosis statistics were both significant at $p < 0.001$ for both variable sets.

For situated learning variables ($k = 39$), Bartlett's test of sphericity (Bartlett, 1954) was significant (χ^2 (741) = 2519, $p < .001$) and the KMO statistic (Kaiser, 1974) was 0.875 suggesting the Pearson correlation matrix was factorable. Anti-image matrix diagonals were all greater than .5 (Field, 2009). Extracted communalities averaged 0.557 and were within values identified in social sciences (Costello & Osborne, 2005). Selecting the number of factors to retain from EFA was informed by multiple criteria, with consideration given to under- and overfactoring (Fabrigar et al., 1999). Initial common factor analysis based on eigenvalues larger than one, the Kaiser criterion (Kaiser, 1960), suggested a six-factor solution. The minimum average partial (MAP) and revised MAP tests supported four and six factor solutions, respectively (O'Connor, 2000). Evaluation of the scree plot suggested two to five factors were latent in the data (Cattell, 1966). Parallel analysis (Horn, 1965; O'Connor, 2000) using PAF, regarded as a more accurate predictor of the number of factors to retain, indicated a cutoff after five factors. Theoretical guidance from situated learning literature was also considered.

A six-factor solution containing 31 retained variables was accepted (Table 4.3). Factor loadings greater than |0.35| were considered salient, however the majority were greater than |0.40| and more in line with recommendations for item retention for smaller samples (Costello & Osborne, 2005). After rotation, extracted factors accounted for 55% of total variance and had Cronbach alpha reliabilities from 0.77 to 0.92. Factors were labeled as (1) effective mentorship methods, (2) sequencing, (3), specific repertoire, (4) mutual engagement, (5) joint enterprise, and (6) broad repertoire. PAF in SPSS does not provide goodness of fit statistics, but a residual correlation matrix was produced and fit statistics were provided through the R Factor extension. The root mean square residual (RMSR = .042) statistic indicated the six factor model had good fit using a recommended .06 cutoff (Hu & Bentler, 1999; Tabachnick & Fidell, 2013). Regression method factor score estimate coefficients of determinacy for predictor variables ranged from 0.888 to 0.963, suggesting scores were good estimates of latent factors. Negatively signed items on factor six were artifacts (i.e., sign indeterminate) of oblimin rotation and do not indicate negatively correlated factors (Table 4.4; Bainter, 2017; Henseler, 2017). Presence of negative signs as artifacts was confirmed with a different oblique (promax) rotation providing a nearly equivalent factor structure without the negative sign.

Six resultant situated learning factors were named by associations with theoretical foundations. Effective mentorship methods (k = 8, summated mean = 4.01) accounted for 37% of total variance and included pedagogical practices carried out by mentors in individual and small group settings. Sequencing (k = 3, summated mean = 4.18) included the conceptual and sequential nature of related tasks and accounted for 4.9% of variation. Specific repertoire (k = 6, summated mean = 3.85) items made up 4.3% of overall variance and included information and tasks germane to the undergraduate's URE program and specific project. Mutual engagement included three items (summated mean = 4.21) focusing on formal and informal interpersonal engagement and connectivity accounting for 3.5% of total variation. Joint enterprise (k = 7, summated mean = 4.09) explained 3.0% of total variance. This factor was represented by items related to work that is shared and furthered in a community. The sixth factor, broad repertoire, was comprised of four items (summated mean = 4.20) related to the general nature and procedures of research and explained 2.8% of total variance.

Undergraduate outcome variables (k = 79) were factorable using the Pearson correlation matrix based on Bartlett's test of sphericity (χ^2 (3081) = 9019, $p < .001$; Bartlett, 1954) and KMO statistic of 0.706 (Kaiser, 1974). Anti-image matrix diagonals were greater than .50 except for three variables ranging from .43 to .47 (Field, 2009). Dependent variable factor retention was informed by multiple criteria. The scree test (Cattell, 1966) was ambiguous with multiple break points suggesting three, four, or six factors were latent in participant outcome data. The MAP and revised MAP tests supported seven and 10 factor solutions, respectively. Parallel analysis indicated a two-factor solution was appropriate (Horn, 1965; O'Connor, 2000). Prior research and theory based on undergraduate research outcomes suggest a varying number of latent constructs.

Table 4.3. Pattern loadings from principal axis factoring with direct oblimin rotation for a six-factor solution for situated learning components of undergraduate research experiences (n = 103).

	Factor Loading						
Item	**1**	**2**	**3**	**4**	**5**	**6**	**Communality (Extracted)**
My mentor acted like a coach (e.g., provided feedback or tips for improvement) for me during the URE.	**0.83**	-0.10	-0.03	-0.06	0.16	-0.17	0.86
I had one-on-one time with my mentor during the URE.	**0.70**	-0.02	0.06	0.07	-0.10	0.07	0.45
My mentor gave me specific suggestions or tools I needed to solve problems in research.	**0.65**	0.22	0.01	0.06	0.08	-0.08	0.76
My mentor at times asked me to explain the work I was doing for research.	**0.58**	0.19	0.01	-0.10	0.23	-0.10	0.69
My mentor demonstrated for me how to perform research-related tasks.	**0.57**	0.04	-0.02	0.17	0.05	-0.16	0.61
My mentor gave me opportunities to think up and solve new research problems.	**0.53**	0.24	0.11	0.05	0.02	-0.15	0.65
There were opportunities for me to consider how my mentor or other peers solved problems during research.	**0.48**	0.15	0.16	0.13	0.08	-0.10	0.61
Small group meetings with others working in my research group were an important part of the URE.	**0.41**	0.05	0.01	-0.10	0.19	-0.28	0.47
There were times when new tasks required me to try new approaches or learn new skills.	0.01	**0.81**	0.02	-0.11	-0.05	-0.12	0.68
New tasks required for the URE still challenged me as my ability increased.	-0.01	**0.77**	0.05	0.06	0.02	0.04	0.63
I had to understand the big picture related to tasks I was working on before working on the smaller, related details.	0.08	**0.53**	0.16	0.18	0.07	-0.01	0.55
Conversations related to the research often involved jargon.	-0.11	0.14	**0.56**	-0.08	0.02	-0.02	0.34
Laboratory / field work safety was an important component of the URE.	0.21	-0.12	**0.53**	0.01	0.03	-0.30	0.57
I felt an emphasis on preparing a final research presentation to share my research with others.	0.12	0.05	**0.46**	0.20	0.16	0.02	0.48
Developing a written research proposal with others was an important component of the URE.	0.14	0.17	**0.45**	0.08	0.02	-0.01	0.39
Conducting a literature review was an important component of the URE.	0.09	0.12	**0.40**	0.15	0.12	-0.10	0.44
I was aware of the application and decision process for the URE.	0.16	-0.08	**0.36**	0.09	0.14	-0.15	0.36

I felt a connection with other undergraduates participating in the URE program.	-0.14	0.07	0.00	**0.81**	0.00	-0.23	0.74
I interacted with scientists and/or researchers outside my research group.	0.22	-0.14	0.22	**0.63**	0.10	0.08	0.65
I participated with other members of the research group in informal social activities outside of work.	0.14	0.11	-0.07	**0.59**	0.01	-0.02	0.48
Setting goals for the group was important during the research experience.	-0.03	-0.08	0.22	-0.10	**0.79**	-0.04	0.68
I felt a sense of belonging to the research group during the URE.	-0.10	-0.03	-0.19	0.24	**0.65**	-0.22	0.63
Individuals in the research group were held accountable to each other.	0.02	0.05	0.16	-0.13	**0.59**	-0.06	0.45
Personal achievements were celebrated by members of the group.	0.29	0.10	-0.25	0.14	**0.51**	-0.05	0.61
My URE placed importance on providing outreach to non-scientists.	0.22	0.15	-0.11	0.16	**0.47**	0.12	0.48
Discussions about graduate school were supported by others during the URE.	0.18	0.02	0.08	0.19	**0.40**	0.05	0.40
Having an orientation at the beginning was an important part of the URE.	0.07	0.20	0.10	0.15	**0.37**	0.05	0.37
Learning about the responsible conduct of research was an important component of the URE.	0.11	0.02	0.10	0.08	-0.05	**-0.71**	0.65
Learning about ethics was an important component of the URE.	0.19	0.19	-0.09	-0.10	0.02	**-0.60**	0.55
Understanding the nature of science was important for the URE.	-0.06	0.03	0.22	0.20	0.08	**-0.57**	0.60
Knowledge of procedures was an important component of the URE (e.g., how your mentor carried out a task).	-0.02	0.05	0.05	0.21	0.15	**-0.44**	0.43
Eigenvalues (Extracted)	11.51	1.51	1.34	1.09	0.94	0.87	
Scale Alpha (Cronbach's)	0.92	0.80	0.77	0.79	0.84	0.80	
% of Total Variance	37.13	4.86	4.31	3.53	3.03	2.82	
Coefficient of Determinacy	0.96	0.92	0.89	0.93	0.94	0.92	
Summated Factor Mean	4.01	4.18	3.85	4.21	4.09	4.20	

Note: All items measured on unidirectional 5-point scale (1 = not at all, 2 = slightly, 3 = moderately, 4 = a good deal, 5 = a great deal).

Table 4.4. Correlation matrix of situated learning rotated factors from principal axis factoring.

Factor	1	2	3	4	5	6
Effective Mentorship Method	1.00					
Sequencing	0.47	1.00				
Specific Repertoire	0.33	0.36	1.00			
Mutual Engagement	0.43	0.33	0.27	1.00		
Joint Enterprise	0.56	0.36	0.37	0.49	1.00	
Broad Repertoire*	-0.50	-0.44	-0.41	-0.35	-0.52	1.00

Note: All correlations significant at alpha 0.01 level (2-tailed).
* Negative signs are a negligible product of oblique rotation and not indicative of true negative correlations.

A six-factor model containing 30 variables associated with participant outcomes was retained (Table 4.5). Extracted communalities averaged 0.692. Factor loadings ≥ |0.40| were considered salient due to a small sample size and in recommendation with literature (Costello & Osborne, 2005). Rotated extracted factors accounted for 69.5% of cumulative variance. Cronbach's alpha reliability statistics ranging from 0.88 to 0.92 were indicative of good reliabilities. Factors were labeled (1) general skills, (2) career trajectory, (3) academic and career readiness, (4) communication of science, (5) cognitive skills, and (6) researcher identity. One variable, "general level of confidence not related to research," was removed from the cognitive skills factor due to cross-loading on the structure matrix, lacking strong theoretical basis for loading, and removal improving scale reliability (alpha from .905 to .917); the model was rerun after removal and determined to have similar factor structure. The RMSR statistic of .033 indicated good fit for a six-factor solution (Hu & Bentler, 1999; Tabachnick & Fidell, 2013). Further, the rotated pattern matrix indicated simple structure with most variables loading moderately to highly on one factor with low or near zero loadings on other factors (Fabrigar et al., 1999). Regression method factor score estimate coefficients of determinacy for outcome variables ranged from 0.943 to 0.962. Negative sign items on factors five and six were artifacts of oblimin rotation and do not indicate factors are negatively correlated (Table 4.6; Bainter, 2017; Henseler, 2017). Presence of artifacts was confirmed with another oblique (promax) rotation providing a nearly equivalent factor structure without the negative sign.

Outcome factors were named with consideration to indicators loaded by factors, prior research, and theory. General skills ($k = 5$, summated mean = 4.72) accounted for 47% of total variance and included indicators related to personal management and other soft skills. Career trajectory ($k = 5$, summated mean = 5.5) accounted for 7.7% of total variation and included items related to interest in current field of study and plans for career and graduate school. Academic and career readiness ($k = 5$, summated mean = 5.20) explained 5.1% of overall variance. This factor was associated with preparedness for new experiences and education, especially resulting from collaborative work and networking. The communication of science factor accounted for 3.4% of total variation and included five items (summated mean = 4.80) resulting from reading primary research literature and discussing research through multiple formats. Indicators related to the conceptual and practical nature of science, linking theory, and data analysis comprised the cognitive skills factor ($k = 5$, summated mean = 4.85) that explained 3.0% of total variance. Researcher identity was composed of five items (summated mean = 4.89) related to the affective nature of research work and strength of a professional identity and explained 2.6% of total variance.

Table 4.5. Pattern loadings from principal axis factoring with direct oblimin rotation for a six-factor solution for outcomes associated with undergraduate research experiences (n = 97).

	Factor						
Item	**1**	**2**	**3**	**4**	**5**	**6**	**Communality (Extracted)**
Time management	**0.90**	0.08	-0.06	-0.12	-0.12	0.00	0.84
Work organization skills	**0.83**	-0.05	0.06	-0.02	-0.01	-0.10	0.78
Ability to work independently	**0.60**	0.10	0.00	0.16	-0.03	-0.02	0.58
General computer skills	**0.52**	0.07	0.07	0.28	0.13	-0.02	0.50
Oral communication skills	**0.49**	0.06	0.05	0.26	-0.09	-0.09	0.66
Probability of continuing a career (academic or otherwise) in a natural resources field of study*	0.09	**0.82**	0.18	-0.14	-0.15	0.11	0.82
Level of interest in attending graduate school*	0.13	**0.81**	-0.01	0.08	0.19	-0.09	0.77
Confirming plans to attend graduate school*	0.00	**0.71**	-0.13	0.14	0.04	-0.16	0.62
Interest and enthusiasm for your current field of study*	0.04	**0.69**	0.13	-0.05	-0.04	-0.14	0.71
Preparation for your career	0.02	**0.55**	0.37	0.02	-0.11	0.02	0.65
Exposure to new opportunities and/or experiences	0.14	0.06	**0.76**	-0.04	-0.07	0.08	0.68
Preparation for other parts of your undergraduate education (e.g., coursework; senior / honor thesis)	0.04	0.03	**0.68**	-0.03	-0.17	-0.18	0.74
Opportunities for networking with faculty, peers, and other scientists	0.09	0.03	**0.62**	0.12	-0.04	-0.18	0.69
Preparation for career and graduate school resulting from collaboration	0.00	0.02	**0.57**	0.17	0.19	-0.32	0.59
Quality of your resume	-0.14	0.30	**0.53**	0.13	-0.14	0.03	0.55
Making use of primary scientific research literature	0.01	-0.01	0.03	**0.76**	-0.11	-0.01	0.69
Answering questions while defending your research	0.03	-0.06	0.19	**0.70**	-0.04	-0.05	0.67
Visual / graphic presentation skills	0.12	0.25	-0.12	**0.59**	-0.07	-0.08	0.66
Understanding of how scientists work on real problems	0.21	-0.04	0.06	**0.59**	-0.17	-0.03	0.69
Written communication skills	0.23	0.10	-0.11	**0.51**	-0.25	-0.11	0.76
Understanding of how to frame research questions	-0.09	0.14	-0.04	0.32	**-0.63**	-0.08	0.71
Ability to analyze data within a theoretical / conceptual framework	0.11	-0.10	0.06	0.16	**-0.63**	-0.10	0.67
Applying critical thinking and problem solving related to research	0.17	0.06	0.19	0.07	**-0.62**	-0.04	0.77
Ability to link theory and practice	0.21	-0.06	0.07	0.02	**-0.61**	-0.22	0.75

Understanding of the research process	0.24	-0.05	0.26	0.26	**-0.43**	0.07	0.70
Feeling of how strongly you have a professional identity as a scientist	0.05	0.04	0.02	0.13	-0.02	**-0.73**	0.73
Having a mentoring relationship with faculty	0.13	-0.07	0.32	0.07	-0.01	**-0.59**	0.71
Motivation related to work as a scientist	0.05	0.31	-0.09	-0.02	-0.31	**-0.55**	0.77
Confidence in being taken seriously by your mentor	0.09	0.17	0.17	0.00	-0.13	**-0.52**	0.67
Readiness for more demanding research	0.19	0.25	0.02	-0.12	-0.17	**-0.49**	0.64
Eigenvalues (Extracted)	14.21	2.32	1.53	1.03	0.90	0.78	
Scale Alpha (Cronbach's)	0.89	0.90	0.88	0.90	0.92	0.90	
% of Total Variance	47.35	7.72	5.10	3.43	3.01	2.59	
Coefficient of Determinacy	0.96	0.96	0.95	0.95	0.94	0.94	
Summated Factor Mean	4.72	5.50	5.20	4.80	4.85	4.89	

*Items measured on symmetrical 7-point rating; all other items on asymmetrical 6-point rating (1 = decrease, 2 = no change, 3 = slight increase, 4 = moderate increase, 5 = good increase, and 6 = strong increase).

Table 4.6. Pearson correlation matrix of regression factor score estimates from oblique rotated factors using principal axis factoring of undergraduate researcher outcomes.

Factor	1	2	3	4	5	6
General Skills	1.00					
Career Trajectory	0.41	1.00				
Academic and Career Readiness	0.36	0.38	1.00			
Communication of Science	0.53	0.28	0.36	1.00		
Cognitive Skills*	-0.52	-0.32	-0.40	-0.50	1.00	
Researcher Identity*	-0.56	-0.51	-0.43	-0.46	0.40	1.00

Note: All correlations significant at alpha = 0.01 level (2-tailed).
*Negative signs are a negligible artifact of oblique rotation and not indicative of true negative correlations.

Table 4.7. Descriptive statistics of regression method factor score estimates.

Factor	N	Mean (SD)	Skewness	Kurtosis
Effective Mentorship Method	92	-0.05 (0.97)	-0.71	-0.55
Sequencing	92	-0.01 (0.94)	-0.70	0.31
Specific Repertoire	92	0.00 (0.91)	-0.83	1.81
Mutual Engagement	92	0.00 (0.93)	-1.43	2.56
Joint Enterprise	92	-0.03 (0.97)	-1.41	2.18
Broad Repertoire (reversed)	92	0.02 (0.90)	-1.16	1.03
General Skills	97	0.00 (0.96)	-0.84	0.07
Career Trajectory	97	0.00 (0.96)	-1.27	1.82
Academic and Career Readiness	97	0.00 (0.94)	-1.65	2.87
Communication of Science	97	0.00 (0.94)	-0.70	-0.31
Cognitive Skills (reversed)	97	0.00 (0.94)	-0.92	0.38
Researcher Identity (reversed)	97	0.00 (0.94)	-1.27	2.12
Valid N (listwise)	88			

Mean, standard deviation, skewness, and kurtosis statistics for factor score estimates are reported in Table 4.7. Estimation using the regression method rescaled variables to a mean of zero, or near zero for means of situated learning variables due to use of pairwise deletion instead of listwise deletion that was used for missing values in EFA of outcomes. Factor score estimates' skewness and kurtosis statistics were within acceptable ranges of normality (Fabrigar et al., 1999; Hair et al., 2010).

Table 4.8. Pearson correlations of regression factor score estimates for situated learning elements and outcomes obtained by principal axis factoring with oblimin rotation from a sample of 88 undergraduates.

	Effective Mentorship Method	Sequencing	Specific Repertoire	Mutual Engagement	Joint Enterprise	Broad Repertoire
General Skills	.540**	.580**	.349**	.374**	.387**	.342**
Career Trajectory	.436**	.357**	.015	.184*	.280**	.279**
Academic and Career Readiness	.495**	.335**	.238*	.405**	.391**	.351**
Communication of Science	.564**	.513**	.552**	.407**	.452**	.550**
Cognitive Skills	.512**	.471**	.578**	.432**	.412**	.588**
Researcher Identity	.682**	.468**	.218*	.282**	.407**	.395**

** Correlation is significant at alpha = 0.01 level (1-tailed).

* Correlation is significant at alpha = 0.05 level (1-tailed).

Regression factor scores estimates of situated learning and outcome latent factors were nearly all significantly and positively correlated (Table 4.8). Negatively-signed factor score estimates resulting from oblimin rotation for *researcher identity*, *joint enterprise*, and *broad repertoire* factors were reversed by multiplying individual score estimates by -1 such that all factors were oriented in the same direction. The strongest bivariate correlation existed between effective mentorship method and researcher identity ($r = .682$). A weak correlation was found for *mutual engagement* and *career trajectory* ($r = .184$), and *specific repertoire* and *career trajectory* were not correlated ($r = .015$).

Factor score estimates were accepted as meeting regression assumptions based on residual statistics and probability plots, Mahalanobis distance, tolerances > 0.2, variance inflation factors < 10, Barlett's test of sphericity (χ^2 (20) = 60.701, $p < 0.001$), and Durbin Watson statistics (range of 1.5 to 2.2). Four cases were identified as potential outliers inconsistently on individual outcome factors; in consideration of multiple criteria and sample size, these cases remained in further analyses. The listwise sample size (n = 88) was deemed adequate for general linear modeling (GLM) given several guides for sample size relative to number of predictor variables (e.g., $20 + 5m$, where m = number of predictor variables) (Field, 2009; Tabachnick & Fidell, 2013). Multivariate GLM with alpha = 0.05 using Pillai's trace (V; Field, 2009) indicated four situated learning factors were significant predictors of all outcomes (Table 4.9) in a full multivariate model. *Mutual engagement* and *joint enterprise* were not significantly associated with any outcome. For multivariate GLM using independent variables as covariates, Pillai's trace is also equivalent to partial eta squared, a measure of effect size.

Table 4.9. Multivariate general linear model results from regressing undergraduate researcher outcome factor scores on situated learning factors with alpha = 0.05, n = 88.

Predictor	***V***	***F***	**df**	***p***
Effective Mentorship Methods	0.309	5.66	6, 76	< .001

Sequencing	0.185	2.88	6, 76	0.014
Specific Repertoire	0.302	5.475	6, 76	< .001
Broad Repertoire	0.184	2.858	6, 76	0.015
Mutual Engagement	0.098	1.373	6, 76	0.236
Joint Enterprise	0.032	0.423	6, 76	0.862

To further elucidate effects of situated learning scores on individual outcomes, post hoc univariate multiple regressions were conducted using forward entry and listwise case deletion for each model (Tabachnick & Fidell, 2013). Final models for general skills, career trajectory, academic preparation, communication of science, cognitive skills, and researcher identity were all significant at alpha = 0.05 (Table 4.10). Joint enterprise was not a significant predictor in any model.

Table 4.10. Forward univariate multiple linear regression analyses with outcome factor scores regressed on situated learning factor scores.

General Skills						
Adjusted $R^2 = .413$, $F(2, 85) = 15.50$, $p < .001$						
		B	SE *B*	β	*t*	*p*
2	(Constant)	-0.01	0.07		-0.080	0.937
	Sequencing	0.41	0.09	0.417	4.461	0.000
	Effective Mentorship Method	0.32	0.09	0.342	3.658	0.000
	Specific Repertoire	.08[a]			0.910	0.365
	Mutual Engagement	.12[a]			1.342	0.183
	Joint Enterprise	.09[a]			0.879	0.382
	Broad Repertoire	-.03[a]			-0.318	0.751

a. Predictors: (Constant), Sequencing, Effective Mentorship Method; others excluded.
Note: $R^2 = 0.33$ for Step 1, $\Delta R^2 = 0.09$ for Step 2 ($p < .001$).

Career Trajectory						
$R^2 = .181$, $F(1, 86) = 20.165$, $p < .001$						
		B	SE *B*	β	*t*	*p*
1	(Constant)	0.04	0.09		0.461	0.646
	Effective Mentorship Method	0.43	0.10	0.44	4.491	0.000
	Sequencing	.19[a]			1.769	0.080
	Specific Repertoire	-.17[a]			-1.677	0.097
	Mutual Engagement	.02[a]			0.137	0.891
	Joint Enterprise	.07[a]			0.623	0.535
	Broad Repertoire	.08[a]			0.734	0.465

a. Predictors: (Constant), Effective Mentorship Method; others excluded
Note: $R^2 = 0.19$ ($p < .001$).

Academic and Career Readiness
Adjusted $R^2 = .281$, $F(2, 85) = 18.004$, $p < .001$

		B	SE *B*	β	*t*	*p*
2	(Constant)	-0.03	0.09		-0.315	0.753
	Effective Mentorship Method	0.40	0.10	0.40	4.017	0.000
	Mutual Engagement	0.26	0.10	0.25	2.519	0.014
	Sequencing	.08[a]			0.789	0.433
	Specific Repertoire	.01[a]			0.104	0.917
	Joint Enterprise	.10[a]			0.923	0.359
	Broad Repertoire	.09[a]			0.885	0.379

a. Predictors: (Constant), Individual and Group Method, Mutual Engagement; others excluded.
Note: $R^2 = 0.25$ for Step 1, $\Delta R^2 = 0.05$ for Step 2 ($p < .05$).

		Communication of Science				
		Adjusted $R^2 = .480$, $F(3, 84) = 27.723$, $p < .001$				
		B	SE *B*	β	*t*	*p*
3	(Constant)	-0.04	0.07		-0.547	0.586
	Effective Mentorship Method	0.31	0.09	0.31	3.443	0.001
	Specific Repertoire	0.34	0.09	0.33	3.730	0.000
	Broad Repertoire	0.27	0.10	0.26	2.732	0.008
	Sequencing	.18[a]			1.986	0.050
	Mutual Engagement	.12[a]			1.365	0.176
	Joint Enterprise	.03[a]			0.262	0.794

a. Predictors: (Constant), Effective Mentorship Method, Specific Repertoire, Broad Repertoire; others excluded.
Note: $R^2 = 0.32$ for Step 1, $\Delta R^2 = 0.14$ for Step 2 ($p < .001$), $\Delta R^2 = 0.05$ for Step 3 (p < .01).

		Cognitive Skills				
		Adjusted $R^2 = .492$, $F(3, 84) = 29.104$, $p < .001$				
		B	SE *B*	β	*t*	*p*
3	(Constant)	0.00	0.07		-0.028	0.977
	Broad Repertoire	0.33	0.09	0.33	3.579	0.001
	Specific Repertoire	0.36	0.09	0.36	4.146	0.000
	Effective Mentorship Method	0.20	0.09	0.21	2.358	0.021
	Sequencing	.12[a]			1.353	0.180
	Mutual Engagement	.15[a]			1.820	0.072
	Joint Enterprise	-.04[a]			-0.396	0.693

a. Predictors: (Constant), Broad Repertoire, Specific Repertoire, Effective Mentorship Method; others excluded.
Note: $R^2 = 0.35$, R^2Adj = 0.34 for Step 1, $\Delta R^2 = 0.13$ for Step 2 ($p < .001$), $\Delta R^2 = 0.03$ for Step 3 ($p < .05$).

		Researcher Identity				
		Adjusted $R^2 = .479$, $F(2, 85) = 41.006$, $p < .001$				
		B	SE *B*	β	*t*	*p*
2	(Constant)	0.02	0.07		0.260	0.796
	Effective Mentorship Method	0.54	0.08	0.59	6.746	0.000
	Sequencing	0.17	0.08	0.18	2.097	0.039
	Specific Repertoire	-.090[a]			-1.050	0.297
	Mutual Engagement	-.017[a]			-0.196	0.845

Joint Enterprise	.043[a]	0.462	0.645
Broad Repertoire	.020[a]	0.211	0.833

a. Predictors: (Constant), Effective Mentorship Method, Sequencing; others excluded.
Note: $R^2 = 0.47$ for Step 1, $\Delta R^2 = 0.03$ for Step 2 ($p < .05$).

4.5 Discussion

This study sought to explore how natural resources URE programs function as situated learning, assess undergraduate outcomes from participation in such programs, and examine potential links between program function and outcomes. Survey respondents were from a broad cross-section of URE types within interdisciplinary fields. Despite sampling limitations and time frame of data collection, this research makes the following contributions to the field. First, degrees to which undergraduate participants perceive their URE programs as situated learning under a blended theoretical framework were quantitatively identified. Second, estimates were provided for relationships between situated learning elements and undergraduate outcomes within natural resources URE programs. Insights from this study may be useful for practitioners or program developers that wish to target certain categories of outcomes or for researchers exploring causal links.

Limitations

This study was based on a small, convenience sample from a small number of discipline-specific undergraduate research experience programs, While participant demographics were similar to other studies' respondents, any comparisons to other data or broader populations should be made with caution with respect to the limitations of small sample sizes and methodological decisions. Gender, race and ethnicity demographics of respondents in the present study were similar to those of other survey-based URE studies, with majorities identifying as female and as white / not Hispanic or Latin (Cater, Ferstel, & O'Neil, 2016; Lopatto, 2004). Most respondents were not first-generation college students. A majority considered themselves eligible for need-based financial aid. About 70% of respondents were either rising juniors or seniors, suggestive of trends noted in literature regarding who participates in URE programs (Linn et al. 2015). Research and evaluation studies using self-report surveys should consider the potential influence of response biases. However, errors due to bias were likely minimal in the present study conducted by an independent third party to URE programs, and respondents had reasonable expectation of anonymity and were candid in open-ended replies about the strengths and weaknesses perceived in their respective programs.

The sample size in this study was lower than a generally recommended minimum (e.g., 200 samples or 5:1 subject to variable ratio) for conducting EFA. However, respondents were from a hidden population where no formal sampling frame exists, and the sample size was within those reported in literature as sufficient for EFA use (MacCallum et al. 1999). Approximated response rates for each program's respondents were within ranges generally found using online surveys, but these estimates rely on accuracy of participant numbers reported by coordinators. One coordinator indicated approximately 250 undergraduates came through the program during 2012 to 2016, but only 10 respondents were associated with that URE. That program's publicly available UR symposium abstracts indicated 135 undergraduates completed the program during that timeframe. Two other program coordinators provided approximate numbers, and estimates of undergraduate participation were not provided for two programs. Other program-specific response rates may be more valid, as seven coordinators provided exact numbers. In personal communications with program coordinators, some suggested difficulty in obtaining retrospective feedback or survey participation from participants after they leave the program. Other programs with stronger or previously established collaborative ties or with extrinsic incentives may have better response rates. One such example of surveying a more formal sampling frame was development of the Undergraduate Research Student Self-Assessment (URSSA) funded by the National Science Foundation to assess impacts of the Bio-REU Program (Hunter, Weston, Laursen, & Thiry 2009. Other survey research may implement minor rewards as tokens of appreciation for participation (Maltese, Harsh, & Jung, 2017).

Small sample sizes, approximately 100 in the present study, may be considered "poor," are often problematic in EFA studies, and may introduce errors such that factor solutions do not accurately represent their populations (Fabrigar et al., 1999; Tabachnick & Fidell, 2013). Velicer and Fava (1998) suggested that studies expecting low subject samples oversample the number of variables so that low and moderately loading variables may be removed from analyses. In this study, alternative EFA solutions with more factors than accepted solutions generally underdetermined (few or low loading variables) and had multiple cross-loadings. Average communality for situated learning factors ($h^2 = .557$) was relatively low for a small sample size, indicating that improvements may be made through question item wording or adjustments to the number of factors. The average extracted communality for outcome variable analysis ($h^2 = 0.69$) was very near the recommended threshold of 0.70 or more (Fabrigar et al., 1999). Potential detrimental effects of the present study's low sample size may be reduced provided that factors were reasonably overdetermined with good reliabilities and model fit statistics were within recommended thresholds (Fabrigar et al., 1999; MacCallum et al., 1999). MacCallum et al. (1999, 2001) suggest that analyses with high (.6 to .8 or mean of .7) or wide (.2 to .8 or mean of .55) communalities and high overdetermination of factors (ratios of 20:3 indicators to factors, or at least six to seven variables per factor and small numbers of factors) mitigate effects of smaller sample sizes. Hogarty et al. (2005) generally found solutions with fewer but overdetermined factors had greater stability. A small number of factors in the present study having generally weaker loadings (e.g., *specific repertoire*) or fewer indicators (e.g., *sequencing*) may be representative of detrimental effects of small sample sizes. Further work refining these subscales potentially through wording improvements or addition of other indicators may improve future analyses.

This study relies on a self-report survey, a weakness noted in URE research reviews (Linn et al., 2015; Pfund, 2016). Such surveys are frequently retrospective and frame questions rated as increases in gains. Students may view themselves highly in some of these areas and report lesser gains accordingly. However, pre-experience surveys of undergraduates assessing skills and abilities also have limitations. Studies of causal relationships with validated pre-post assessments and comparisons to control groups of undergraduates without research experience are limited likely due to methodological and ethical considerations, but techniques such as propensity-score matching may alleviate such problems (Carter et al., 2016; Haeger et al., 2020).

Situated Learning Factors

The myriad diversity of program elements in URE has been generally noted in literature, but this study examined across a variety of URE programs the degree to which students experienced specific components in their URE program. Results indicate undergraduates experience legitimate peripheral participation through interacting and contributing to research in URE programs. This study's examination of 12 natural resources URE programs through a situated learning lens provides broad context for mechanisms associated with undergraduates' gains. Cognitive apprenticeship and COP concepts related to practice were represented by factors resulting from EFA. *Effective mentorship methods* was largely represented by items associated with mentorship, perhaps the most well-studied UR component (Linn et al., 2015; Pfund, 2016; Thiry & Laursen, 2011). Taraban and Logue (2012) identified five constructs in their Undergraduate Research Questionnaire (URQ): research mindset, research methods, faculty support, peer support, and academic mindset. The URQ subscales blended specific outcomes with some UR components experienced during research, but their analysis suggested communication about research, advanced training, and interactions with peers in addition to faculty mentors were important for successful URE. *Effective mentorship methods* in the present study aligns well with a faculty support construct and also indicates importance of peer or small group supports in addition to those provided by quality individualized mentoring. However, types of peer support may need differentiation due to some items relating to peer undergraduates in research groups either were not loaded highly or were cross-loaded by *effective mentorship method* or were loaded by *mutual engagement*.

Sequencing of knowledge, practices, and tasks was identified as being important for undergraduates' URE. As undergraduates progress through a project, they may view themselves as being able to better navigate through increasingly challenging or higher-order tasks as a sign of gains in skill and communication ability. Thiry and Laursen (2011) discuss scaffolding of instruction and other intellectual supports to guide student work toward greater independence and ability. Results indicate discipline-related concepts and procedures (*specific repertoire*) and more general research considerations (*broad repertoire*) had greater associations with gains in communication and cognitive skills than other aspects.

Interpersonal connections and engagement within and external to research groups (*mutual engagement*) included three items discussed in UR literature. Connectedness between UR participants as cohorts is an area with renewed interest as programs' participants may be geographically separated due to institutional cooperation, structural considerations, or policy reasons such as pandemics (Erickson et al., 2022). Taraban and Logue (2012) observed that peer support during UR participation bears on outcomes, particularly for biological sciences undergraduates.

Joint enterprise was supported by multiple indicators of immediate and longer-term purposes of UR that all participants may cohesively work toward. Linn et al. (2015) note the role of orientations in aligning expectations with realities of conducting research activities. Student presentation of research is an end-goal of UR programs, but other objectives frequently may include building and maintaining pathways for undergraduates to engage in future scholarly research through graduate or professional work, academic support, career preparation, or to provide practical outreach to groups outside the community of practice. John and Creighton (2013) suggested that quality of contact with 'mature practice' may be just as important as the quantity of time spent with other people. Undergraduate researchers may frequently need personal and emotional support in addition to professional socialization and intellectual support (Thiry & Laursen, 2011), and these may come through the domain of joint enterprise as students interact with attentive mentors.

Project specific tasks (i.e., *specific repertoire*) and conversations such as literature reviews or proposal development were considered by respondents as having relatively less importance in their URE than other skills or procedures relevant to current, specific project work. However, the latter may be important for developing *cognitive skills* and gains in *communication* *of science* in addition to shaping a *researcher identity* (Pickering, Grignon, Steven, Guitart, & Byrne, 2015). Given that more strongly reported gains were associated with interpersonal relationships and information sharing, whether vertically between mentors and mentees or horizontally between peers, the notion of community of practice as a framework may be more applicable to development of URE programs instead of viewing them simply as cognitive apprenticeships. Cognitive apprenticeship theory's principle of cooperation may be an analog for similar COP concepts. From a community of practice perspective, potential influences of mentorship and pedagogical practices on cultivating career trajectory should be further examined within natural resources contexts.

Outcome Factors

Specific outcomes were consolidated into a six-factor solution, and factors generally aligned with domains reported in literature. Seymour et al. (2004) through qualitative analysis of interviews identified seven domains of benefits associated with UR: personal/professional, thinking and working like a scientist, skills, clarification/confirmation of career paths, career/graduate school preparation, changes in attitudes toward learning and working as a researcher, and other benefits. In Hunter et al.'s (2007) study of intensive, summer URE at four liberal arts colleges, three categories of benefits- "thinking like a scientist," (growth in intellectual and practical understanding of how research is conducted and the nature of science) "becoming a scientist," (attributes of professional practices, attitudes, temperament and identity) and "personal-professional gains" (such as increased confidence and ability to form collegial relationships)- accounted for 62% and 61% of observations by faculty and students, respectively. Other benefits identified include clarifying a career path, preparation for careers, work-related skills, generalized benefits (e.g., work experience, financial income, and resume building), and working independently. Lopatto's (2004) Survey of Undergraduate Research Experiences (SURE) at Howard Hughes Medical Institute-funded programs included 20 diverse student-reported gains that exhibited similar patterns as outcomes reported by natural resources-related respondents in this study. Undergraduates in both studies reported greater gains in areas related to understanding of research, how scientists conduct research, and tolerance for working through problems and independent work. General skills such as written and oral communication were noted in both studies as being lesser gains. In the present study, the negative skew of most outcome items and factor score estimates suggests most students made moderate to strong gains in several domains of benefits. However, less than average outcomes and potentially detrimental effects were reported by a smaller number of respondents; such effects are reported to limited degrees in other studies (Kardash, 2000).

Another survey of broad gains associated with UR was the Student Assessment of Learning Gains, and later the URSSA, that evaluated six domains: personal/professional, thinking and working like a scientist, skills, becoming a scientist, career clarification, and enhanced career preparation (Hunter et al., 2009). The URSSA instrument was revised by Weston and Laursen (2015) who identified through confirmatory factor analysis (CFA) four areas with moderate to strong correlations: personal gains, thinking and working like a scientist, skills, and attitudes and behaviors. However, URSSA model fit was not improved with alternative models with fewer factors, and other domains of benefits, such as career clarification, were not included in alternatives. Strong correlations between factors in the URSSA structural validation were identified by Weston and Laursen (2015) as being a primary concern. Low to moderate correlations were identified between outcome factors, suggestive of reasonable separations between underlying concepts associated with URE programs. Other efforts employing survey and CFA methods to identify outcome-related models suggest seven factors associated with gains in research skills alone (Maltese et al., 2017).

The *general skills* outcome represented personal skills and somewhat resembled similarly named factors identified in literature. However, research-related skills such as defending arguments or conducting field observations are frequently also included in broad skill categories (Weston & Laursen, 2015). Differences with prior research suggest that more globally applied personal skill gains may differ from skills specifically used in research activities. *General skills'* inclusion of oral communication suggests this concept may be useful broadly when considering other specific examples of research-associated oral communication. Establishing the degree to which UR confers general skills in comparison to other apprenticeship style opportunities, such as professional internships, may be of further interest.

Career trajectory is of considerable interest with a litany of associated published examinations given that UR is widely held to significantly impact clarification and confirmation of career interests leading to increased likelihood of attending graduate school or employment in related disciplines (Davis & Wagner, 2019; Lopatto, 2004; Seymour, Hunter, Laursen, & DeAntoni, 2004). Further, the concept aligns with COP theory of an individual's trajectory working toward the interior of a community as they mature into a full member of the practice. The moderate relationship between development of a *researcher identity* and *career trajectory* in the present study merits further research, particularly with longitudinal perspectives, with respect to natural resource careers (Linn et al., 2015). Student training with, for example natural resource agencies such as the United States Forest Service, may not lead to long-term institutional goals such as increased employee diversity (Dockry, Sachdeva, Fisher, Kenefic, Locke, & Westphal, 2022). Further, persistence in careers related to earned baccalaureate degrees is a significant concern in STEM disciplines (Jelks & Crain, 2020).

Academic and career readiness identifies some instrumental benefits associated with URE programs, particularly those leading to gainful employment. The role of URE as effective conduits for transitioning students to career success is an area of continued interest, particularly in fields like natural resources with strong need for employees as growing populations place greater demands on resource utilization and as aging cohorts retire. The role of new experiences established through URE participation may also be associated with career clarification, although it was weakly correlated with *career trajectory*. Networking and frequency of contacts with individuals more central (i.e., experts) to research communities of practice has been associated with inward bound trajectories leading to careers as knowledge producers instead of novices or technicians (Feldman et al., 2013). Haeger et al. (2020) indicate the need to consider if and how UR participation affects clarification of career aspirations.

The *communication of science* factor separated some communication-related skills from other general skills and incorporated outward communication and interpreting information through reading of scientific literature. Inclusion of 'understanding of how scientists work on real-world problems' into this factor may result from respondents' interpretations of research communicated to them and translating it to practical problems or due to an increased understanding of applied science that typically occurs within natural resources disciplines. Literature suggests that UR participants report greater levels of communication skills than nonparticipants (Carter, Ro, Alcott, & Lattuca, 2016; Seymour et al., 2004). Emphasis on communicating with individuals outside and within the immediate community is of interest, particularly in natural resources disciplines (Lopatto, 2017).

Cognitive skills items were among those typically associated with gains reported in other domains of understanding of research or thinking and working like a scientist (Hunter et al., 2007; Weston & Laursen, 2015. At least some individual items in this factor (e.g., applying critical thinking and problem solving or analyzing data within a theoretical framework) may be associated with higher-order cognitive development. Through a COP lens, the community evaluates at least to some degree a member's competence, and thus membership, through alignment of knowledge and skills. Cognitive ability increase resulting from UR participation is an area where development of independent or direct, validated measures has been called for and reiterated (Haeger et al., 2020; Laursen, 2015).

Researcher identity development has seen increased research emphasis and aligns with COP theory's identity concept (Davis & Wagner, 2019; Faber, Kajfez, Lee, Benson, Kennedy, & Creamer, 2022). This study found undergraduates' *researcher identity* had stronger associations with *effective mentorship method*, *sequencing* of research tasks, and *joint enterprise* than with other components. Palmer, Hunt, Neal, & Wuetherick (2015) suggested the importance of mentorship in identity development and alluded to needs for addressing faculty development in mentorship practices, a component other researchers note is lacking, especially for less-established mentors (Linn, et al., 2015). Haeger and Fresquez (2016) determined prolonged, socioemotional and culturally-relevant mentoring was associated with stronger mentee development. Davis and Wagner (2019) found correlations between identity development of natural sciences students and intellectual interest, and they noted students should be encouraged to onboard a research project for research question development. First year and sophomore students in Davis' and Wagner's (2019) study reported greater connection to their major than juniors, and disability status was associated with a decreased connection; however, no differences in race or gender were observed. Legitimate peripheral participation theories suggest identity development is a product of tensions between the individual and the community, particularly with respect to the concept of identity as a measure of fit within a specific community (Lave & Wenger, 1991; Wenger, 1998). Future research examining undergraduate researcher identity development should give consideration to the role of mentorship and the various tensions associated with UR and learning through cognitive apprenticeships (Haeger & Fresquez, 2016; Laursen, 2015).

Relationships Between Situated Learning and Outcomes

Effective mentorship methods, a factor consistently associated with URE participants' diversity of benefits, accounts for some specific practices and principles associated with positive mentorship (Shanahan et al., 2015). Such practices were particularly associated with development of a researcher identity. In other literature, quality mentorship has been linked to undergraduates' science efficacy, identity, and values (Estrada, Hernandez, & Schulz, 2018). The role of peers and small-group experiences during situated learning may also bear on identity development and validation (Atkins, Dougan, Dromgold-Sermen, Potter, Sathy, & Panter, 2020; Riley & Burke, 1995). Further, characteristics of mentors may bear on increasing gains made by women or other types of underrepresented students in UR as they consider inward trajectories or careers in STEM disciplines (Moghe et al., 2021; McGill et al., 2021).

Sequencing had greater correlations with *general skill* gains and *communication of science* and, to lesser degrees, gains in *cognitive skills* and *researcher identity*. This factor was a significant predictor of researcher identity and marginally significant predictor of communication of science and of career trajectory. This finding aligns with Vygotsky's (1987) zone of proximal development theory suggesting that tasks just out of reach provide cognitive and technical skill growth. This finding provides support for evidence of gains in communication skills reported in literature as students face new challenges or situations throughout the research process (Carter, Ro, Alcott & Lattuca, 2016; Seymour et al., 2004). The relatively weak associations with *career trajectory* and *academic and career readiness* seem appropriate given CA theory's emphasis on this domain providing scaffolding for learning and knowledge application.

Mutual engagement was moderately associated with outcomes other than *career trajectory* and *researcher identity* that had weak correlations. The role of social and professional networking functioning as a source of legitimacy supporting professional socialization has been documented (Hunter et al., 2007; John & Creighton, 2013). Much interpersonal engagement may occur organically and implicitly throughout social learning opportunities, but the degree to which such activities are associated with outcomes other than sense of belonging and inclusion remains less well understood in a UR context.

The finding of a moderate correlation between *joint enterprise* and *researcher identity* further supports links established in prior research. Theory suggests this relationship may result from undergraduates' negotiation of identities amidst navigating through their research group's joint enterprise (Wenger, 1998). Taraban and Logue (2012) identified correlations between peer support and strength of a research mindset. Indicators of joint enterprise, such as sense of belonging and mutual accountability, may be factors considered by undergraduate researchers when imagining themselves as members of the research practice.

Specific repertoire and *broad repertoire* correlations with *cognitive skills* suggest the potential role of knowledge, processes, and tools in developing researcher cognitive ability. Relationships between *communication of science* and *broad repertoire* as well as *specific repertoire* support links made by other researchers with respect to students' self-reflections through oral or written articulation of their perceptions of the nature of science (Linn et al., 2015). Relationships between both types of repertoire and other outcomes followed similar patterns. These two factors potentially may benefit from collapsing into a single shared repertoire factor despite a relatively low bivariate relationship. However, the current separation suggests the role of different types of information or equipment may influence outcomes differently. Undergraduates' identity and career choice alignments with broader aspects of scientific research (e.g., the nature of science) may influence their career trajectories, where project-related repertoire may influence other types of gains.

4.6 Conclusion

This quantitative study examined the role of natural resources URE programs as situated learning and indicated the strengths of relationships between situated learning elements and undergraduate participants' outcomes. Concepts from cognitive apprenticeship and community of practice theories were blended to provide support for considerations of URE as situated learning opportunities for legitimate peripheral participation. Undergraduates reported a variety of gains associated with domains similar to those identified in previous literature and bolster support for viewing UR as high-impact educational opportunities. Further, relationships between UR program elements and outcomes were established, allowing for further work to examine causal mechanisms of participant gains. The self-report survey used may benefit from refinement and should be used in conjunction with other data sources to triangulate and provide validation for gains associated with situated learning elements found in URE programs.

As practical guidance resulting from this study's findings, URE program staff and mentors are encouraged to consider the role of positive mentorship principles, plan research projects as educational processes where undergraduate researcher growth is a targeted end much like presentations or publications, and provide opportunities for undergraduates' ownership of the research process. First, research mentors, as active role models, should encourage undergraduate researchers, demonstrate cognitive and technical processes, and provide suggestions and opportunities for navigating the research process, its challenges, and interpersonal networks. Mentorship training, particularly related to pedagogy, is likely to enhance research mentors' capacity to guide undergraduates through research work. Second, mentors with the mindset that URE are educational processes should provide sequencing that includes undergraduates early in the planning process from literature reviews to conceptualization of the research. Such practices may encourage student ownership and create bridges for undergraduate development and refinement of career trajectories and researcher identities. Third, providing relevant, immersive, and engaging research projects situated within the broader context of nature of science is important. The influence of broad and specific repertoire (general aspects of research and the nature of science and tools, practices, and knowledge more salient to specific research projects) on understanding and communicating about scientific research suggests providing means for undergraduate researchers to immerse themselves in a project and its broader relevance. A good research project a student invests in may potentially overcome perceptions of weaker URE program components.

The degree of associations between effective mentorship methods and related benefits warrants further study to identify the nuances of these relationships. Further, additional work is needed to understand the role of UR elements other than mentoring in providing benefits to undergraduates, especially when considering alternative models (e.g., CURE) where mentorship may differ. Course-based undergraduate research opportunities may provide appropriate comparisons to elucidate the conferral of gains by research-related work and allow greater gains to a broader diversity of students that otherwise may not participate in apprenticeship style URE or have more direct access to a research mentor.

4.7 Acknowledgements

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Chapter 5: Outcomes of a Novel Natural Resources Undergraduate Research Experience Program, the PINEMAP Undergraduate Fellowship

5.1 Abstract

The Pine Integrated Network: Education, Mitigation, and Adaptation Project Undergraduate Fellowship Program was a research experience in natural resources including full-time summer research at a mentor's university and participation in a fall online course on communicating about forest resources to different audiences. Program goals included engaging undergraduate students in forest resources research and providing graduate students with mentoring experience. Program evaluation included pre- and post-summer surveys on undergraduate's attitudes toward research, qualitative data from mentor reflections, and final retrospective surveys on undergraduates' and mentors' outcomes. Totals of 45 undergraduates and 33 graduate and faculty mentors participated in the program over four years. Undergraduate outreach about natural resources to public schools was estimated to reach over 7,400 students across 85 schools and 116 teachers. Undergraduate attitudes toward research were moderately to strongly positive on average prior to and after summer research. Undergraduates' greatest gains were related to confidence, preparation for graduate school and careers, and general personal skills and outcomes. Graduate student and other mentors had comparable outcomes across multiple domains, and they described interpersonal skill growth more frequently than professional, cognitive, socioemotional or instrumental gains resulting from their mentoring experiences. Results suggest undergraduates in this program obtained greater exposure and preparation for the research process, and mentors, particularly graduate students, increased skills and attitudes associated the interpersonal nature of mentorship in professional and faculty work.

5.2 Introduction

Outcomes of undergraduate research experience (URE) programs may vary just as widely as included elements depending on the degree of planning and rigor of process (Moore, 2010). Researchers and evaluators focus on the actual value of internships and URE programs in providing benefits to students in light of variety in goals and structures of URE programs (Hunter, Laursen, & Seymour, 2007; Kardash, 2000; Seymour et al., 2004; Thiry & Laursen, 2011). Benefits to students include domains established in URE literature: personal or professional gains (Hunter et al., 2007; Lopatto, 2004, 2007; Seymour et al., 2004), the increased ability to think and work as a researcher (Hunter et al. 2007; Kardash, 2000; Seymour et al. 2004), various practical lab or field skill improvements (Hunter et al., 2007; Kardash, 2000; Lopatto, 2004, 2007), clarification of career paths (Hunter et al. 2006, Lopatto, 2007; Seymour et al., 2004), and enhanced career preparation (Hunter et al., 2007, Junge et al., 2010).

Opportunities for communication are an essential feature of URE where participants frequently report enhanced communication skills (Cirino, Emberts, Joseph, Allen, Lopatto, & Miller, 2017; Lopatto, 2010). The culmination of UR programs often includes participation in an event where undergraduates share research through oral or poster presentations and, in some cases, a formal report. This final event is often the extent of a student's communication of the project and results to those outside the immediate research group. In a forestry education and research context, good communication skills are among those deemed critical for graduates entering the work force (Sample, Bixler, McDonough, Bullard, & Snieckus, 2015). Additionally, some undergraduate curricula are being arranged to support a greater emphasis on "society-ready" graduates (Bullard, Stephens, Coble, Coble, Darville, & Rogers, 2014). Sample et al.

(2015) found that employers ranked communicating effectively in the workplace and effectively with clients and the public at the top of several employee competencies. Further, McMullin et al (2016) determined that effective written and oral communication skills along with communicating effectively to nontechnical audiences were rated highly as contributors of employee success in the fisheries profession. Forest landowners and the general public may frequently lack knowledge and expertise associated with natural resource management, and this gap provides opportunities for current and future resource managers to educate non-foresters. However, given the importance of sharing research and providing technical guidance outside the immediate scientific community, additional attention to elements of formal communication to peers or lay audiences resulting from URE in natural resource disciplines would be beneficial.

Undergraduates are not the only participants with outcomes resulting from URE participation. Mentorship models in URE programs are often complex and ambiguous unless intentional and explicit relationships form, and, while much research occurs under supervision of a faculty member, graduate students may frequently be primary mentors for undergraduate participants (Aikens, Sadselia, Watkins, Evans, Eby, & Dolan, 2016; Lopatto, 2010). While benefits to undergraduates are well-documented, less research examines URE impacts on faculty or graduate student mentors (Haeger, Banks, Smith, & Armstrong-Land, 2020). Dolan & Johnson (2009) reported that graduate and postdoctoral students experienced a wide range of previously theorized gains from personal (e.g., work life enjoyment), cognitive (e.g., intellectual growth), and professional (e.g. understanding tenure track faculty work) domains. This work on mentor outcomes is supported by other reports of gains and challenges associated with mentoring undergraduates (Dolan & Johnson, 2010; Laursen et al., 2012; Luchini-Colbri & Wawrzynski, 2014; Reddick et al., 2012). Appendix D contains outcomes and challenges reported in other studies. Post-baccalaureate scientists-in-training may benefit in these and other ways due to mentoring undergraduates, especially when a deliberate mentoring relationship exists between graduate students and undergraduate mentees.

The Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) was a coordinated agriculture project funded by the US Department of Agriculture's National Institute of Food and Agriculture from 2011-2016 (award 2011-68002-30185; Eigenbrode, Morton, & Martin, 2014). The PINEMAP consortium consisted of 11 southeastern universities and institutions including the United States Forest Service and had research emphases in six disciplinary areas: silviculture, modeling, genetics, economics and policy, education, and extension. PINEMAP's goals included use of educational projects that integrated scientific disciplines and expanded science to public school students and educators. Education discipline projects included development of an interdisciplinary graduate online course focused on climate, forest research, and stakeholder communications (Monroe, Ireland, & Martin, 2015); development and evaluation of an educational module on southern forests and climate change (Monroe, Oxarart, Ritchie, & Li, 2018); and an URE with emphasis on conducting and communicating forestry research to different audiences. The URE project, the PINEMAP Undergraduate Fellowship Program, henceforth "PINEMAP Fellowship," is the focus of the present evaluation and research study.

The PINEMAP Fellowship was a novel distributed (i.e., students were not co-located at a singular site), summer URE followed by undergraduate fellows' participation in an online special topics course, and it was characterized in a related study as an extended, graduate student-mentored summer URE type. The PINEMAP Fellowship's goals were to 1) engage undergraduate students in forest resources research, 2) provide graduate students with opportunities for assistance with research while gaining mentoring experience, and 3) provide educational outreach to public secondary school students. The program was advertised through a variety of job board outlets associated with ecology and natural resources management and through PINEMAP researcher personal networks. Undergraduates completed an application, identified disciplinary areas of interest, provided transcripts of college courses, and listed references. Graduate students conducting PINEMAP research submitted proposals for internal grants that funded bi-weekly summer pay of $5,500 for undergraduates accepted into the program. Undergraduate fellows relocated for up to 12 weeks during the summer to conduct research with graduate student and other mentors in varying forestry disciplines at PINEMAP collaborating institutions. While undergraduates were considered as a cohort, they frequently joined other personal networks at their host mentor's institution. Assistance in locating housing during summer was provided by mentors and the program coordinator, and reimbursements for travel costs to and from the host institution were provided on an as-needed basis. Undergraduates met together online at checkpoints during the summer but otherwise kept to schedules set by mentors. After the first year, one of these meetings included a panel discussion on life as a graduate student, how to look and apply for graduate school positions, and other career-related planning. Another summer group checkpoint specifically oriented the cohort toward the fall semester's research reporting and education activities.

Undergraduate fellows, after returning to their home institutions, participated in a fall semester, three credit-hour, letter-graded, online synchronous class, "Effective Communication Skills," that emphasized communicating to diverse audiences about forest resources. Students received $1,500 across two disbursements at mid-semester and after successful completion of the course. The class met once weekly to learn and discuss effective communication strategies, differences in target audiences, how to develop technical communications for peer researchers, and development of educational, hands-on presentations targeting other audiences. Undergraduates continued contact with research mentors as they developed technical communications associated with summer research projects: a scientific abstract, poster presentation, and narrated slide presentation. Undergraduates also participated in a peer-review activity of poster drafts prior to revisions for outputs for use at the PINEMAP annual conference or other meetings. As part of course activities, students conducted outreach through teaching forest resources lessons to public secondary school students. For this purpose, undergraduates developed an educational lesson covering a natural resources topic of their interest and that targeted a selection their state board of education's student learning standards and objectives for their target grade level audience (e.g., 10^{th} grade biology). During weeks that students developed and practiced their lesson, they worked with the program coordinator to identify approximately 10 teachers at nearby public schools that were willing to host them as guest speakers. Students then scheduled with teachers to deliver their natural resource lesson. Secondary school teachers' assessments of presentations were used as a graded component of the overall course grade.

During 2012 to 2016, 45 undergraduates and 33 mentors participated in the program. Mentors included 7 MS students, 16 PhD students, 2 tenure-track faculty, 5 nontenure-track faculty, and 3 project / research associates at the time of participation. Due to the PINEMAP network of land grant universities specifically including some land-grant historically black colleges and universities, this program was able to target and recruit several minority undergraduate researchers. Because the program went beyond the summer, post-freshman to post-junior academic classes were targeted for recruitment. This study's evaluation and research objectives were to identify outcomes associated with undergraduate participation in the fellowship program, describe graduate students' and other mentors' outcomes resulting from advising undergraduates in research, and provide public secondary school students opportunities to learn about forest resources and sustainable forest management from an undergraduate researcher. Because of PINEMAP's recruited demographic groups, potential variation in outcomes was of interest for some groups of undergraduate researchers and for graduate student mentors and those at higher academic ranks.

5.3 Methods

This mixed method study used quantitative pre-post and retrospective format surveys at multiple points during the program's funding period to evaluate undergraduate and mentor outcomes, and these were supported by some qualitative data sources (Table 5.1). Demographic characteristics of the PINEMAP Fellowship's undergraduate population and from mentor survey respondents are described in Table 5.2. Students' home institutions included 16 different four-year colleges or universities across 10 states or territories, and 11 undergraduates represented 10 institutions outside the PINEMAP network. Research activities were conducted under approval of Virginia Tech's institutional review board (# 12-535 and 14-283). Statistical analyses were conducted using IBM SPSS Statistics 28.0 (IBM Corp., Armonk, NY).

Table 5.1. Data sources for evaluating the PINEMAP Fellowship. Pre-post format instruments were provided at the beginning and end of the semester for each cohort.

Instrument	Format	Timing	Purpose
ATR	Pre-post online survey	Summer	Attitudes toward research and satisfaction
PRPSA	Pre-post online survey	Fall	Undergraduates' communication anxiety
Student presentation form	Rubric for host teachers	December	Document audience sizes; student presentation evaluations
Course evaluation	Post-course assessment	December	Online course effectiveness
Retrospective undergraduate survey	Online summative survey	June 2016	Assess situated learning perceptions and outcomes
Reflective journal	Content analysis of document	December	Mentor participant experiences
Retrospective mentor survey	Online summative survey	November 2016	Assess challenges and outcomes

Table 5.2. Demographics of undergraduate researchers and mentors in the PINEMAP Fellowship.

Undergraduate demographics	*N*	%	Mentor demographics	*n*	%
Gender			Gender		
Female	24	53	Female	9	41
Male	21	47	Male	10	45
Race and Ethnicity			Non-response	3	14
American Indian / Alaskan Native	1	2	Race and Ethnicity		
Asian / Pacific Islander	2	4	Asian / Pacific Islander	3	14
Black	9	20	Hispanic	1	5

Hispanic	5	11	White / Not Hispanic	16	72
White / Not Hispanic	28	62	Non-response	2	9
Academic Classification			Academic Rank		
Rising Sophomore	7	16	Master student	7	32
Rising Junior	13	29	Doctoral student	8	36
Rising Senior	19	42	Assistant or Post-doctoral Researcher	2	9
Returning Senior	6	13	Assistant Professor	2	9
			Associate Professor	1	5
			Other project or research staff	2	9

Note: Mentor gender, racial and ethnicity data were from 22 retrospective survey respondents thus missing data for 11 mentors.

Undergraduate attitudes toward research

Undergraduate fellows' attitudes toward research (ATR) were assessed with online surveys in a short-term (0 to 3 months), pre-post format surrounding the summer research experience. Surveys were paired using student-generated five-digit codes. The pre-experience survey was distributed to undergraduates during May or at the beginning of their summer research experience. For 2012, a pilot year, surveys were provided on Adobe Forms Central, and afterward were provided through Qualtrics (Provo, UT). A modified 3-factor Attitudes Toward Research scale (Papanastasiou, 2005; Walker, 2010) included additional survey items to identify demographic characteristics and personal expectations and goals for the fellowship (Table 5.3). Modifications to Walker's (2010) 3-factor ATR scale included removal of "research acquired knowledge is as useful as arithmetic" from the positive attitudes toward research factor, addition of seven items related to research methods, and two additional items related to society's value of research. Additionally, Likert-type response options were changed from a 7-point to rating of 1 = strongly disagree to 5 = strongly agree with an added not applicable option. Negative attribute items were later reverse coded such that all items were oriented in the same direction for analysis. For each construct, a higher mean composite score indicates more favorable attitudes. Demographic information (e.g., gender, race, ethnicity, and academic classification) was also requested at the end of the survey.

Table 5.3. Variables assessed in the pre-post modified Attitudes Toward Research (Walker, 2010) survey including related research experience and satisfaction items.

Item	Rating
Usefulness of research	1 = Str. disagree, 5 = Str. agree
Skills I have acquired from this internship will be helpful to me in the future	
Research is useful for my career	
Research is connected to my field of study	
Most undergraduate students benefit from research	
Research is very valuable	
Research is useful to every professional	
Knowledge from research is as useful as writing	
Research should be indispensable in my professional training	
I will employ research approaches in my profession	

Research-oriented thinking plays an important role in my daily life	
Positives of research	1 = Str. disagree, 5 = Str. agree
I enjoy research	
I am interested in research	
I am inclined to study the details of research procedures carefully	
Negatives of research	1 = Str. disagree, 5 = Str. agree
Research makes me anxious*	
I find it difficult to understand the concepts of research*	
I make many mistakes in the research process*	
Research is difficult*	
Research methods	1 = Str. disagree, 5 = Str. agree
I understand the importance of experimental design	
I understand the scientific method	
I understand the role of statistics in research	
I understand how to interpret results from research	
I can read and understand primary literature (e.g., scientific journals)	
I understand the importance of integrity in research	
I understand the importance of accurate data collection and recording	
Societal values of research	1 = Str. disagree, 5 = Str. agree
Society would value the research I was involved in	
Research is beneficial to overall quality of life	
Fellowship goal and expectation items	
Which activities do you want to (did you) perform / or be (were) involved in?	
Literature review (including review of current policy and practices)	
Survey preparation	
Policy review	
Data collection	
Data analysis	
Sample preparation	
Lab equipment use	
Study design	
Other (text entry)	
What expectations do you have for your fellowship?	Open-ended
What are your goals for participating in this fellowship?	Open-ended
Prior to this program, have you participated in a college/university course on research or an undergraduate research experience?	1 = Yes, 2 = No, 3 = NA
Which status best describes you during the previous spring / semester?	1 = First year, 5 = Fifth year, 6 = Other
Did you declare a major or concentration yet?	1 = Yes, 2 = No, 3 = NA
Major or concentration declaration text	Open-ended
Goals beyond undergraduate degree options	

Fellowship valuation and satisfaction items	1 = Str. disagree, 5 = Str. agree
The internship provided levels of responsibility consistent with my ability and growth	
I had few opportunities to develop my communication skills*	
There were opportunities to problem solve	
I had opportunities to develop critical thinking skills	
My mentor attempted to offer feedback on my progress and abilities	
My mentor made little effort to make it a learning experience for me*	
I was not included in formal/informal lab/research group meetings*	
I was involved with projects of other graduate students or researchers	
I would recommend this internship program to other students	
I have a better appreciation for professionalism	
There was too little communication from the internship coordinator*	
Quality of personal interaction with your mentor	1 = Very poor, 5 = Very good
Quality of personal interaction you had with the program coordinator	1 = Very poor, 5 = Very good
Quality of the learning experience of your internship	1 = Very poor, 5 = Very good
Quality of your overall internship experience	1 = Very poor, 5 = Very good
What were the most valuable aspects of the PINEMAP fellowship for / you?	Open-ended
What were the least valuable aspects of the PINEMAP Internship for you?	Open-ended
Other comments (this section is open-ended for additional comments not covered previously):	Open-ended

*Negatively worded statements were reverse coded for analysis.

Undergraduates completed post-experience ATR surveys during August at the end of the fellowship's summer research component. In addition to pre-experience survey items, the post-experience version included an additional block of items related to practices associated with UR participation and mentorship, and overall internship satisfaction. Participation and mentorship items used the same balanced 5-point ratings as ATR items. Approximately half of the satisfaction items were negatively worded, and responses were reverse coded for analysis. Four questions were related to the quality of interactions with mentors, the learning experience, and the fellowship overall. Quality items were on a balanced rating where 1 = very poor and 5 = very good. A checklist of research activities was provided for respondents to indicate which activities they performed. Four open-ended questions: "Were your expectations for the fellowship met?" "Were your goals for the fellowship met?" "What were the most valuable aspects of the PINEMAP fellowship for / you?" and "What were the least valuable aspects of the PINEMAP fellowship for you?" A final open-ended question on the post-experience survey allowed for other comments related to the summer research experience component not previously covered.

Pre- and post-summer research ATR scores were compared for identifying potential effects of the research experience on undergraduate attitudes. Composite scores for negative, positive, methods, use, and societal value aspects of research were created by averaging items from each subscale. Differences between pre- and post-summer ATR subscale composite scores were evaluated using paired samples t- tests. Differences in group means of ATR subscales were examined using independent samples t-tests for potential influences of prior UR experience, gender, race/ethnicity, and academic class in the prior year. Dummy variables were created for race/ethnicity (0 = White, non-Hispanic; 1 = Other) and for academic class (0 = first or second year, "underclass"; 1 = third-year or higher, "upperclass") due to limited numbers of respondents from minority or underrepresented group categories.

Online communications course

Given the nature of the Fellowship Program's outreach component, particularly with respect to instructing public secondary school students, undergraduate participants' speaking anxiety was evaluated in a pre-post format using McCroskey's (1970) Personal Report of Public Speaking Anxiety. The PRPSA is a Likert-type scale of 34 items with ratings from 1 = strongly disagree to 5 = strongly agree. Twelve items in the scale are positively worded, and 22 items are negatively worded. Scores were calculated using the formula provided by McCroskey (1970): 72 – (sum of positively worded items) + (sum of negatively worded items). Scores have a potential range of 34 to 170, a hypothesized neutral of 102, and lower scores indicate less speaking anxiety. The unmodified questionnaire was administered online as pre-post survey during the first and last weeks of the 15-week fall semester course. A paired samples t-test of differences between scores was used to determine whether post-course speaking anxiety was significantly lower than pre-course speaking anxiety.

Undergraduates also responded to an online course evaluation survey at the end of the semester in which they participated in the communication skills course. Two batteries of 8 closed-ended and 1 open-ended questions evaluated individually each of the course's two co-instructors (the fellowship program's principal investigator and the program coordinator,) and a third battery of 10 closed-ended questions concerning course structure. Aforementioned blocks were modeled after the co-instructors' university's general course evaluation, and these are not reported due to being outside the scope of this research. A battery of 9 closed-ended questions evaluated the helpfulness of assignments and written and oral communication outcomes. Closed-ended items forced responses using ratings from 1 = strongly disagree to 5 = strongly agree with a not applicable option. The survey concluded with 4 open-ended questions where students could respond with comments regarding the public-school presentations, research-oriented presentation assignments, aspects of the course that aided students' positive outcomes, and potential improvements to the course.

Retrospective self-report survey

At the end of the program in 2016, a request for education and employment status was sent to undergraduate participants to their last known email address. This was followed by an online self-report retrospective survey (Appendix E) developed as a pilot test for a related study examining situated learning characteristics and outcomes of participating in the PINEMAP Fellowship and other natural resources URE programs. A retrospective approach was used because of a desire to incorporate multiple annual cohorts. The survey was designed to collect information on situated learning variables describing the degree to which respondents considered their specific URE and to assess outcome variables based on previously theorized and reported benefits associated with undergraduate participation. This evaluation report focuses on the outcomes associated with participation in the PINEMAP Fellowship, thus situated learning data are not reported here.

The survey contained 154 items across 9 blocks. Introductory questions were used to identify the URE associated with the survey and to determine whether respondents were students enrolled at institutions hosting the URE, the last year of participation, and the type of primary mentor in the URE. Outcome variables were assessed through batteries of items categorized into six domains described in literature. Personal and Professional outcomes were related to confidence and affect toward research. Application of Knowledge and Skills were associated with problem solving and carrying out the practice of research. Understanding of Science and Research items were associated with knowledge and comprehension of the nature of science and the research process. General Skills items were broad personal skills not related specifically to science research. Preparation for Graduate School and Career items were related to professional development, new opportunities, and networking. Clarify and Confirm Education and Career describes items associated with refinement of professional interests and career goals Blocks were prefaced with the text, "Please identify the level of change you experienced as a result of your participation in this URE for the following." The pilot version's unbalanced Likert-type ratings included: 1 = decrease, 2 = no change, 3 = slight increase, 4 = moderate increase, 5 = strong increase. A negative rating was included due to previous research suggesting that some individuals have mixed or negative outcomes resulting from UR participation (Thiry, Laursen, & Hunter, 2011). Clarify and Confirm Education and Career items were assessed with balanced 5-point ratings where 1 = strongly decreased and 5 = strongly increased. Demographic data requested included gender, ethnicity, race, undergraduate rank at the time of participation, first generation college student status, and need-based financial aid status. Two open-ended questions allowed respondents to provide qualitative feedback on personal experiences during the program and on potential improvements. Respondents were instructed at the end of each block to provide feedback on wording and inclusion or exclusion of individual items within respective blocks.

The 45 PINEMAP Fellowship undergraduate participants who completed at least the summer research component were censused primarily for program evaluation purposes and secondarily for pilot testing for a more broadly distributed survey. Survey distribution and data collection were conducted through Qualtrics (Provo, UT) online survey software. Initial emailed survey invitations including introductory information and a link to the survey were sent through the Qualtrics system in June 2016. Follow-up reminder emails were sent one and two weeks after the initial invitation. Surveys remained open for four weeks and closed mid-July 2016.

Mentor outcomes and challenges

Mentors in the program were asked to submit a two-page reflective paper on their mentoring experience at the end of the fall semester after the summer research and online course ended. This was requested for each year in which a mentor participated in the PINEMAP Fellowship. Writing prompts provided to mentors for guided writing included perceived changes in their ability to direct and mentor undergraduates, other positive or negative outcomes resulting from participation, actions the mentor took to help undergraduates mature as researchers and students, perceptions of mentee's response to the mentoring, interpersonal professional socio-emotional relationship with mentee(s), and logistical considerations and potential improvements to the program. To examine writing for mentor outcomes, a direct content analysis coding approach was implemented using labels associated with domains of benefits and specific outcomes reported in literature examining URE mentorship (Dolan & Johnson, 2009; Hsieh & Shannon, 2005): instrumental (immediately useful at accomplishing an end), socioemotional (affective personal outcomes), interpersonal (skill related to communicating, mentoring, and instructing), professional (research career and professional development), and cognitive (deepened knowledge and perspectives). Language describing difficulties of mentoring was coded as challenges.

A long-term (participation 1 year or more prior) retrospective survey of PINEMAP mentors was designed to assess outcomes associated with mentoring undergraduate researchers and also functioned as a pilot test for broader distribution as part of a larger study (Appendix F). Outcome-related survey items were organized into five blocks. categorized as either instrumental, socioemotional, interpersonal, professional, and cognitive outcomes. Items in each block were assessed through balanced Likert-type ratings where 1 = strongly decrease, 2 = decrease, 3 = no change, 4 = increase, and 5 = strongly increase. Instrumental and professional outcome items also had a not applicable option in consideration that some items may not be relevant to more experienced or tenured faculty. Cognitive outcomes were assessed through an unbalanced Likert-type rating where 1 = decrease, 2 = no change, 3 = slight increase, 4 = moderate increase, and 5 = strong increase. Challenges associated with mentoring in the URE were organized into one block and were assessed through Likert-type ratings where 1 = not at all challenging, 2 = slightly challenging, 3 = moderately challenging, 4 = very challenging, and 5 = extremely challenging. The remaining question blocks evaluated the URE as a learning and mentoring experience, previous experience mentoring undergraduates, and demographic information Survey distribution and data collection were conducted during November 2016 as described for the undergraduate retrospective survey.

Outreach to public secondary school groups

The PINEMAP Fellowship's outreach component were evaluated using metrics associated with the numbers of schools, teachers, and secondary students that observed undergraduate presentations. Lists of secondary school teachers near undergraduates' home institutions were compiled by the program coordinator and used by undergraduate fellows to establish contact for the purposes of requesting a visit to teach a science lesson. Teachers that agreed to host undergraduate presenters were requested to complete a presentation evaluation that provided the grade level, number of students in the class, and assessment of the undergraduate's presentation. This form was also used by some teachers to comment on their perceptions of the outreach presentations.

5.4 Results

Undergraduate attitudes toward research

The pre-experience ATR survey was completed by 37 undergraduates (82% response rate), 33 undergraduates completed the post-experience ATR survey (73% response rate), and both surveys were completed by 28 respondents (62% response rate). Sixteen total respondents across both surveys indicated participation in UR prior to the PINEMAP Fellowship. Levene's tests for equality of variances were all not significant, thus homogeneity of variances was assumed. Test statistics presented include two-tailed p values due to the possibility of increased or decreased attitudes. Effect sizes reported are Cohen's d point estimates.

Post-graduation academic goals remained the same for 26 of 28 undergraduates that completed pre- and post-UR surveys. Of the 33 post-survey respondents, 16 planned for master degree in life sciences, 1 had plans for a master degree in physical sciences, 4 identified doctoral degree in biology-related fields, 3 identified other graduate certifications or degrees, 4 identified master or doctoral degree in social sciences, 4 identified pursuing graduate work was not a goal, and 1 did not respond. One student's goals shifted from gaining an education certificate to pursuing a master degree in life sciences. Another student's goal shifted from pursuing a master degree in life sciences to not planning on attending graduate school. Responses to open-ended questions that included statements about graduate school provide support for finding changes in academic goals. For example, the student shifting from a teaching certification to a graduate life sciences degree wrote, “I think this summer has really helped me to decide on where I want to go in graduate school.” The other goal-shift away from graduate school was associated with the statement, “I would suggest this to my friends in the forestry major who are interested in graduate school, but not those who just want to work after college.”

Table 5.4 Paired samples tests of differences in pre- and post-URE attitudes toward research subscale mean scores of PINEMAP Fellowship undergraduates.

ATR Subscale	*M* Pre	*M* Post	*M* Difference (SD)	*t*	df	*d*	*p*
Negative attributes	3.27	3.38	0.11 (0.47)	1.206	27	0.20	0.238
Positive attributes	4.10	3.93	-0.17 (0.47)	-1.888	27	0.30	0.070
Usefulness of research	4.13	4.13	-0.01 (0.33)	-0.139	27	0.03	0.890
Research methods	4.38	4.37	-0.01 (0.32)	-0.083	27	0.06	0.934
Societal values	4.09	4.04	-0.05 (0.53)	-0.532	27	0.05	0.599

Paired samples t-tests of changes in mean attitudes (post-survey minus pre-survey) for each ATR subscale indicated attitudes were not significantly different after participating in PINEMAP Fellowship’s summer URE for respondents to both surveys (Table 5.4). Generally, participants had moderate to positive attitudes toward research. Attitudes toward research methods were strongest and followed by moderate attitudes toward the positives, usefulness, and societal value of research; negative attitudes were weakest but still favorable. Attitudes toward the negative aspects of research slightly increased, attitudes toward the positives of research slightly declined, and attitudes toward usefulness, research methods, and societal value of research were stable.

Table 5.5. Independent samples t-test of mean attitude changes (post-pre) in ATR subscales for prior UR, academic class, gender, and race/ethnicity.

Subscale	*M* (*SD*) Change	M (*SD*) Change	*M* Difference	*t*	df	*p*	*d*
	No prior UR (n = 19)	Prior UR (n = 9)					
Negatives	0.13 (0.50)	0.06 (0.41)	0.08	0.391	26	0.70	0.16
Positives	-0.19 (0.50)	-0.11 (0.41)	-0.08	-0.423	26	0.68	0.17
Usefulness	-0.10 (0.32)	0.18 (0.29)	-0.27	-2.183	26	0.04	0.88
Methods	-0.06 (0.35)	0.11 (0.23)	-0.17	-1.337	26	0.19	0.54
Society	-0.03 (0.61)	-0.11 (0.33)	0.08	0.387	26	0.70	0.16
	Underclass (n = 9)	Upperclass (n = 18)					
Negatives	0.09 (0.47)	0.12 (0.50)	-0.03	-0.140	25	0.89	0.06
Positives	-0.30 (0.56)	-0.08 (0.40)	-0.22	-1.173	25	0.25	0.48
Usefulness	-0.12 (0.35)	0.08 (0.28)	-0.20	-1.621	25	0.12	0.66
Methods	-0.15 (0.26)	0.11 (0.28)	-0.25	-2.248	25	0.03	0.92
Society	-0.11 (0.65)	-0.03 (0.50)	-0.08	-0.370	25	0.72	0.15
	Male (n = 12)	Female (n = 15)					
Negatives	-0.10 (0.29)	0.26 (0.55)	-0.36	-2.051	25	0.05	0.79

Positives	-0.14 (0.39)	-0.18 (0.55)	0.04	0.211	25	0.83	0.08
Usefulness	-0.10 (0.30)	0.06 (0.36)	-0.16	-1.239	25	0.23	0.48
Methods	-0.12 (0.33)	0.07 (0.30)	-0.19	-1.524	25	0.14	0.59
Society	-0.13 (0.38)	0.03 (0.64)	-0.16	-0.757	25	0.46	0.29
	Non-Hispanic White (n = 15)	Underrepresented (n = 13)					
Negatives	0.04 (0.59)	0.19 (0.28)	-0.15	-0.819	26	0.42	0.31
Positives	-0.16 (0.41)	-0.18 (0.54)	0.02	0.133	26	0.90	0.05
Usefulness	-0.03 (0.43)	0.01 (0.18)	-0.04	-0.327	26	0.75	0.12
Methods	-0.04 (0.36)	0.04 (0.28)	-0.08	-0.686	26	0.50	0.26
Society	0.07 (0.42)	-0.19 (0.63)	0.259	1.298	26	0.21	0.49

Potential differences between demographic groups were examined using post-hoc analyses of mean differences (post- minus pre-URE). Attitude changes were generally not significantly different between students differing in prior UR, academic class, gender, and race/ethnicity (Table 5.5). However, differences were identified in three subscales for some demographic variables. Respondents with UR experience prior to the PINEMAP Fellowship had significantly more positive attitudes toward the usefulness of research while those without prior experience had slight declines. Students at higher academic classes displayed more positive attitudes toward research methods significantly different than the decline for recent freshman or sophomore year students. Although gender was not statistically significant at alpha = 0.05, women's more positive attitudes toward the negative aspects of research approached significance when compared to changes in men's attitudes.

Responses to open-ended questions about met expectations in the ATR post-survey were examined and broadly coded to identify whether research experience expectations either were met or exceeded (n = 19), were partially met (n = 9), or were not met (n = 2). This item was not provided to three respondents in the 2012 survey, and one student indicated not having expectations going into the internship. Students who identified met or exceeded expectations most frequently emphasized gains in knowledge and 'real world' application of research, increased interest in graduate school, and communication skill gains and networking. Statements of met expectations included learning gains and application of prior and current knowledge: "Yes. My expectations for this internship included learning more about various studies PINEMAP is conducting, how the research I was involved in could be applied in the 'real' world, and also gaining the opportunity to further my connections and improve my communication skills." "I was able to learn a lot from my research investigation and apply a lot of terms I use in geology. […] It actually opened my mind to explore another field of interest for graduate school such as Forestry." "I also met a great many new people who taught me lots about general research and what graduate school is like."

Students with mixed met expectations generally identified the program positively met their expectations of developing research skills or knowledge about forestry research but lacked development of personal research projects: "[it] did meet my expectations as far as learning more about forestry research and silviculture practices [but not] for developing and working on my own research project. I was able to do this, but only about 25% of the work I did focused on my own project." Other mixed responses focused on mentorship and later stages of research such as data analysis: "I didn't get to do too much data analysis due to the large amount of complicated data. However, I did get to work on my public speaking skills by having to teach for three hours. […] This is a skill that I want to improve. I have facilitated strong relationships with my mentor, her adviser, and other graduate students which will provide huge benefits for me in the long run. […]" Other students identified learning gains but lacked development of a mentoring relationship, "I was hoping to develop a good relationship with my mentor and although he was very friendly and helpful when we met, he's a very busy guy with a high-up position so I rarely had interaction with him. My expectations of getting to learn a lot were met." Unmet expectations were described as either the lack of work or work "on too many different projects and their purpose was not really explained," as one student indicated.

Most students (n = 23) identified meeting their goals for summer research. However, some students (n = 6) indicated mixed success or ambiguity in meeting goals, one indicated goals were not met, and one student provided a brief response that could not be evaluated. This item was not included for three respondents in 2012. Met goals were mostly related to gaining experience with research methods and new disciplinary knowledge: "I was directly involved in all aspects of our research: from developing the research objective, designing the methods, field work collecting specimens, lab work and data analysis." Other met goals included developing communication skills and networking: "being able to present my work and research to other professionals as well as teach to high school students periodically," and "the internship also helped with my communication and networking skills as I was required to communicate with professionals from all over." A small number of students indicated confirming interest in graduate school: "I'm really happy going [there] gave me my extra push I needed in the right direction with graduate school." Mixed or ambiguous goal-related responses were attributed to tempering initial expectations: "I may have had high expectations at first but I reevaluated them and took away quite a few positives," and "made me realize what I enjoy and what I don't enjoy in terms of research and focus areas." Comments tended to highlight meeting goals of starting and developing personal projects and networking in addition to learning gains. However, one comment indicated unmet goals of study site visitation or being treated as a new professional, and the student attributed this to a change in research content, "I wanted to learn more about plant biology but I ended up working on a water purification project."

Online communications course

The communication and outreach distance education course was completed by 40 of 41 undergraduates that continued past the summer. Students typically took the course during the fall semester subsequent to their summer research, but two students in 2015 deferred the course to the 2016 spring semester. The pre-course PRPSA survey was completed by 40 students, and the post-course survey was completed by 24 students. Both pre- and post-course PRPSA surveys were submitted by 23 of the 38 students (60%) that completed the course (Figure 5.1). Pre-course anxiety scores ranged from 75 to 139. Post-course anxiety scores ranged from 59 to 128. On average, respondents reported significantly lower speaking anxiety after the course (M = 91.7, SE = 3.98) than speaking anxiety at the beginning of the course (M = 107.2, SE = 3.59, $t(22) = 5.267$, $p < .001$, $d = .702$). Demographic information was not collected for this component of the study, so comparisons could not be made for gender, academic class, or race / ethnicity.

The course evaluation was completed by 27 undergraduates (68% response rate). One respondent's submission was removed due to discrepancies between answering "strongly disagree" for all items but providing positive responses to open-ended items. Descriptive statistics for course components and student self-reported cognitive and communication skill outcomes suggest the course was successful at developing positive outcomes (Figure 5.2).

Several open-ended comments regarding outreach presentations provided support for quantitative findings, “by the end of my presentations I felt I was really able to connect to the students and keep them interested.” Required practice sessions were described as a mechanism for anxiety reduction, “practices for the public school presentations in a live classroom were the most beneficial in reducing speech anxiety.” Other comments identified increased confidence and organizational skills, “Public presentations to schools was a great experience and has improved my abilities and confidence in organizing and presenting a project.”

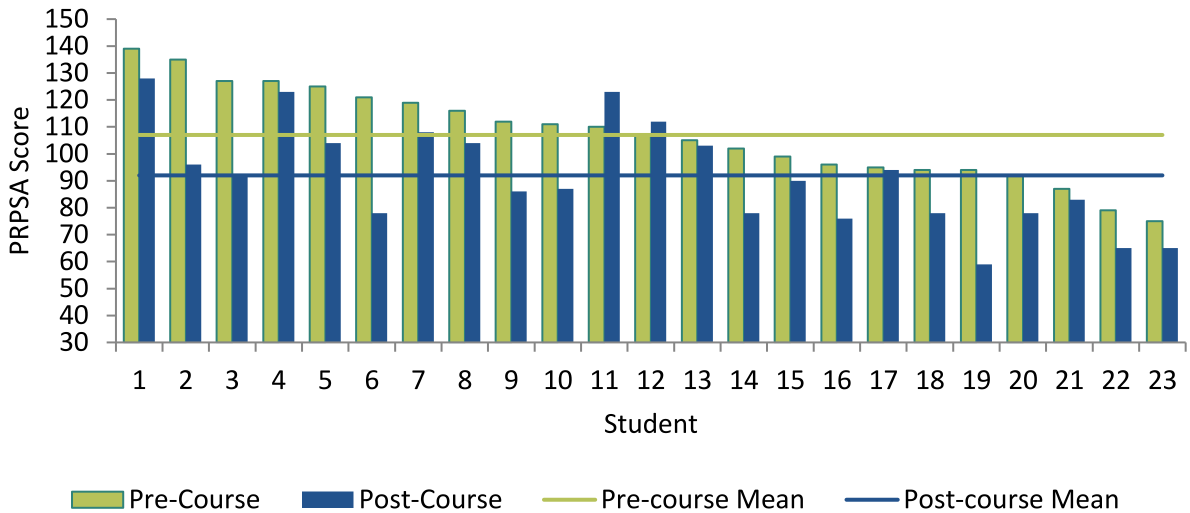

Figure 5.1. Paired pre-post PRPSA scores of participants in the communication and outreach course, 2012-2016.

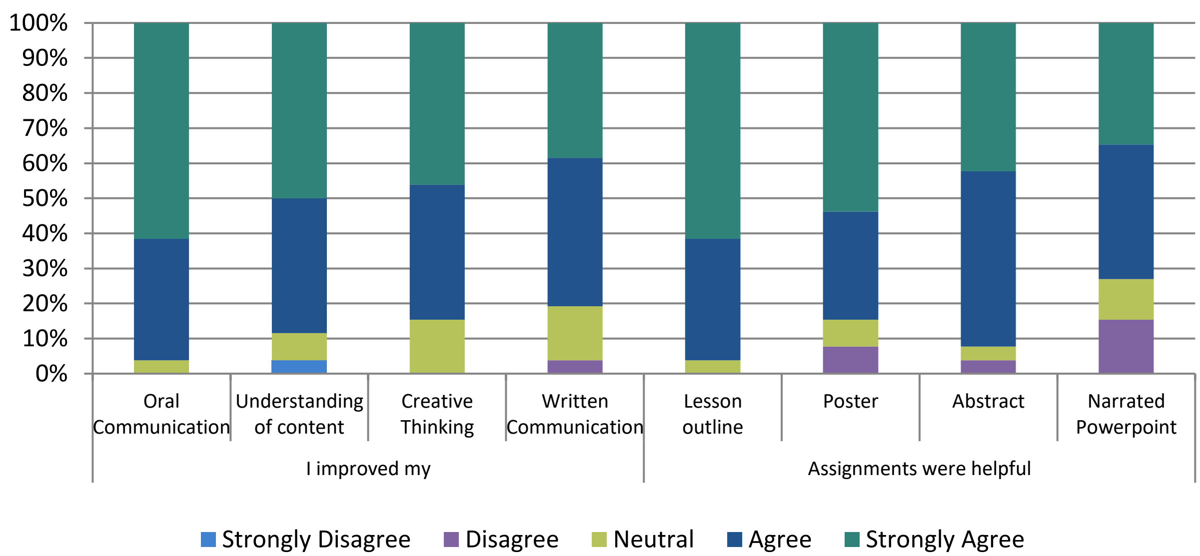

Figure 5.2. Course evaluation ratings of student outcomes and assignments after participating in the PINEMAP Fellowship’s communications and outreach course.

Respondents more strongly agreed that oral communication skills were improved, followed by increased understanding of subject matter and improved creating thinking and written communication skill. Responses suggested that the outreach presentation outline, abstract writing, and poster development were more helpful than other assignments for developing communication and other skills. Students remarking on the value of these assignments sometimes framed them in the context of graduate school preparation, “They never make undergraduates do things such as practice writing professional abstracts and posters, so I was thankful for this experience.” The PowerPoint presentation assignment was helpful to a lesser degree, and some open-ended comments provided clarification for this, “Abstract and presentation were new assignments—I feel like not many classes do that in college. The powerpoint was just another powerpoint, eveybody [sic] does that all the time.” However, other students identified cognitive benefits associated with developing research presentations in different formats, “Doing the poster and powerpoint really helped me learn more about the concepts and ideas of the study I was part of. I am walking away with a much greater understanding to it all.” Students identified that detailed feedback on initial submissions was also a beneficial component of course instruction, and at least one respondent noted the value of peer critiques of poster drafts. Timing of assignments was a weaker aspect of the course, as some students noted that scheduling outreach presentations midsemester could be difficult on top of research-based assignments and other courses.

Retrospective self-report survey

Of 35 students that responded to a request for current academic and employment status, 19 were still enrolled as undergraduates, 3 were enrolled in graduate school, 2 completed graduate school and were working professionally, and 11 graduates were in the work force. The natural resources URE pilot survey was completed by 28 PINEMAP undergraduates (62% response rate); an additional 3 incomplete responses were missing more than 50% of data. Specific indicator descriptive statistics and scale statistics and reliability (Cronbach’s alpha) for long-term outcomes reported by PINEMAP Fellowship undergraduates are found in Table 5.6. Because a different 5-point rating scale was used for Clarify and Confirm Education and Career block than others, this scale could not be directly compared to other outcome scales. Undergraduates identified greater increases for the Personal and Professional scale than in other comparable domain scales, and these increases were identified in both subdomains of confidence and in becoming a scientist.

Table 5.6. Item and scale statistics and reliability (Cronbach alpha) for scales of long-term outcomes reported by PINEMAP Fellows in the 2016 URE retrospective survey.

Scale	**Mean**	**SD**	**Skew**	**Kurtosis**
Personal and Professional (k = 23; alpha = 0.95)	***3.92***	***0.22***		
Attention to detail related to work as a scientist	4.29	0.94	-1.21	0.64
Confidence in your ability to conduct research	4.21	0.83	-0.85	0.23
Having a mentoring relationship with faculty	4.21	0.74	-0.37	-1.01
General level of confidence	4.18	0.77	-0.33	-1.21
Confidence in discussing science concepts	4.14	0.89	-0.97	0.55
Motivation related to work as a scientist	4.11	0.99	-1.20	1.84
Feeling like a scientist due to your ability to conduct research	4.07	0.86	-0.52	-0.48
Confidence in presenting research	4.07	0.94	-1.01	0.51
Feeling that you are becoming a scientist	4.04	0.92	-0.69	-0.25
Confidence in feeling like a scientist	3.96	0.84	-0.74	0.51
Confidence that you contributed real knowledge to science	3.89	0.96	-0.32	-0.91

Confidence in being taken seriously by your mentor	3.89	1.03	-0.87	0.77
Feeling like a scientist due to being taken seriously by others	3.86	0.89	-0.38	-0.46
Confidence in understanding the nature of science	3.86	0.89	-0.38	-0.46
Feeling like a scientist due to presenting your research	3.82	1.12	-0.47	-1.14
Ownership of your research project by displaying responsibility, intellectual engagement, and initiative	3.82	1.09	-0.36	-1.19
Feeling like a scientist due to your ability to contribute to science	3.79	0.92	-0.16	-0.82
Feeling like a scientist due to increased understanding of the nature of science	3.79	1.03	-0.41	-0.90
Creativity and independence in decision making	3.75	0.84	-0.27	-0.31
Professional collegiality with peer undergraduate researchers	3.71	1.08	-0.51	-0.96
Feeling of how strongly you have a professional identity as a scientist	3.71	0.94	0.05	-1.01
Feeling like a scientist due to gains in writing skills	3.57	1.03	-0.31	-1.00
Feeling like a scientist due to the possibility of a scholarly publication	3.43	1.29	-0.22	-1.42
Application of Knowledge and Skills (k = 11; alpha = 0.92)	*3.83*	*0.19*		
Relating research results to the bigger picture in your field of interest	4.14	1.04	-0.94	-0.34
Understanding of how scientists work on real problems	4.04	1.07	-1.05	0.84
General critical thinking and problem solving ability	4.00	0.90	-0.65	-0.16
Understanding of how to frame research questions	3.93	1.09	-0.60	-0.92
Ability to think independently	3.89	0.83	-0.21	-0.62
Use of critical thinking and problem solving related to research	3.82	0.77	0.33	-1.21
Ability to link theory and practice	3.79	0.96	-0.36	-0.69
Ability to develop and refine a research study's design	3.71	0.94	-1.12	1.67
Ability to analyze data within a theoretical / conceptual framework	3.68	1.09	-0.22	-1.22
Understanding of the nature of scientific knowledge	3.68	0.95	-0.98	1.34
Making use of primary scientific research literature	3.46	1.04	0.21	-1.06
Understanding of Science and Research (k = 12; alpha = 0.86)	*3.87*	*0.17*		
Understanding of the research process	4.14	0.89	-0.64	-0.59
Knowledge and understanding of science and research work	4.04	0.88	-0.77	0.22
Understanding of your science discipline	4.00	0.77	-0.53	0.33
Readiness for more demanding research	3.96	0.92	-0.54	-0.47
Depth and consolidation of knowledge due to presenting and/or teaching you did	3.93	0.98	-0.62	-0.49
Understanding of how knowledge is constructed	3.93	0.98	-0.87	0.03
Understanding of theory and concepts in your field of study	3.89	0.99	-0.50	-0.72
Appreciation of coursework's relevance to understanding science	3.86	0.97	-0.48	-0.62
The certainty of your knowledge about science	3.79	0.83	-0.39	-0.10
Recognizing connections between your field and other science disciplines	3.75	0.93	-0.36	-0.55
Knowledge and understanding of ethical conduct	3.68	1.12	-0.31	-1.24
Tolerating and persevering through setbacks and challenges	3.50	1.14	0.00	-1.39
General Skills and Outcomes (k = 16; alpha = 0.91)	*3.83*	*0.39*		
The feeling that your research experience was a good summer job	4.64	0.62	-1.59	1.57

Technical skills related to laboratory and/or field work	4.25	0.89	-0.88	-0.21
Communication-related presentation skills	4.18	0.91	-1.02	0.52
General communication skills	4.07	0.86	-0.90	0.70
Visual / graphic presentation skills	4.00	1.09	-0.56	-1.13
Work organization skills	4.00	1.05	-0.61	-0.89
Your access to good lab equipment resulting from participating in the research	4.00	1.09	-0.74	-0.73
The level of your general knowledge not related to science	3.81	0.92	-0.24	-0.76
Written communication skills	3.75	1.01	-0.16	-1.07
Ability to work independently	3.75	1.18	-0.36	-1.36
Ability to analyze data	3.61	0.96	-0.19	-0.77
General computer skills	3.50	1.00	0.00	-0.97
Skills related to collaborative work	3.50	1.00	0.00	-0.97
Skill in interpreting results	3.46	0.88	0.29	-0.50
Reading comprehension ability	3.43	1.00	-0.27	-1.07
Ability to retrieve information from the library or internet	2.96	1.07	0.66	-0.91
Preparation for Graduate School and Career (k = 10; alpha = 0.88)	*3.80*	*0.66*		
Exposure to new opportunities and/or experiences	4.50	0.69	-1.07	-0.02
Opportunities for networking with faculty, peers, and other scientists	4.36	0.91	-2.07	5.79
Quality of your resume	4.22	0.93	-1.09	0.46
Real-world work experience	4.18	0.77	-0.33	-1.21
Preparation for graduate school and career	4.07	0.77	-0.66	0.61
Preparation for career and graduate school resulting from collaboration	4.00	1.02	-0.68	-0.61
Opportunities for networking and idea exchange resulting from attending a research conference	3.82	1.19	-0.77	-0.38
Preparation for other parts of your undergraduate education, including coursework and senior / honor thesis	3.57	1.23	-0.37	-1.05
Finding or securing funding for your graduate school attendance	2.82	1.25	0.61	-0.93
Opportunities for writing grant applications	2.64	1.16	1.23	0.21
Clarify and Confirm Education and Career (k = 12; alpha = 0.55)*	*3.84*	*0.33*		
Awareness of new fields of study	4.32	0.67	-0.48	-0.64
Your level of interest in conducting outdoor field work	4.11	0.97	-1.59	3.23
Interest and enthusiasm for your field of study	4.07	0.77	-0.66	0.61
Confirmation of your interest in a research career	4.04	0.79	-0.07	-1.37
Probability of continuing a career (academic or otherwise) in your current field of study	4.00	0.98	-1.01	1.53
Level of interest in attending graduate school	4.00	1.12	-1.02	0.43
Knowledge of career and/or education options	4.00	0.67	0.00	-0.55
Recognition of the fit between your personal interests and your field of study	4.00	0.86	-1.50	4.39
Your level of interest in conducting laboratory work	3.54	1.04	-0.86	0.98
Interest in pursuing an education career	3.43	1.10	-0.25	-0.64
Probability that you will not or did not attend graduate school	2.79	1.37	0.14	-1.04
Certainty that a research career is not what you want	2.61	1.20	0.01	-1.04

*Note: 1 = decrease, 2 = no change, 3 = slight increase, 4 = moderate increase, 5 = strong increase. Clarify and confirm education and career items used a balanced 5-point rating and cannot be directly compared to other outcomes.

Post-hoc independent samples t-tests were used to examine for differences between scale means for demographic characteristics. Mean scores for undergraduates without prior summer or academic semester research experience (n = 13) were greater than those with prior experience (n = 15) on all six scale measures with significant differences occurring for Application of Knowledge and Skills (*M* difference = .60, $t(26) = 2.351$, $p = 0.027$, $d = .891$) and for General Skills (*M* difference = .57, $t(26) = 2.656$, $p = 0.013$, $d = 1.006$). Underrepresented ethnicity (n = 8) was associated with significantly greater gains than for non-Hispanic white individuals (n = 20) in Personal and Professional outcomes (*M* difference = 0.63, $t(26) = 2.432$, $p = 0.020$, d = 1.017), and was marginally significant for greater gains in the Application of Knowledge and Skills (*M* difference = .59, $t(26) = 2.026$, $p = 0.053$, $d = .848$) and the Understanding of Science and Research (*M* difference = 0.47, $t(26) = 1.963$, $p = 0.060$, $d = .821$) domains; differences were not significant for other outcome domains. Gender (14 males and 14 females) and academic class (8 under-class and 20 upper-class) were not associated with significant differences in scale means.

Mentor reflections

From 43 pages of mentors' reflections, 272 statements were coded as benefits or challenges. Of these, 228 statements related to benefits associated with mentoring undergraduates in research, and the remaining 44 referred to challenges of undergraduate research (Table 5.7). All mentor reflections suggested having obtained an overall benefit in their participation, even if the challenges associated with mentoring consumed time or if the mentor received no gains in research productivity. Several challenge-related statements related to effort involved in familiarizing students with the mentor's research or dealing with challenges of mentoring undergraduates.

Table 5.7. Categorization of benefits and challenges coded from PINEMAP Fellowship mentor reflective papers.

Domain	**#**	**%**	**Example statement**
Benefits	*228*	*84*	
Interpersonal	66	24	"The most important lesson I learned from this internship is how to communicate effectively with undergraduates"
Professional	51	19	"For those of us having graduate students one day, this is an excellent introduction to the process"
Cognitive	49	18	"It was challenging to me to consider what larger concepts [she] could learn through the work that we performed"
Instrumental	35	13	"helped me on a lot of projects that saved me time and a lot of stress"
Socioemotional	27	10	"for the first time, I understood that why some teachers love their jobs that much"
Challenges	*44*	*16*	
Instrumental	17	6	"I definitely underestimated the amount of time I would spend mentoring"

Interpersonal	12	4	"mentee does not have much knowledge about forestry soil, so it was difficult to explain a lot concept to her”
Socioemotional	8	3	"I have no experience at all and doubt that undergraduate will have a good time"
Professional	6	2	"brainstorm ways to alleviate these issues and have productive conversations to see how we can improve on work efficiency"
Cognitive	1	< 1	"I struggled with the most was being able to understand my own research well enough to communicate it to others and be able to come up with tasks for others"

Mentor retrospective survey

The mentor long-term retrospective pilot survey (Appendix F) was completed by 22 respondents (67% response rate). A majority of respondents were graduate students (n = 15) while non-graduate student mentors (n = 7) included a variety of academics and professionals. In addition to demographics described in Table 5.2 above, mentors generally had training in mentoring undergraduates (77%) and/or prior experience mentoring undergraduates (73%).

Scale and item descriptive statistics and Cronbach alpha reliabilities are reported for mentor outcome domains (Table 5.8). Listwise deletion for the procedure resulted in smaller sample sizes for Instrumental (n=16), Cognitive (n=20), and Challenges (n=20) scale reliabilities. For all domains of outcomes, mentors identified neutral to moderate gains in instrumental, socioemotional, interpersonal, and professional outcomes. Cognitive outcomes were slightly increased. Challenges in general were rated as slightly challenging.

Table 5.8. Item means, standard deviation, and scale item numbers and Cronbach alpha reliabilities for scales of outcomes and challenges associated with mentoring undergraduates in a long-term retrospective pilot survey.

Scale	**Mean**	**SD**	**Skew**	**Kurtosis**
Instrumental gains (k = 7, alpha = 0.85)	*3.53*	*0.28*		
Quality of your relationship with your undergraduate mentee(s)	3.95	0.87	-1.95	6.45
Your job / professional qualifications	3.86	0.64	0.11	-0.32
Your research productivity	3.55	1.14	-0.44	-0.43
Chances of new funding from extramural sources (e.g., having UR in a proposal increased chances of funding)	3.39	0.70	1.61	1.41
Quality of your relationship with your peer colleagues	3.36	0.58	1.39	1.20
Quality of your relationship with your own mentor	3.32	0.67	2.00	2.81
Your research quality	3.23	0.81	0.13	3.13
Socioemotional gains (k = 9, alpha = 0.91)	*3.64*	*0.14*		
Personal satisfaction from contributing to the benefit of the undergraduate(s)	3.82	0.59	0.03	0.01
Sense of responsibility for others	3.73	0.63	0.27	-0.46
Level of confidence	3.68	0.72	0.57	-0.76
Personal satisfaction	3.68	0.84	0.16	-0.65
General self	3.68	0.78	0.65	-0.99
Sense of community	3.68	0.72	0.57	-0.76
Sense of cooperation	3.68	0.72	0.57	-0.76

Sense of fun and enthusiasm while working with undergraduates	3.50	1.01	-0.61	0.47
Enjoyment of work life	3.32	0.84	-0.69	1.87
Interpersonal gains (k = 6, alpha = 0.78)	*3.88*	*0.20*		
Capability for mentoring	4.05	0.49	0.15	2.08
Mentoring skills	4.05	0.49	0.15	2.08
Probability of changing how you mentor future undergraduates	4.05	0.65	-0.04	-0.37
Communication skills	3.86	0.47	-0.55	1.69
Teaching skills	3.68	0.57	0.05	-0.51
Research group diversity	3.59	0.67	0.70	-0.43
Professional gains (k = 6, alpha = 0.77)	*3.49*	*0.18*		
Opportunities for learning managerial skills	3.82	0.50	-0.41	0.75
Preparation for your career due to skill development	3.55	0.74	1.00	-0.32
Organizational skills	3.50	0.60	0.74	-0.31
Understanding of faculty work	3.41	0.59	1.15	0.51
Desire for future work with undergraduate researchers	3.36	0.73	-1.52	4.03
Clarity of career aspirations	3.32	0.57	1.67	2.15
Cognitive gains (k = 12, alpha = 0.95)*	*2.89*	*0.26*		
Frequency of explaining and answering questions about your work	3.50	0.80	0.00	-0.20
Acquisition of different perspectives	3.23	0.69	0.65	1.18
Awareness of different models or ways for mentoring	3.05	1.00	0.53	-0.75
Ability to think differently about a situation or topic	2.95	0.81	0.73	0.70
Ability to teach undergraduates due to a better understanding of them (e.g., relating material to them)	2.90	0.94	0.60	-0.74
Perspective on your self	2.86	0.94	0.29	0.04
Intellectual growth	2.82	0.85	0.88	0.42
Thinking through experimental designs more carefully	2.82	1.05	0.94	-0.46
Depth of understanding of your own work	2.82	0.91	0.81	-0.21
Recall of knowledge you might not otherwise have remembered	2.73	0.77	0.53	-1.04
Perspective on your academic field	2.68	0.84	-0.37	-0.09
Assessment of the completeness of your work	2.68	1.00	1.04	1.12
*Challenges** (k = 17, alpha = 0.86)*	*1.82*	*0.36*		
Amount of time and effort involved	2.48	0.93	0.08	-0.66
Gauging the undergraduate's knowledge and abilities	2.43	0.75	0.67	0.28
Balancing the undergraduate's needs and your own needs	2.24	0.83	0.08	-0.47
The balance between research productivity and education (e.g., course load) goals	2.14	1.11	1.15	1.04
Balancing UR work and professional work	2.10	0.94	0.19	-1.13
Changes in research productivity	1.95	1.07	1.45	2.28

The amount of external value or recognition of efforts or contributions	1.95	1.32	1.39	0.95
Emotional costs to you	1.90	1.18	1.41	1.33
Scheduling time with the undergraduate	1.81	1.08	1.48	2.31
Establishing trust with the undergraduate	1.76	0.94	2.11	6.32
A personal lack of experience and knowledge in managing undergraduates	1.71	0.85	1.17	1.18
Limited and/or unreliable resources for mentoring	1.67	0.97	1.50	1.52
Limited and/or unreliable resources for doing UR (e.g., equipment availability or funding)	1.62	0.81	0.84	-0.87
Conflict between organizational / institutional goals / methods for UR and those of your research group or department	1.52	1.08	2.45	5.75
General tensions between the undergraduate and the rest of the research group	1.48	0.98	2.71	8.22
An ambiguous mentorship structure among the undergraduate's mentors (e.g., who's directions take precedence)	1.43	0.60	1.08	0.35

Note: Domains except for cognitive and challenges used the following rating: 1=strongly decreased, 2=decreased, 3=neutral, 4=increased, 5=strongly increased

*Cognitive items were rated 1=decreased, 2=neutral, 3=slightly increased, 4=moderately increased, 5=strongly increased.

**Challenges items were rated 1=not at all challenging, 2=slightly challenging, 3=moderately challenging, 4=very challenging, 5=extremely challenging

Table 5.9. Independent samples tests of differences in mean gains for graduate student mentors and non-graduate student mentors.

	Non-grad student		**Grad student**					
Domain	**Mean**	**SD**	**Mean**	**SD**	***t***	**df**	***d***	***p***
Instrumental	3.36	0.19	3.60	0.61	-1.008	20	0.22	0.326
Socioemotional	3.41	0.21	3.75	0.68	-1.267	20	0.27	0.220
Interpersonal	3.76	0.25	3.93	0.43	-0.97	20	0.21	0.344
Professional	3.31	0.18	3.58	0.48	-1.409	20	0.30	0.174
Cognitive	2.78	0.36	2.99	0.78	-0.669	20	0.15	0.511
Challenges	1.74	0.55	1.91	0.53	-0.706	19	0.16	0.489

Due to the program's reliance on and interest in providing opportunities to graduate students for mentoring undergraduates, data were examined for potential differences in gains when considering academic position (graduate students versus non-graduate student mentors). Master and doctoral students reported average, but not significant, increases greater than those reported by other mentors for all outcome domains and challenges (Table 5.9). No significant differences between academic level were observed for all categories of outcomes or challenges associated with mentoring. Further, post-hoc independent samples t-tests of outcomes for master and doctoral students identified no significant differences between these groups. Similarly, prior experience and training mentoring were not associated with differences in outcomes.

Outreach to secondary schools

At least 340 presentations were documented by the 40 PINEMAP fellows completing the course (Table 5.10). Because multiple undergraduates attended the same institution, the proximity of participating secondary schools was limited, and some schools and teachers were repeated within or across years. Unique numbers of teachers and schools that participated in the program were determined, but some students may have observed presentations by multiple undergraduates visiting the same teachers' classrooms.

Table 5.10. Metrics for PINEMAP Fellow outreach to secondary school groups by cohort year.

	2012	2013	2014	2015	Total	Unique
Fellowships completed	5	12	11	12	40	-
Presentations delivered	53	107	81	99	340	-
Schools visited	14	25	24	32	95	85
Teachers visited	29	40	32	37	138	116
Students reached	1060	2629	1518	2216	7423	-

On student presentation forms, host teachers were able to provide written assessments of student presentations. These open-ended responses provided informative perceptions of this component of the PINEMAP Fellowship. Public school teachers including general comments valued the program and commented on it as a positive and engaging experience for their classes. For example, one environmental science teacher wrote, "Thank you so much for providing this opportunity! This has got to be as great for your students as it is for mine. I cannot imagine giving a presentation like this when I was a sophomore in college!" Teachers saw the program as providing valuable lessons for students that "fit perfectly" within the curricular units due to the training the fellows received on state science standards. This observation also extends to the program's broader relevance, as one teacher wrote, "Connection to current research & global issues = more please!" Undergraduate work in the public schools also had unexpected positive outcomes, as one host teacher asked an undergraduate fellow to consider collaborating in the development of an environmental club at the school that would involve other interested local university students (e.g., undergraduates and graduate students) in giving presentations.

5.5 Discussion

The PINEMAP Fellowship represented a distributed URE characterized as extended, graduate student-mentored summer research. Findings suggest undergraduates experienced gains in a variety of domains, primarily in understanding and application of science research, communication skills and abilities, and preparation for graduate school. The relatively high proportion of program alumni that graduated with undergraduate degrees that continue to or through graduate programs suggests the PINEMAP Fellowship was an instrumental component of supporting plans for graduate research. Although average gains for mentors in each domain were relatively weak, graduate students reported higher but comparable gains than non-graduate student mentors. Mentors experienced and described gains in interpersonal benefits to greater degrees than other positive outcomes from mentoring. Triangulation of data from multiple instruments provides convergent validity in support of the gains reported by program participants. Furthermore, the goal of providing educational outreach was supported through undergraduate-prepared presentations to approximately 7,400 secondary school students over 4 years.

Undergraduate outcomes

PINEMAP undergraduates' attitudes toward research generally remained stable after participating in the fellowship's summer research component. Some explanation for lack of broad attitude gains may be due to modifications to the Attitudes Toward Research survey or due to undergraduate researcher population characteristics. This study's survey modifications included fewer, thus coarser, response options and a pre-post format implementation instead of a one-time survey as originally developed to provide a baseline assessment of a college education course's students' attitudes toward research but not necessarily to evaluate changes in response to research participation (Papanastasiou, 2005; Walker, 2010). Undergraduates in the sciences and undergraduate researchers, both general characteristics of this sample, perhaps may initially report positive attitudes, as in this study, potentially with an upward bias. Other studies of undergraduate researchers also report stable attitudes toward science or research during and/ or after UR participation. Frantz, DeHaan, Demetrikopoulos, and Carruth (2006) identified no significant changes for neuroscience students' general attitudes toward science but did report increases in more specific attitudes toward the discipline and confidence with research. Similarly, course-based and other research participation is linked to increased methodological knowledge but not positive changes in attitudes toward research (Rubenking & Dodd, 2017; Sizemore & Lewandowski, 2009). Additionally, plans for attending graduate school remained unchanged for nearly all students after summer UR participation, similar to other reports examining education plans (Lopatto, 2007).

Despite lack of significant positive gains in research-related attitudes broadly, evidence was identified for some groups' more positive attitudes toward research negatives, usefulness, and methods compared to reference groups. Prior experience with research methods has been linked to more positive affect toward research and other outcomes (Craney et al. 2011; Thiry et al., 2012; Wisecup, 2017). Craney et al (2011) note that students involved in research for multiple summers reported similar initial ratings and increased gains in some areas, while students without prior involvement may report minor decreases after an initial summer UR. ATR results also suggest this influence, as students with prior research experience generally had more positive attitudes, particularly toward the usefulness of research. Additionally, students in higher academic classes reported more positive attitude changes across subscales, although this influence was significant only for research methods. Evaluation of gains in novices' attitudes toward research may be obscured due to a potential inability to accurately evaluate their perceptions of a process in which they have not authentically participated. However, the retrospective survey's scale outcome means were slightly greater for respondents that reported not having prior UR experience, and this suggests that the program provided stronger gains, at least in some areas, for novice and/or underclass undergraduate researchers or regarding non-attitude, while those with prior UR were able to build more on existing research skills. This result was supported by one experienced respondent's note on the pilot study that items were framed as "level of change" but that they already felt confident in some areas, thus marking a more neutral response due to lack of a marked increase.

Striking a good balance between undergraduate researchers' knowledge, skills, and abilities and their research goals and expectations may be difficult. However, successfully doing so allows undergraduate researchers to deepen their learning and maximize growth while also producing quality research data that furthers mentors' outcomes. Further, lower attitudes toward research reported by inexperienced researchers or those at lower academic classes may be improved over time, as retrospective survey data identified greater gains for novices than for undergraduates with prior experience or at higher classes who reported more positive attitudes. In other words, findings suggest that additional research experience may have tempered gains in some areas while increasing other outcomes for PINEMAP undergraduates. Students rarely indicated the internship did not meet expectations or was a poor learning experience provided mixed reviews of different aspects of the program, and this was supplemented with very rare low ratings on some retrospective survey items. Summer URE are complex, and students may undertake UR for various reasons including job experience. The PINEMAP Fellowship may not have met each undergraduate's expectations or goals, but all students may have benefitted from instrumental gains such as pay or work experience despite a perceived lack of intellectual gains such that they felt the overall experience was positive. This concept is supported by the retrospective survey item's high score that the experience was a good summer job.

Undergraduate retrospective survey respondents identified long-term moderate to strong gains in many areas similar to outcomes reported in similar studies of life science-related UR (Lopatto, 2007; Thiry & Laursen, 2009). PINEMAP undergraduates experienced greater gains in Personal and Professional and Understanding of Science and Research than in other areas. Undergraduates in this study reported weaker gains in the Clarify and Confirm Education and Career domain than identified in other comparable areas for studies with small samples (Thiry & Laursen, 2009). Thiry, Weston, Laursen, and Hunter (2012) reported prior research was associated with greater gains in identity development but found no significant main effects of prior research experience or academic class for intellectual and personal outcomes. In that study, experienced researchers reported greater gains than novice researchers, and the combination of prior experience and academic class was associated with differences in gains across some domains. Undergraduates without prior research experience had greater, but not significantly so, gains for all domains. Retrospective survey findings suggest the program conferred many benefits across several domains and may have been marginally more valuable for first-time undergraduate researchers and underrepresented ethnic individuals. Generally, significant differences associated with gender and academic class were not found.

Salient to the program were this study's findings of undergraduates' public speaking anxiety reduction and communication skill improvement. The PRPSA, a measure of public speaking anxiety, was appropriate for this use given the nature of research communications to large and diverse audiences. Other surveys, such as McCroskey's Personal Report of Communication Anxiety (PRCA-24), identify subscales for different types of communication apprehension such as interpersonal or large group communication and may be more appropriate for broader application (McCroskey, 1982). Students identified through other survey questions, as in the ATR survey, gains in communication skills associated with discussing research with mentors or non-scientists. The reduction in speaking anxiety along with strong gains reported by undergraduates in general communication ability and visual communication skills in the General Skills domain indicates positive communication-related outcomes. Both PRPSA and retrospective survey data sources' indication of communication skills gains in conjunction with qualitative responses and course evaluation data provides convergent validity to the idea that the PINEMAP Fellowship provided positive communication-related outcomes. Undergraduates' reduced communication and speaking anxiety may lead to secondary benefits as they graduate and enter the job market or pursue graduate studies, but such research may be largely unexplored apart from employer needs (Bullard et al. 2014; McMullin et al. 2016).

Mentor outcomes

PINEMAP mentor retrospective survey respondents identified small gains in all domains, with the greatest in interpersonal benefits followed by socioemotional, instrumental, professional, and cognitive gains. Other than frequently discussed interpersonal gains, retrospective survey results contrasted with the frequency of other domains coded in reflective papers where mentors more often discussed professional and cognitive gains than others. Experienced mentors, especially at higher academic ranks, may perceive benefits, costs, and engagement of working with undergraduate researchers differently than novice mentors (Vandermaas-Peeler et al., 2015). However, this study's data suggested similar patterns of gains for both groups. While the PINEMAP Fellowship's graduate student mentors' outcomes may not have been muted as benefits and challenges perceived by non-graduate student mentors, differences were not significant. The finding of similar mentor outcomes reflects other work where benefits and challenges were not perceived differently by mentors of different academic rank, although no PINEMAP mentors identified as full professor for whom gains may plateau (Vandermaas-Peeler, Miller, & Peeples, 2015). Lack of strong gains by mentors described in the retrospective survey may be due to the prevalence of prior mentoring experience and mentorship training.

Nolan et al. (2020) identified few benefits specific to mentors associated with mentoring undergraduates but broadly outlined teaching, scholarship, and service as areas for potential benefits that have been supported in other studies. Dolan and Johnson (2009) identified instrumental and socio-emotional gains, followed by interpersonal gains, were most frequently discussed by graduate and postdoctoral mentors. Similarly, research productivity, an instrumental gain, and intrinsic benefits have been frequently identified benefits to faculty guiding undergraduate researchers (Laursen, et al., 2012). The finding of higher ratings for interpersonal and socioemotional benefits has also been described in other studies where graduate student UR mentors identified gains in developmental relationships with mentees as well as cognitive gains (Reddick et al., 2012). Establishment of mentoring relationships with undergraduates is both beneficial and motivational for mentors (Hall et al., 2017), and PINEMAP Fellowship mentors rated this as the greatest gain in the instrumental domain, ahead of relationships with peers or their own mentors. Further, PINEMAP mentors benefited emotionally more from such relationships than from other specific socioemotional outcomes.

Challenges and barriers to mentoring UR are considerable and include ambiguity of mentorship structures (Dolan & Johnson, 2009; Hall et al., 2017; Nolan et al., 2020). While the Fellowship Program intended to make the mentorship structure clear, and this is reflected in the lowest mean score for specific challenges; structure did not seem to be a concern even if others in localized research groups took on informal mentorship roles. Many other challenges associated with mentoring undergraduate researchers are described in literature, but instrumental barriers such as perceived lack of time, funding, or merit, may be more frequently reported and more difficult than other challenges to negotiate while balancing outcomes of both mentor and mentee in such relationships (Laursen et al, 2012; Vandermaas-Peeler, Miller, & Peeples, 2015). Given the relatively similar degrees of challenges and benefits reported, PINEMAP Fellowship mentors also likely experienced the difficulties in the balance of offering quality experiences for their undergraduate mentees while reaping the benefits associated with mentoring them. While no differences for outcomes between mentor type were found, additional research on graduate student mentors in UR may elucidate if, and how, outcomes may vary when compared to faculty mentors.

Limitations

As program evaluation research, findings were not meant for generalization. However, limitations included small sample sizes and potential response biases due to self-report surveys and evaluation by an internal investigator. Potential ceiling effects in pre-post survey methods, as with the ATR instrument, may mask gains made by novice undergraduates if they rated highly their attitudes toward research without a robust understanding of scientific research. Response biases for retrospective surveys, if not all surveys, should be minimized due to data collection after the program's conclusion and funding. Additionally, multiple methods were utilized, and pre-post surveys were considerably temporally distanced.

5.6 Conclusion

This study's findings suggest the PINEMAP Fellowship met goals of engaging diverse undergraduates with opportunities for experiencing undergraduate research that were beneficial for their personal and professional development while providing research assistance to PINEMAP mentors that allowed growth as professionals. Negative outcomes from undergraduate survey responses and mentor statements were rare but indicated that participant needs or expectations may not have been fully met. Findings align with prior URE research that such programs are integral and worthwhile components of the scientific research pipeline in higher education. This evaluation also suggests that distributed, primarily graduate student-mentored UR programs may offer similar degrees of the myriad benefits associated with more traditional summer UR programs.

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Chapter 6: Conclusion

6.1 Summary

This study of natural resources undergraduate research experiences had three primary objectives to discern the scope and role of natural resources URE programs during 2012-2016. The first objective was to establish an estimate of the number of URE programs in this discipline during that time frame and quantitatively describe the presence and degree of structural and functional elements associated with URE program development and implementation. This assessment led to a proposed typology of programs that characterizes clusters based on a smaller number of critical variables. The second objective was to explore how natural resources URE programs function as situated learning and the relationships between situated learning elements and participant outcomes. The third broad objective was to evaluate a novel URE program, the PINEMAP Fellowship, as a case study example from the aforementioned typology with respect to participant outcomes and educational outreach.

A survey of natural resources URE program coordinators and directors was conducted through a modified respondent-driven sampling method useful for studying hidden populations. This research estimated there were 127 natural resources URE programs operating during 2012-2016. Further, this sampling methodology suggested that the personal networks of coordinators in this field were small and fragmented, and that definitions of "natural resources" remain inconsistent such that perceived programs were not considered by their coordinators as URE programs in natural resources disciplines. Additionally, cluster analysis identified that seven theoretically significant program characteristics were important predictors of membership in one of seven types of URE programs. The most prevalent type, Underclass Intensive Traditional, represents typical summer-style URE programs in STEM disciplines. However, other types varied in offerings that included extended formats, postgraduate mentors, professional development, distributed programs, and shorter or longer durations. There exists a need to consider how programs market themselves to a diversity of potential undergraduate researchers and how best to meet those students' academic and professional goals.

Undergraduate URE program participant data identified indicators and domains of situated learning and suggested a diversity of associated gains. Factors associated with positive mentorship practices and of sequencing tasks and understanding identified how cognitive apprenticeship theory blended with community of practice theory in UR programs. Cognitive apprenticeship domains were supplemented with community of practice theory's mutual engagement, joint enterprise, and two kinds of shared repertoire (practices, knowledge, and tools) associated with carrying out research projects and with broader understanding of science research. Effective mentorship method was a critical and consistent predictor of all domains of positive outcomes. Other factors predicting multiple outcomes were associated with interpersonal engagement and with the nature of the research project itself. To enhance undergraduates' career trajectories and readiness and their identities as researcher, research mentors are encouraged to practice and refine positive mentorship through active role modeling and to for novice mentors to seek training in pedagogical practices and mentorship. The influence of the carrying out the research project itself (as in broad and specific repertoire) necessitates provision of immersive and engaging research projects, particularly by incorporating undergraduates early in the research process. Undergraduates then likely will see increased cognitive gains, better understanding of their research and its broader context, and enhanced ability to communicate about science.

An evaluation of the PINEMAP Fellowship identified that, while some individuals experienced mixed outcomes, but the program conferred positive outcomes for undergraduates and for mentors, and these gains were comparable to outcomes described in other URE research. Short-term assessments indicated no general gains in attitudes toward research, but more advanced students may see specific attitude gains. Further, undergraduates' plans for career and education trajectories remained constant, and this was supported by 31% of graduated alumni completing or enrolling in postgraduate programs. Longer-term program assessment indicated moderate gains across several domains were attributed to the fellowship program and suggests students with prior research experience saw better gains. This finding further bolsters assertions that participation in multiple or longer opportunities for undergraduates in natural resources and other disciplines to engage in authentic research provides educational advantages. Graduate student mentors' gains were comparable to those of more established faculty research mentors of undergraduates. Providing opportunities for graduate students to explicitly mentor undergraduate researches can enhance such experiences for both mentors and their current and future mentees. These earlier opportunities may provide enhanced benefits as postgraduates mature into faculty mentors, particularly due to greater improvements in interpersonal gains that enhance capacity for guiding undergraduates in the research process. Finally, the outreach component of the fellowship program allowed participants to educate over 7,000 secondary school students about natural resources topics. This evaluation suggests that atypical UR programs, particularly distributed, graduate student-mentored research experiences, provide a diversity of benefits similar to other models of internship-style URE programs. Program developers wanting but unable to provide more traditional URE programs or those who may need to adaptively manage programs may consider borrowing features of different program types while maintaining the provision of impactful experiences.

6.2 Conclusions

This research examined a cross-section of a population understudied in broader URE literature, natural resources URE programs, and produced an estimate of the number of programs operating within a five-year span in addition and a proposed typology of such programs. This study's findings suggest that natural resources undergraduate research experiences in natural resources provide impactful gains on participants' identities as researchers, inward trajectories and readiness for STEM and natural resources research careers, and ability to communicate with diverse groups. These gains more aptly come from mentors who deliberately model research skills and processes and that provide meaningful and inclusive participation in authentic research projects that are well-sequenced as educational processes. Less-experienced mentors also realize gains in their ability to provide positive mentorship and experiences through guiding undergraduates into their own disciplines. Among remaining questions are whether similar distinctions between program types are reliable across current natural resources and other URE programs, are the relationships between situated learning domains and outcome domains indicative of causal mechanisms, and does mentoring undergraduate researchers confer similar or varied degrees and types of outcomes for mentors at different points in their career trajectory?

6.3 Recommendations for Future Research

Although this research study was cross-sectional and incorporated a diversity of participants and program types, small sample sizes and lack of at least quasi-experimental design were limitations in being able to conduct more rigorous analyses and generalize results. If researchers of URE are to better understand the mechanisms through which positive outcomes are achieved, there is need to continue work identifying the degree to which various structural and functional characteristics of URE are implemented across wide range of URE formats, particularly within summer internship-styled URE programs. Relatively little data examine the scale of undergraduate research decades after the Boyer Commission (1998) called for increased efforts in incorporating research into undergraduate education and providing additional equitable opportunities, particularly for underrepresented students as identified in the Boyer 2030 Commission (2022) report. Such research may be significantly challenging but is necessary due to gaps in knowledge of the extent to which this high impact practice occurs. Further development and support for a typology of programs may lead to broader practical consideration of how programmatic features best align with undergraduate students' needs and desires in furthering their understanding of their disciplines while contributing to institutional research programs. Since features identified by cluster analysis as important predictors in this study are relatively common metrics published by individual programs, examining the reliability of the clustering solution across other URE programs and in other disciplines is feasible. Researchers with greater access to broader and potentially more connected networks of program coordinators in other STEM disciplines may be able to use these methods as groundwork for a more established typology and evaluating the differences in such groupings using techniques such as discriminant analysis.

Next, researchers continue to call for increased understanding of the processes through which participant gains are obtained. Incorporating factors from a situated learning framework provides potential for such associations. Part of this project was exploratory in nature, and further instrument refinement and use of factor analytic methods may allow for development of valid and reliable survey instruments that more holistically allow modeling such processes. Development and testing of a formal model using proposed constructs, particularly mentor-associated practices (individual and group pedagogical strategies) due to its relatively high degree of association with multiple gains, may be useful in establishing where resources and effort should be allocated within URE programs for maximizing benefits to undergraduates. Additionally, participant perspectives of community of practice may vary, and establishing how both undergraduates and their mentors view their communities of practice is an area for study. Using data sources complementary to self-report survey data (e.g., independent observations by mentors) to triangulate student and mentor trajectories toward or outward from a more central position and outcomes associated with the work of navigating these trajectories continues to be important for research validity in non- and quasi-experimental educational research studies where self-selection and other biases may occur. The study of undergraduate research offers considerable opportunities for improving understanding of this high impact practice and how to increase opportunities and outcomes for a diversity of participants.

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Appendices

Appendix A. Categories of gains and specific gains by undergraduate students identified in literature including reviews of prior work (Junge et al., 2010; Seymour et al., 2004).

Personal and professional gains

Increased confidence in general (Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

In ability to do research (Seymour et al., 2004; Hunter et al., 2007; John & Creighton, 2011)

In contributing real knowledge to science (Seymour et al., 2004; Hunter et al., 2007; John & Creighton, 2011)

Increased confidence in ''feeling like a scientist'' (Seymour et al., 2004; Hunter et al., 2007)

Because of being taken seriously by others (Seymour et al., 2004)

In general (nonspecific statements) (Seymour et al., 2004)

Because of ability to do research (Seymour et al., 2004)

Because of ability to contribute to science (Seymour et al., 2004)

Because of increased understanding of the nature of science (Seymour et al., 2004)

Because of presenting research (Seymour et al., 2004; Hunter et al., 2007)

Because of possibility of scholarly publication (Seymour et al., 2004)

Because of gain in writing skills (Seymour et al., 2004)

Increased confidence in other areas (Seymour et al., 2004)

In presenting/defending research (Seymour et al., 2004)

In general (i.e., nonspecific statements) (Seymour et al., 2004)

In being taken seriously by mentor and others (Seymour et al., 2004)

In understanding of the nature of science (Seymour et al., 2004; Hunter et al., 2007)

Confidence in my knowledge of my subject (John & Creighton, 2011)

Confidence to discuss academic concepts (John & Creighton, 2011)

Establishing a mentoring relationship with faculty (Seymour et al., 2004)

Peer/professional collegiality (i.e., with other UR students) (Seymour et al., 2004; Hunter et al., 2007)

Becoming a scientist (Hunter et al., 2007)

Creative and independent approach in decision making (Seymour et al., 2004; Hunter et al., 2007)

Shows responsibility, intellectual engagement, initiative (i.e., ownership) (Seymour et al., 2004; Hunter et al., 2007)

Identification with and bonding to a professional identity as a scientist. (Seymour et al., 2004; Hunter et al., 2007)

Greater intrinsic interest in learning: increased motivation, attention to detail (Seymour et al., 2004)

Thinking and working like a scientist

Application of knowledge and skills (Seymour et al., 2004; Hunter et al., 2007)

Critical thinking and problem-solving skills related to research (Kardash, 2000; Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)

Using critical thinking and problem-solving skills in an authentic research experience (Seymour et al., 2004; Hunter et al., 2007)

Linking theory and practice (Seymour et al., 2004; Lopatto, 2004, 2007; Junge et al., 2010)

Analyzing data within theoretical/conceptual framework (Kardash, 2000; Seymour et al., 2004; Junge et al., 2010)

Understanding how to frame research questions, develop/refine a research design (Kardash, 2000; Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)

Understanding nature of scientific knowledge (Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

Critical thinking/problem-solving skills, in general (i.e., nonspecific statements) (Seymour et al., 2004; Junge et al., 2010)

Relate results to the “bigger picture” in your field (Kardash, 2000)

Make use of primary scientific research literature (Kardash, 2000)

Think independently (Kardash, 2000)

Understanding how scientists work on real problems (Lopatto, 2004)

Knowledge and understanding of science and research work (Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

Greater knowledge; understanding in depth; understanding theory/concepts; making connections between/within science; solidifying knowledge (Kardash, 2000; Seymour et al., 2004; Junge et al., 2010; John & Creighton, 2011)

Consolidating and deepening knowledge through presentation and teaching (Seymour et al., 2004; Junge et al., 2010)

Increased appreciation of the relevance of coursework to understanding science (Seymour et al., 2004; Hunter et al., 2007)

Developing temperament: increased patience and perseverance; increased tolerance for frustration, setbacks, and failure (Seymour et al., 2004; Lopatto, 2004; Junge et al., 2010)

Readiness for more demanding research (Seymour et al., 2004; Lopatto, 2004; Junge et al., 2010)

Understanding of the research process (Lopatto, 2004; Junge et al., 2010)

Understanding how knowledge is constructed (Lopatto, 2004; Junge et al., 2010)

Learning ethical conduct (Lopatto, 2004, 2007; Junge et al., 2010)

Understanding of my discipline in general (John & Creighton, 2011)

Understanding connections between disciplines (John & Creighton, 2011)

General skills

Communication skills (Seymour et al., 2004; Hunter et al., 2007)

Presentation skills/ability to defend oral argument (Kardash, 2000; Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

General improvement in communication (i.e., nonspecific statements) (Seymour et al., 2004)

Writing skills (Kardash, 2000; Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

Lab/field skills: instrumentation, measurement, technical skills (Kardash, 2000; Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

Work organization skills (e.g., time management, note-taking, details of lab management) (Seymour et al., 2004; Hunter et al., 2007)

Computer skills (Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)

Reading comprehension skills (Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

Collaborative working skills (Seymour et al., 2004; Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)

Information retrieval (library/internet research skills) (Seymour et al., 2004; Hunter et al., 2007)

Learning to work independently (Lopatto, 2004, 2007; Hunter et al., 2007; Junge et al., 2010)
Ability to analyze data (Kardash, 2000; Lopatto, 2004, 2007; Junge et al., 2010)
Skill in the interpretation of results (Lopatto, 2004; Junge et al., 2010)
General knowledge increase, good summer job, access to good laboratory equipment, etc. (Hunter et al., 2007)

Enhancing graduate school and career preparation

Real-world work experience (Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)
Opportunity to network with faculty, peers, other scientists (Seymour et al., 2004; Hunter et al., 2007)
Enhanced resume (Seymour et al., 2004; Hunter et al., 2007)
Exposure to new opportunities/experiences (Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)
Good for current education: good preparation for senior thesis, coursework (Seymour et al., 2004)
Conferences offer new opportunities for networking/exchange of ideas (Seymour et al., 2004)
Collaboration enhances career/graduate school preparation (Seymour et al., 2004)
Career preparation, in general (Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)
Identify graduate funding (Junge et al., 2010)
Write grant application (Junge et al., 2010)

Clarifying, confirming, and refining career/education paths

Clarify/confirm student's interest in field of study; deciding which area of study to pursue; recognition of fit between own interests and field of study (Seymour et al., 2004; Hunter et al., 2007; Junge et al., 2010)
Clarify/confirm level of interest in graduate school (Seymour et al., 2004; Hunter et al., 2007)
Increase probability that student will go on to graduate school (Seymour et al., 2004; Hunter et al., 2007)
Increase student's interest/enthusiasm for field of study (Seymour et al., 2004; Hunter et al., 2007)
Introduces student to new field of study (Seymour et al., 2004; Hunter et al., 2007)
Stimulates/confirms interest in research career (Seymour et al., 2004)
Clarifies that a research career is not what student wants (Seymour et al., 2004)
Increases knowledge of career/education options (Hunter et al., 2007)

Appendix B. Descriptive statistics of situated learning components of URE included in the six-factor model and items removed from EFA models due to low or cross-loading (n = 103).

Item	Mean (SD)	Skew	Kurtosis
I felt a sense of belonging to the research group during the URE.	4.45 (0.92)	-1.8	3.04
Knowledge of procedures was an important component of the URE (e.g., how your mentor carried out a task).	4.45 (0.79)	-1.61	3.04
Understanding the nature of science was important for the URE.	4.42 (0.85)	-1.62	2.65
I felt an emphasis on preparing a final research presentation to share my research with others.	4.35 (0.94)	-1.63	2.52
I felt a connection with other undergraduates participating in the URE program.	4.35 (0.94)	-1.49	1.97
Laboratory / field work safety was an important component of the URE.	4.32 (0.92)	-1.35	1.33
There were times when new tasks required me to try new approaches or learn new skills.	4.29 (0.78)	-0.95	0.53
I had one-on-one time with my mentor during the URE.	4.28 (0.96)	-1.27	0.87
I had to understand the big picture related to tasks I was working on before working on the smaller, related details.	4.24 (0.87)	-0.86	-0.2
Setting goals for the group was important during the research experience.	4.21 (1.02)	-1.47	2.03
Learning about the responsible conduct of research was an important component of the URE.	4.19 (1.03)	-1.12	0.48
My mentor demonstrated for me how to perform research-related tasks.	4.17 (0.95)	-0.9	-0.2
I interacted with scientists and/or researchers outside my research group.	4.17 (1.02)	-1.14	0.62
My mentor acted like a coach (e.g., provided feedback or tips for improvement) for me during the URE.	4.15 (1.02)	-0.97	-0.25
I participated with other members of the research group in informal social activities outside of work.	4.11 (1.15)	-1.11	0.13
Personal achievements were celebrated by members of the group.	4.09 (1.01)	-1.11	0.94
My mentor gave me specific suggestions or tools I needed to solve problems in research.	4.08 (1.00)	-0.89	0
There were opportunities for me to consider how my mentor or other peers solved problems during research.	4.03 (1.00)	-0.77	-0.24
Individuals in the research group were held accountable to each other.	4.02 (1.01)	-1.21	1.41
New tasks required for the URE still challenged me as my ability increased.	4.01 (0.90)	-0.92	0.7
I was aware of the application and decision process for the URE.	3.99 (1.10)	-0.8	-0.18

Having an orientation at the beginning was an important part of the URE.	3.99 (1.09)	-0.88	0.05
Discussions about graduate school were supported by others during the URE.	3.98 (0.93)	-0.56	-0.26
My URE placed importance on providing outreach to non-scientists.	3.94 (1.10)	-1.14	0.91
My mentor at times asked me to explain the work I was doing for research.	3.87 (1.02)	-0.77	0.26
Small group meetings with others working in my research group were an important part of the URE.	3.79 (1.19)	-0.71	-0.47
My mentor gave me opportunities to think up and solve new research problems.	3.76 (1.26)	-0.5	-1.03
Learning about ethics was an important component of the URE.	3.75 (1.07)	-0.45	-0.47
Conducting a literature review was an important component of the URE.	3.68 (1.28)	-0.66	-0.67
Conversations related to the research often involved jargon.	3.5 (1.06)	-0.34	-0.23
Developing a written research proposal with others was an important component of the URE.	3.28 (1.53)	-0.29	-1.39
Items removed from EFA model			
General problem solving strategies about equipment or concepts were shared during the URE.	4.27 (0.92)	-1.34	1.77
I had ownership in the research project(s) I worked on.	4.22 (1.04)	-1.48	1.87
Work I did meaningfully contributed to the group's research.	4.18 (1.01)	-1.09	0.54
Others in the group gave assistance as I prepared my final research presentation(s).	4.17 (1.04)	-1.31	1.18
Other individuals in the group were invested in developing my identity as a scientist.	4.07 (0.93)	-0.95	0.88
I knew during the URE the kinds of reporting and output goals that members of the group were working toward.	4.03 (0.95)	-0.89	0.29
Research during the URE required the use of specialized equipment or software.	3.93 (1.18)	-0.79	-0.52
I had opportunities to attend research seminars during my URE.	3.83 (1.32)	-0.88	-0.41

Appendix C. Descriptive statistics of outcomes from URE included in the six-factor model and of items removed during EFA model iterations due to low or cross-loading (n = 101).

Item	Mean	SD	Skew	Kurtosis
Time management	4.59	1.29	-0.71	-0.48
Work organization skills	4.79	1.22	-0.85	-0.20
Ability to work independently	4.84	1.32	-1.02	-0.12
General computer skills	4.52	1.30	-0.50	-0.82
Oral communication skills	4.86	1.05	-0.85	0.19
Probability of continuing a career (academic or otherwise) in a natural resources field of study*	5.77	1.49	-1.38	1.45
Level of interest in attending graduate school*	5.6	1.30	-0.82	0.58
Confirming plans to attend graduate school*	5.37	1.45	-0.40	-0.73
Interest and enthusiasm for your current field of study*	5.94	1.30	-1.17	0.67
Preparation for your career	4.84	1.22	-1.08	0.73
Exposure to new opportunities and/or experiences	5.45	0.80	-1.87	4.21
Preparation for other parts of your undergraduate education (e.g., coursework; senior / honor thesis)	5.08	1.15	-1.29	0.86
Opportunities for networking with faculty, peers, and other scientists	5.13	1.07	-1.27	0.99
Preparation for career and graduate school resulting from collaboration	4.91	1.16	-0.89	-0.10
Quality of your resume	4.69	1.25	-0.60	-0.74
Making use of primary scientific research literature	5.41	0.91	-1.68	2.41
Answering questions while defending your research	4.77	1.13	-0.78	-0.08
Visual / graphic presentation skills	4.82	1.16	-0.79	-0.19
Understanding of how scientists work on real problems	5.08	0.99	-1.08	0.81
Written communication skills	4.64	1.25	-0.62	-0.56
Understanding of how to frame research questions	4.68	1.11	-0.95	0.87
Ability to analyze data within a theoretical / conceptual framework	4.78	1.15	-0.75	-0.18
Applying critical thinking and problem solving related to research	4.91	0.98	-0.74	-0.07
Ability to link theory and practice	4.71	1.10	-0.71	-0.19
Understanding of the research process	5.16	1.00	-1.28	1.20
Feeling of how strongly you have a professional identity as a scientist	4.81	1.13	-0.81	0.32
Having a mentoring relationship with faculty	4.9	1.32	-1.29	1.13
Motivation related to work as a scientist	4.8	1.27	-1.19	1.26
Confidence in being taken seriously by your mentor	4.87	1.31	-1.23	0.96
Readiness for more demanding research	5.04	1.20	-1.62	2.65
Items removed from model				
Awareness of new fields of study*	6.15	0.96	-0.96	0.28

Recognition of the fit between your personal interests and your field of study*	5.93	1.05	-1.00	1.12
Knowledge of career and/or education options*	5.74	0.95	-0.20	-0.57
The feeling that your research experience was a good summer job	5.37	1.14	-2.26	4.92
Tolerating and persevering through setbacks and challenges	5.21	0.95	-1.31	2.55
Real-world work experience	5.15	1.00	-1.33	2.10
Technical skills related to laboratory and/or field work	5.11	1.09	-1.39	1.51
Ownership of your research project by displaying responsibility, intellectual engagement, and initiative	5.07	1.04	-1.12	0.77
Understanding of your science discipline	5.02	1.03	-1.01	0.42
Confidence in presenting research	5.01	1.08	-1.23	1.49
Communicating about your research to people outside your field	4.99	1.14	-1.00	0.17
Skill in interpreting results	4.99	1.11	-0.94	0.04
Attention to detail related to work as a scientist	4.99	1.12	-0.99	0.58
Understanding of how scientific knowledge is constructed	4.98	1.03	-0.93	0.49
Professional collegiality with peer undergraduate researchers	4.96	1.18	-1.18	1.02
Confidence in discussing science concepts	4.95	1.00	-0.99	1.26
Ability to analyze data	4.94	1.09	-0.76	-0.33
Confidence in understanding the nature of science	4.94	1.16	-1.31	1.40
Relating research results to the bigger picture in your field of interest	4.93	1.10	-1.17	1.37
Knowledge and understanding of work involved in scientific research	4.92	1.05	-0.76	-0.12
Confidence in your ability to conduct research	4.91	1.22	-1.25	1.51
Appreciation of coursework's relevance to understanding science	4.91	1.15	-1.00	0.07
Feeling that you are becoming a scientist	4.90	1.15	-0.88	0.16
General critical thinking and problem solving ability	4.90	1.00	-0.75	0.14
Confidence in feeling like a scientist	4.87	1.21	-0.94	0.42
Recognizing connections between your field and other science disciplines	4.87	1.14	-0.88	-0.07
Understanding of the nature of scientific knowledge	4.86	1.01	-0.68	-0.05
Understanding of theory and concepts in your field of study	4.86	1.05	-0.79	0.11
Ability to think independently	4.83	1.10	-0.69	-0.11
Creativity and independence in decision making	4.81	1.24	-0.92	0.13
Skills related to collaborative work	4.79	1.21	-0.79	-0.04
Depth and consolidation of knowledge due to presenting and/or teaching you did	4.77	1.12	-0.72	-0.08

Opportunities for networking and idea exchange resulting from attending a research conference	4.73	1.40	-0.82	-0.51
Preparation for graduate school	4.70	1.22	-0.89	0.48
Ability to develop and refine a research study's design	4.67	1.22	-0.50	-0.80
The certainty of your knowledge about science	4.67	1.16	-0.96	0.89
Knowledge and understanding of ethical conduct	4.67	1.13	-0.68	-0.28
The level of your general knowledge not related to science	4.64	1.22	-0.69	-0.47
Confidence that you contributed real knowledge to science	4.56	1.34	-0.67	-0.40
General level of confidence not related to research	4.51	1.36	-1.00	0.29
Ability to retrieve information from the library or internet	4.46	1.40	-0.56	-0.99
Reading comprehension ability	4.40	1.34	-0.47	-0.91
Probability of finding or securing funding for your graduate school attendance	4.25	1.54	-0.38	-1.28

Appendix D. Outcomes and challenges for postgraduate and faculty undergraduate research mentors in literature.

Benefits

Instrumental

- Improved qualifications (Dolan & Johnson, 2009)
- Increased research productivity (Laursen et al., 2012; Dolan & Johnson, 2009; Dolan & Johnson, 2010; Luchini-Colbry & Wawrzynski, 2014)
- Increased graduate student interaction with a faculty mentor (Dolan & Johnson, 2009)
- Increased extramural support (Dolan & Johnson, 2010)
- Funding due to advisor's efforts (Dolan & Johnson, 2010)

Intrinsic / Socio-emotional benefits

- More enjoyable work life (Dolan & Johnson, 2009)
- Enhanced confidence (Dolan & Johnson, 2009)
- Personal satisfaction (Laursen et al., 2012; Dolan & Johnson, 2009; Luchini-Colbry & Wawrzynski, 2014)
- Enhanced self-awareness (Dolan & Johnson, 2009)
- Better sense of community (Dolan & Johnson, 2010)
- Opportunities or atmosphere of fun / enthusiasm (Dolan & Johnson, 2010)
- Enhanced sense of cooperation and helpfulness (Dolan & Johnson, 2010)
- Gains in sense of responsibility for others (Dolan & Johnson, 2010)

Interpersonal

- Improved mentor skills (Dolan & Johnson, 2009; Reddick et al., 2012)
- Improved teaching skills (Dolan & Johnson, 2009)
- Improved communication skills (Dolan & Johnson, 2009)
- Increased diversity within group or academic field (Dolan & Johnson, 2010; Reddick et al., 2012)
- Development of lasting relationships (Luchini-Colbry & Wawrzynski, 2014)

Professional

- Improved understanding of faculty head's job (Dolan & Johnson, 2009)
- Career clarification (Dolan & Johnson, 2009)
- Developed advising and mentoring skills for career success (Dolan & Johnson, 2010; Reddick et al., 2012)
- Opportunities for learning managerial skills (Dolan & Johnson, 2010)
- Deepen perspective and understanding of self and academic discipline (Reddick et al., 2012)
- Gain a sense of undergraduates that informs teaching (Dolan & Johnson, 2010)
- Faculty advisor provides models of mentorship (Dolan & Johnson, 2010; Luchini-Colbry & Wawrzynski, 2014)
- Faculty advisor provides mentoring on mentoring (Dolan & Johnson, 2010)
- Faculty establishes or influences a culture or tone of mentoring
- Changes in future mentoring practices (Luchini-Colbry & Wawrzynski, 2014)
- General intellectual growth (Dolan & Johnson, 2009)
- Stimulates additional questioning and explaining (Dolan & Johnson, 2010)
- Non-faculty mentors offer feedback to faculty on undergraduates (Dolan & Johnson, 2010)
- Provides better sense of postgraduates (Dolan & Johnson, 2010)

Challenges or Costs

- Instrumental
  - Daily balance between scholarly productivity and education (Laursen et al., 2012)
  - Decreased productivity of research (Laursen et al., 2012; Dolan & Johnson, 2009)
  - Time and effort (Laursen et al., 2012; Dolan & Johnson, 2009; Dolan & Johnson, 2010)
  - Lack of experience and knowledge in managing UR projects (Laursen et al., 2012)
  - Limited and/or unreliable resources (Laursen et al., 2012)
  - Balancing work-life scheduling(Laursen et al., 2012; Dolan & Johnson, 2010)
  - Relevant gender issues (Laursen et al., 2012)
  - General increase in tension (Dolan & Johnson, 2010)
  - Difficulty in gauging students' knowledge and ability (Dolan & Johnson, 2009; Dolan & Johnson, 2010)
  - Difficulty in gauging postgrad interest in mentoring (Dolan & Johnson, 2010)
- Socio-emotional
  - Emotional costs (Dolan & Johnson, 2009)
  - Process of establishing trust (Dolan & Johnson, 2009)
  - Increased frustration (Dolan & Johnson, 2010)
- External / Situational
  - Extra time required and effort in gaining funding
  - Conflicts between faculty-evolved UR and institutional goals (Laursen et al., 2012)
  - Difficulties in requiring students to conduct research (Laursen et al., 2012)
  - Lack of recognition, value, or other reward from institution (Laursen et al., 2012; Dolan & Johnson, 2009; Dolan & Johnson, 2010)
  - Ambiguous mentorship structure between multiple mentors (Dolan & Johnson, 2009)

Appendix E. Undergraduate URE Retrospective Survey final version

Start of Block: Front

Q1.1 Welcome to the Survey of Undergraduate Research Experiences in Natural Resources for Undergraduates
The program coordinator or director of a natural resources related undergraduate research experience (URE) program provided you with a link to this survey. This survey asks about your experience in that specific natural resources URE program and your outcomes as a participant. You might think of this as an independent program evaluation for that URE program. The goal of our study is to understand how URE programs in natural resource disciplines vary in focus and format and what outcomes they provide for participants. The survey takes about 15 minutes to complete. Please answer as accurately and honestly as you can about the program. Future participants in the undergraduate research experience you were involved in and others like it will benefit from your answers. Your participation in this survey is voluntary. You may stop at any time. This is an anonymous survey, but we will ask at the end of the survey if you would provide your contact information for a potential follow-up interview. Responses you provide during the survey will be confidential, and only general results will be reported to your URE program coordinator and in papers for peer-review. No personal identifying information you provide will be shared with anyone. Submission of your responses implies consent. This work has been approved by Virginia Tech's Institutional Review Board (#14-283).
Thank you for participating! Your response matters. Survey responses you provide will improve the visibility of natural resources URE programs and aid in understanding how they benefit undergraduate students. If you have any questions about this survey or your rights as a participant, please contact John Kidd (jbkidd@vt.edu). Sincerely, John B. Kidd, Dr. John F. Munsell, and Dr. John R. SeilerDept. of Forest Resources and Environmental Conservation228 Cheatham Hall, Virginia Tech310 West Campus DriveBlacksburg, VA 24061

Q1.2 This survey is about your participation in a specific natural resources URE program. *Consider only that program for your responses to this survey*.

Please enter the name of that URE program below.

____

X→

Q1.3 Were you enrolled as a student at the college, university, or institution where you conducted research as part of this URE program?

○ No, I was a "visiting researcher" from another home institution. (Please identify your undergraduate institution.) (1) ____

○ Yes, the locations are the same. (2)

Q1.4 In what year did you last participate in this URE program as an undergraduate?

○ 2012 (1)

○ 2013 (2)

○ 2014 (3)

○ 2015 (4)

○ 2016 (5)

○ 2017 (6)

○ Other (please specify) (7) ____

Q1.5 Which best describes your primary mentor at the time you participated in the URE program?

○ Undergraduate (1)

○ Master student (2)

○ PhD student (3)

○ Post-doctoral researcher (4)

○ Faculty or staff with PhD (5)

○ Faculty or staff without PhD (6)

○ Not sure (please describe) (7)
____

End of Block: Front

Start of Block: Community of Practice items

X→

Q2.1 This section (2 / 9) is about program organization and activities.
1. This section is about the various knowledge and tools used during the URE. Please identify the extent to which you experienced from your perspective each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)	N/A (6)
1. Conducting a literature review was an important component of the URE. (1)	○	○	○	○	○	○
2. Understanding the nature of science was important for the URE. (2)	○	○	○	○	○	○
3. Learning about ethics was an important component of the URE. (3)	○	○	○	○	○	○
4. Learning about the responsible conduct of research was an important component of the URE. (4)	○	○	○	○	○	○
5. Knowledge of procedures was an important component of the URE (e.g., how your mentor carried out a task). (6)	○	○	○	○	○	○
6. Conversations related to the research often involved jargon. (7)	○	○	○	○	○	○
7. Research during the URE required the use of	○	○	○	○	○	○

specialized equipment or software. (8)						
8. Laboratory / field work safety was an important component of the URE. (9)	○	○	○	○	○	○
9. General problem solving strategies about equipment or concepts were shared during the URE. (10)	○	○	○	○	○	○

Q2.2 2. This section is about collaboration during the URE. Please identify the extent to which you experienced from your perspective each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. Individuals in the research group were held accountable to each other. (1)	○	○	○	○	○
2. Setting goals for the group was important during the research experience. (2)	○	○	○	○	○
3. I felt a sense of belonging to the research group during the URE. (3)	○	○	○	○	○
4. Work I did meaningfully contributed to	○	○	○	○	○

the group's research. (11)					
5. I had ownership in the research project(s) I worked on. (4)	○	○	○	○	○
6. Personal achievements were celebrated by members of the group. (5)	○	○	○	○	○
7. I knew during the URE the kinds of reporting and output goals that members of the group were working toward. (6)	○	○	○	○	○
8. Other individuals in the group were invested in developing my identity as a scientist. (7)	○	○	○	○	○
9. I was aware of the application and decision process for the URE. (8)	○	○	○	○	○
10. Developing a written research proposal with others was an important component of the URE. (9)	○	○	○	○	○
11. Others in the group gave assistance as I	○	○	○	○	○

prepared my final research presentation(s). (10)	

Q2.3 3. This section is about your personal interactions with others during the URE. Please identify the extent to which you experienced from your perspective each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. I had one-on-one time with my mentor during the URE. (1)	○	○	○	○	○
2. Small group meetings with others working in my research group were an important part of the URE. (2)	○	○	○	○	○
3. I had opportunities to attend research seminars during my URE. (3)	○	○	○	○	○
4. I felt a connection with other undergraduates participating in the URE program. (4)	○	○	○	○	○
5. I participated with other members of	○	○	○	○	○

the research group in informal social activities outside of work. (5)					
6. I felt an emphasis on preparing a final research presentation to share my research with others. (6)	○	○	○	○	○
7. My URE placed importance on providing outreach to non-scientists. (7)	○	○	○	○	○
8. Having an orientation at the beginning was an important part of the URE. (8)	○	○	○	○	○
9. Discussions about graduate school were supported by others during the URE. (9)	○	○	○	○	○
10. I interacted with scientists and/or researchers outside my research group. (10)	○	○	○	○	○

End of Block: Community of Practice items

Start of Block: Cognitive Apprenticeship items

Q3.1
This section (3 / 9) is about instructional methods used during your URE.

4. This section relates to teaching methods used during your participation with the URE program. Please identify the extent to which you experienced from your perspective each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. My mentor demonstrated for me how to perform research-related tasks. (1)	○	○	○	○	○
2. My mentor acted like a coach (e.g., provided feedback or tips for improvement) for me during the URE. (2)	○	○	○	○	○
3. My mentor gave me specific suggestions or tools I needed to solve problems in research. (3)	○	○	○	○	○
4. My mentor at times asked me to explain the work I was doing for research. (4)	○	○	○	○	○
5. There were	○	○	○	○	○

opportunities for me to consider how my mentor or other peers solved problems during research. (5)					
6. My mentor gave me opportunities to think up and solve new research problems. (6)	○	○	○	○	○

Q3.2 5. This section relates to the general order of tasks performed during this URE program. Please identify the extent to which you experienced from your perspective each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. New tasks required for the URE still challenged me as my ability increased. (1)	○	○	○	○	○
2. There were times when new tasks required me to try new approaches or learn new skills. (2)	○	○	○	○	○
3. I had to understand the big picture related to	○	○	○	○	○

tasks I was working on before working on the smaller, related details. (3)	

End of Block: Cognitive Apprenticeship items

Start of Block: Outcomes

Q4.1
This section (4 / 9) is about your personal and professional outcomes.

6. This section is about your personal and professional outcomes. Please identify the level of change you experienced as a result of your participation in this URE for the following:

	Decrease (1)	No Change (2)	Slight Increase (3)	Moderate Increase (4)	Good Increase (5)	Strong Increase (6)
1. General level of confidence not related to research (1)	o	o	o	o	o	o
2. Confidence in your ability to conduct research (2)	o	o	o	o	o	o
3. Confidence that you contributed real knowledge to science (3)	o	o	o	o	o	o
4. Confidence in feeling like a scientist (4)	o	o	o	o	o	o
5. Confidence in presenting research (12)	o	o	o	o	o	o

6. Confidence in being taken seriously by your mentor (13)	○	○	○	○	○	○
7. Confidence in understanding the nature of science (14)	○	○	○	○	○	○
8. Confidence in discussing science concepts (15)	○	○	○	○	○	○
9. Having a mentoring relationship with faculty (16)	○	○	○	○	○	○
10. Professional collegiality with peer undergraduate researchers (17)	○	○	○	○	○	○
11. Feeling that you are becoming a scientist (18)	○	○	○	○	○	○
12. Creativity and independence in decision making (19)	○	○	○	○	○	○
13. Ownership of your research project by displaying responsibility, intellectual engagement, and initiative (20)	○	○	○	○	○	○
14. Feeling of how strongly you have a professional	○	○	○	○	○	○

identity as a scientist (21)						
15. Motivation related to work as a scientist (22)	○	○	○	○	○	○
16. Attention to detail related to work as a scientist (23)	○	○	○	○	○	○

End of Block: Outcomes

Start of Block: Block 8

Q5.1
This section (5 / 9) is about outcomes related to your knowledge and skills.

7. This section is about your application of knowledge and skills. Please identify the level of change you experienced as a result of your participation in this URE for the following:

	Decrease (1)	No Change (2)	Slight Increase (3)	Moderate Increase (4)	Good Increase (5)	Strong Increase (6)
1. Applying critical thinking and problem solving related to research (1)	○	○	○	○	○	○
2. Ability to link theory and practice (2)	○	○	○	○	○	○
3. Ability to analyze data within a theoretical / conceptual framework (3)	○	○	○	○	○	○
4. Understanding of how to frame research questions (4)	○	○	○	○	○	○

5. Ability to develop and refine a research study's design (5)	○	○	○	○	○	○
6. Understanding of the nature of scientific knowledge (6)	○	○	○	○	○	○
7. General critical thinking and problem solving ability (7)	○	○	○	○	○	○
8. Relating research results to the bigger picture in your field of interest (8)	○	○	○	○	○	○
9. Making use of primary scientific research literature (9)	○	○	○	○	○	○
10. Ability to think independently (10)	○	○	○	○	○	○
11. Understanding of how scientists work on real problems (11)	○	○	○	○	○	○
12. Answering questions while defending your research (12)	○	○	○	○	○	○

Q5.2 8. This section is about your outcomes related to knowledge and understanding of science and research. Please identify the level of change you experienced as a result of your participation in this URE for the following:

	Decrease (1)	No Change (2)	Slight Increase (3)	Moderate Increase (4)	Good Increase (5)	Strong Increase (6)
1. Knowledge and understanding of work involved in scientific research (1)	○	○	○	○	○	○
2. Understanding of theory and concepts in your field of study (2)	○	○	○	○	○	○
3. Recognizing connections between your field and other science disciplines (3)	○	○	○	○	○	○
4. The certainty of your knowledge about science (4)	○	○	○	○	○	○
5. Depth and consolidation of knowledge due to presenting and/or teaching you did (5)	○	○	○	○	○	○
6. Appreciation of coursework's relevance to understanding science (6)	○	○	○	○	○	○
7. Tolerating and persevering through setbacks and challenges (7)	○	○	○	○	○	○
8. Readiness for more demanding research (8)	○	○	○	○	○	○
9. Understanding of the research process (9)	○	○	○	○	○	○

10. Understanding of how scientific knowledge is constructed (10)	○	○	○	○	○	○
11. Knowledge and understanding of ethical conduct (11)	○	○	○	○	○	○
12. Understanding of your science discipline (12)	○	○	○	○	○	○

Q5.3 9. This section is about your general skills outcomes. Please identify the level of change you experienced as a result of your participation in this URE for the following:

	Decrease (1)	No Change (2)	Slight Increase (3)	Moderate Increase (4)	Good Increase (5)	Strong Increase (6)
1. Oral communication skills (1)	○	○	○	○	○	○
2. Written communication skills (2)	○	○	○	○	○	○
3. Visual / graphic presentation skills (3)	○	○	○	○	○	○
4. Communicating about your research to people outside your field (4)	○	○	○	○	○	○
5. Technical skills related to laboratory and/or field work (5)	○	○	○	○	○	○

6. Time management (16)	○	○	○	○	○	○
7. Work organization skills (6)	○	○	○	○	○	○
8. General computer skills (7)	○	○	○	○	○	○
9. Reading comprehension ability (8)	○	○	○	○	○	○
10. Skills related to collaborative work (9)	○	○	○	○	○	○
11. Ability to retrieve information from the library or internet (10)	○	○	○	○	○	○
12. Ability to work independently (11)	○	○	○	○	○	○
13. Ability to analyze data (12)	○	○	○	○	○	○
14. Skill in interpreting results (13)	○	○	○	○	○	○
15. The level of your general knowledge not related to science (14)	○	○	○	○	○	○
16. The feeling that your research experience was	○	○	○	○	○	○

a good summer job (15)	

End of Block: Block 8

Start of Block: Career and Education Plans

Q6.1
This section (6 /9) is about your graduate school and career preparation outcomes.

10. This section asks about your graduate school and career preparation outcomes. Please identify the level of change you experienced for the following as a result of participating in this URE:

	Decrease (1)	No Change (2)	Slight Increase (3)	Moderate Increase (4)	Good Increase (5)	Strong Increase (6)
1. Preparation for graduate school (1)	o	o	o	o	o	o
2. Preparation for your career (11)	o	o	o	o	o	o
3. Real-world work experience (2)	o	o	o	o	o	o
4. Opportunities for networking and idea exchange resulting from attending a research conference (3)	o	o	o	o	o	o
5. Quality of your resume (4)	o	o	o	o	o	o
6. Exposure to new opportunities and/or experiences (5)	o	o	o	o	o	o

7. Preparation for other parts of your undergraduate education (e.g., coursework and senior / honor thesis) (6)	○	○	○	○	○	○
8. Opportunities for networking with faculty, peers, and other scientists (7)	○	○	○	○	○	○
9. Preparation for career and graduate school resulting from collaboration (8)	○	○	○	○	○	○
10. Probability of finding or securing funding for your graduate school attendance (9)	○	○	○	○	○	○

Q6.2 11. This section relates to how your experience clarified and confirmed your career and education plans. Please identify the level of change you experienced as a result of participating in this URE for the following:

	Strongly Decreased (1)	Decreased (2)	Slightly Decreased (3)	No Change (4)	Slightly Increased (5)	Moderately Increased (6)	Strongly Increased (7)
1. Probability of	○	○	○	○	○	○	○

continuing a career (academic or otherwise) in a natural resources field of study (1)							
2. Probability of continuing a career (academic or otherwise) in an a field of study not related to natural resources (13)	○	○	○	○	○	○	○
3. Level of interest in attending graduate school (2)	○	○	○	○	○	○	○
4. Confirming plans to attend graduate school (3)	○	○	○	○	○	○	○
5. Your level of interest in obtaining a professional degree (e.g., law, medicine, veterinary) (6)	○	○	○	○	○	○	○
6. Interest and enthusiasm	○	○	○	○	○	○	○

for your current field of study (4)							
7. Awareness of new fields of study (5)	○	○	○	○	○	○	○
8. Confirmation that a research career is not what you want (7)	○	○	○	○	○	○	○
9. Knowledge of career and/or education options (8)	○	○	○	○	○	○	○
10. Interest in pursuing an education / teaching career (9)	○	○	○	○	○	○	○
11. Recognition of the fit between your personal interests and your field of study (10)	○	○	○	○	○	○	○
12. Your level of interest in conducting outdoor field work (11)	○	○	○	○	○	○	○
13. Your level of interest in	○	○	○	○	○	○	○

conducting laboratory work (12)

End of Block: Career and Education Plans

Start of Block: Rating the REU

Q7.1
This section (7 /9) is about your perceptions of the overall quality of the URE program.

12. Please rate the following about your experience participating in this URE:

	Poor (1)	Fair (2)	Good (3)	Very Good (4)	Excellent (5)
1. Quality of your working relationship with your mentor. (1)	○	○	○	○	○
2. Quality of your working relationship with other members of your research group during the URE. (2)	○	○	○	○	○
3. The quality of learning experience from your participation in this URE. (3)	○	○	○	○	○
4. The quality of life experience from participating in this URE. (4)	○	○	○	○	○

Q7.2 13. Please rate the following about your experience participating in this URE:

	Strongly Disagree (1)	Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Agree (5)	Strongly Agree (6)
1. I would recommend this URE to other students. (1)	○	○	○	○	○	○
2. I would again make the decision to participate in this URE for the first time. (2)	○	○	○	○	○	○

Q7.3 14. Rate the following related to your physical needs during participation of the URE, regardless of whether they were provided by the URE program:

	Poor (1)	Fair (2)	Good (3)	Very Good (4)	Excellent (5)	N/A (6)
1. Your housing situation during the URE. (1)	○	○	○	○	○	○
2. Your eating habits / nutrition during the URE. (2)	○	○	○	○	○	○
3. Access to equipment and/or information needed to carry out the project(s) you	○	○	○	○	○	○

worked on. (3)						
4. Your transportation ability relative to personal needs during the URE. (4)	○	○	○	○	○	○

Q7.4 15. Are there any aspects of your experience as an undergraduate in this program you'd like to mention that were not covered in this survey?

____

____

____

____

____

Q7.5 16. From your perspective, are there any actions that could be taken to improve this undergraduate research experience program or others like it?

____

____

____

____

____

End of Block: Rating the REU

Start of Block: Block 10

Q8.1
This section (8 /9) asks about your status during your time as part of the URE.

17. Which level of undergraduate best describes you during your participation in this URE?

○ Freshman / Rising Sophomore (1)

○ Sophomore / Rising Junior (2)

○ Junior / Rising Senior (3)

○ Senior (4)

◯ Other (5) ____

Q8.2 18. What is / was your primary undergraduate major or degree? *Enter only your primary major; if you dual-majored, enter the second major in the next question.*

____

Q8.3 19. Are / were you a dual major?

◯ No (1)

◯ Yes (Please specify your secondary major) (2)

____

Q8.4 20. What was your approximate Grade Point Average (on a 4.0 scale) during your participation in the URE program?

◯ > 4.0 (1)

◯ 3.7 to 4.0 (2)

◯ 3.3 to 3.69 (3)

◯ 3.0 to 3.29 (4)

◯ 2.7 to 2.99 (5)

◯ 2.3 to 2.69 (6)

◯ 2.0 to 2.29 (7)

◯ < 2.0 (8)

*

Q8.5 21. How many academic year semesters (or quarter equivalent), NOT including summers, of undergraduate research did you have before entering this URE program?

____

*

Q8.6 22. How many summers of undergraduate research did you have before entering this URE program?

____

Q8.7 23. How many weeks did you work for this URE program?

____

Q8.8 24. On average, how many hours per week did you work during the URE?

____

Q8.9 25. Have you participated in undergraduate research as an undergraduate since finishing this URE program?

- ○ No (1)
- ○ Yes (2)

End of Block: Block 10

Start of Block: Demographics

Q9.1 **This section (9 /9) relates to your demographic information.**

These questions are asked to develop an understanding of who participates in natural resources undergraduate research and will not be reported other than as generalities in publications. You have the option to not answer any of these questions.

Q9.2 26. What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Other (3) ____

○ Prefer to not answer (4)

Q9.3 27. What is your ethnicity?

○ Not Hispanic or Latino / Latina (1)

○ Hispanic or Latino / Latina (2)

○ Prefer to not answer (3)

Q9.4 28. What is your race? Select all that apply.

▢ Alaskan Native (1)

▢ American Indian or Native American (2)

▢ Asian (3)

▢ Black or African American (4)

▢ Native Hawaiian or Pacific Islander (5)

▢ White or Caucasian (6)

▢ Other (please specify) (7) ____

▢ Prefer to not answer (8)

Q9.5 29. Do / did you have a disability as an undergraduate that was documented by your institution?

○ No (1)

○ Yes (2)

○ Prefer to not answer (3)

Q9.6 30. Are / were you a first generation college student?

- No (1)
- Yes (2)

Q9.7 31. At your home undergraduate institution, do / did you qualify for need-based financial aid? *For example, subsidized federal student loans.*

- No (1)
- Yes (2)
- Not sure (3)

Q9.8 32. What is your highest level of education to date?

- Undergraduate coursework (1)
- Bachelor degree (2)
- Some Master graduate work (3)
- Master degree (4)
- Some Doctoral graduate work (5)
- Doctoral degree (6)

Q9.9 33. Which best identifies your current sector of employment?

- Student (1)
- College or university staff (2)
- College or university faculty (3)
- Primary or secondary (K-12) school faculty (4)
- Industry (5)
- Non-profit organization (6)

○ Military (7)

○ Local Government (8)

○ State Government (9)

○ Federal Government (10)

○ Other (11) ____

End of Block: Demographics

Start of Block: Block 9

Q10.1
As part of this research, we will look at a small number of specific natural resources URE programs for in depth study, and this will involve interviews with participants of those programs. If your program is selected, we would like to follow up with you. This is only for the purposes of this research, and we will not share your contact information with third parties.

If you are willing to be contacted for a follow up interview, please enter your contact email below:
____

Q10.2 **Click the "Next >>" button below to submit your responses.** Thank you! Your responses will be useful in helping establish the participant outcomes of natural resources undergraduate research experiences and will help future students who participate in them.

End of Block: Block 9

Appendix F. URE Mentor Retrospective Survey - final

Start of Block: Front page

Q1.1 Welcome to the Survey of Undergraduate Research Experience Programs in Natural Resources for Mentors
The program coordinator or director of a natural resources undergraduate research experience (URE) program provided you with a link to this survey. This survey asks about your experience in that specific natural resources URE program and your outcomes as a mentor. You might think of this as an independent program evaluation for that URE. The goal of our study is to understand how URE programs in natural resource disciplines vary in focus and format and what outcomes they provide for participants, including both undergraduates and their mentors. The survey takes about 13 minutes to complete. Please answer as accurately and honestly as you can about your experience in the program. Future participants in the undergraduate research experience you were involved in and others like it will benefit from your answers. Your participation in this survey is voluntary. You may stop at any time. This is an anonymous survey, but we will ask at the end of the survey if you would provide your contact information for a potential follow-up interview. Responses you provide during the survey will be confidential, and only general results will be reported to your URE program coordinator and in papers for peer-review. No personal identifying information you provide will be shared with anyone. Submission of your responses implies consent. This work has been approved by Virginia Tech's Institutional Review Board (#14-283).
Thank you for participating! Your response matters. Survey responses you provide will improve the visibility of natural resources URE programs and aid in understanding how they benefit mentors. If you have any questions about this survey or your rights as a participant, please contact John Kidd (jbkidd@vt.edu). Sincerely, John B. Kidd, Dr. John F. Munsell, and Dr. John R. Seiler Dept. of Forest Resources and Environmental Conservation228 Cheatham Hall, Virginia Tech310 West Campus Drive Blacksburg, VA 24061

End of Block: Front page

Start of Block: Block 2

Q2.1 The coordinator or director of a specific natural resources URE program that you participated in directed you to this survey.

Please enter the name of that program in the space below:
____

Q2.2 In what year(s) did you participate in this URE program? *Select all that apply.*

☐ 2012 (1)

☐ 2013 (2)

☐ 2014 (3)

☐ 2015 (4)

☐ 2016 (5)

☐ 2017 (6)

☐ Other (please specify) (7) ____

Q2.3
For this survey, we use "research group" and "group" meaning individuals in your research lab group that you work closely with (i.e., a primary investigator and individuals that conduct research on projects that PI directs). This should NOT include other undergraduates in the URE cohorts unless those individuals worked in your research group.

End of Block: Block 2

Start of Block: Community of Practice - Shared Repertoire

Q3.1
Section 1 / 13

The following items relate to the various knowledge and tools used by members of your research group during the URE.

Please identify the extent to which you experienced, from your perspective, each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. Knowledge of work-related procedures (both formal	○	○	○	○	○

and informal) was important to the group. (2)					
2. Conversations related to research often involved jargon. (3)	○	○	○	○	○
3. Group members shared general problem solving strategies about equipment or concepts. (4)	○	○	○	○	○
4. The group's research involved specialized equipment or software. (5)	○	○	○	○	○
5. Conducting a literature review was an important component of the undergraduate's research (1)	○	○	○	○	○

End of Block: Community of Practice - Shared Repertoire

Start of Block: Community of Practice - Joint Enterprise

Q4.1
Section 2 / 13

The following items relate to collaboration between members of your research group during the URE.

Please identify the extent to which you experienced, from your perspective, each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. Individuals in the research group were held accountable to each other (1)	○	○	○	○	○
2. Setting goals was important to the research group (2)	○	○	○	○	○
3. There was some sense of belonging for all members of the group (3)	○	○	○	○	○
4. Individuals had ownership in the research projects they worked on. (4)	○	○	○	○	○
5. Personal achievements were celebrated by members of the group. (5)	○	○	○	○	○
6. Group members all knew the kinds of reporting, outputs, and goals the group worked toward. (6)	○	○	○	○	○

7. Individuals in the group were invested in developing others' identities as researchers or scientists (7)	○	○	○	○	○

End of Block: Community of Practice - Joint Enterprise

Start of Block: Community of Practice - Mutual Engagement

Q5.1
Section 3 / 13

The following items relate to personal interactions between members of your research group (i.e., undergrad, grad students, primary investigators, and / or other research faculty/staff) during the URE.

Please identify the extent to which you experienced, from your perspective, each of the following:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. There was one-on-one time between group members. (1)	○	○	○	○	○
2. Small group meetings were important for the group. (2)	○	○	○	○	○
3. Members of the research group felt a connection with each other. (3)	○	○	○	○	○

4. There was an emphasis on sharing research progress or results with others. (4)					
5. An orientation (formal or informal) for new members was important to the group. (5)					
6. Group members participated together in informal social activities outside of work. (6)					

End of Block: Community of Practice - Mutual Engagement

Start of Block: Cognitive Apprenticeship - Pedagogy

Q6.1
Section 4 / 13

How much did you implement the following instructional practices when mentoring your undergraduate(s)? *If you mentor multiple students, consider how you typically implemented these practices.*

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. Personally demonstrating how to perform research related tasks (1)					

2. Observing and taking actions to improve an undergraduate's performance (2)	○	○	○	○	○
3. Providing suggestions or tools when the student(s) came to you for help (3)	○	○	○	○	○
4. Asking the student(s) to explain the work being done (4)	○	○	○	○	○
5. Providing opportunities for the student(s) to consider how their peers or other researchers might solve work-related problems (5)	○	○	○	○	○
6. Providing opportunities to think of and to solve new research problems / questions. (6)	○	○	○	○	○

End of Block: Cognitive Apprenticeship - Pedagogy

Start of Block: Cognitive Apprenticeship - Sequencing

X→

Q7.1
Section 5 / 13

The following items relate to the general order of tasks performed by undergraduates during the URE program. Please identify the extent to which:

	Not At All (1)	Slightly (2)	Moderately (3)	A Good Deal (4)	A Great Deal (5)
1. I gave the undergraduate(s) more challenging tasks as their ability increased. (1)	○	○	○	○	○
2. I required the undergraduate(s) to learn new skills or try new approaches as they were given tasks. (2)	○	○	○	○	○
3. I made sure the undergraduate(s) understood the context for their work before giving them work on narrower or specific, related tasks. (3)	○	○	○	○	○

End of Block: Cognitive Apprenticeship - Sequencing

Start of Block: Instrumental outcomes

Q8.1
Section 6 / 13

Identify how participation as a mentor in the URE affected instrumental outcomes, including:

	Strong Decrease (1)	Moderate Decrease (2)	Slight Decrease (3)	No Change (4)	Slight Increase (5)	Moderate Increase (6)	Strong Increase (7)	N/A (8)

1. Your research productivity (1)								
2. Your research quality (2)								
3. Quality of your relationship with your undergraduate mentee(s) (3)								
4. Quality of your relationship with your own mentor (4)								
5. Quality of your relationship with your peer colleagues (e.g., Co-PIs or other graduate students) (5)								
6. Your job / professional qualifications (6)								
7. Chances of new funding from extramural sources (e.g., having UR in a proposal increased chances of funding). (7)								

End of Block: Instrumental outcomes

Start of Block: Socioemotional outcomes

Q9.1
Section 7 / 13

Identify how your participation as a mentor in the URE affected social and emotional outcomes, including your:

	Strong Decrease (1)	Moderate Decrease (2)	Slight Decrease (3)	No Change (4)	Slight Increase (5)	Moderate Increase (6)	Strong Increase (7)
1. Enjoyment of work life (1)	○	○	○	○	○	○	○
2. Level of confidence (2)	○	○	○	○	○	○	○
3. Personal satisfaction (3)	○	○	○	○	○	○	○
4. General self-awareness (4)	○	○	○	○	○	○	○
5. Sense of community (5)	○	○	○	○	○	○	○
6. Sense of fun and enthusiasm while working with undergraduates (6)	○	○	○	○	○	○	○
7. Sense of cooperation (7)	○	○	○	○	○	○	○
8. Sense of responsibility for others (8)	○	○	○	○	○	○	○
9. Personal satisfaction from contributing to the benefit of the undergraduate(s) (9)	○	○	○	○	○	○	○

End of Block: Socioemotional outcomes

Start of Block: Interpersonal outcomes

Q10.1
Section 8 / 13

Identify how participating as a mentor in the URE affected interpersonal outcomes, including your:

	Strong Decrease (1)	Moderate Decrease (2)	Slight Decrease (3)	No Change (4)	Slight Increase (5)	Moderate Increase (6)	Strong Increase (7)
1. Capability for mentoring (1)	○	○	○	○	○	○	○
2. Mentoring skills (2)	○	○	○	○	○	○	○
3. Teaching skills (3)	○	○	○	○	○	○	○
4. Communication skills (4)	○	○	○	○	○	○	○
5. Research group diversity (5)	○	○	○	○	○	○	○
6. Probability of changing how you mentor future undergraduates (6)	○	○	○	○	○	○	○

End of Block: Interpersonal outcomes

Start of Block: Professional outcomes

Q11.1
Section 9 / 13

Identify how participation as a mentor in the URE affected professional outcomes, including your:

	Strong Decrease (1)	Moderate Decrease (2)	Slight Decrease (3)	No Change (4)	Slight Increase (5)	Moderate Increase (6)	Strong Increase (7)	N/A (8)
1. Understanding of faculty work (1)	○	○	○	○	○	○	○	○
2. Clarity of career aspirations (2)	○	○	○	○	○	○	○	○
3. Preparation for your career due to skill development (3)	○	○	○	○	○	○	○	○
4. Opportunities for learning managerial skills (4)	○	○	○	○	○	○	○	○
5. Desire for future work with undergraduate researchers (5)	○	○	○	○	○	○	○	○
6. Organizational skills (6)	○	○	○	○	○	○	○	○
7. Time management (7)	○	○	○	○	○	○	○	○
8. Skills related to advising students (8)	○	○	○	○	○	○	○	○

End of Block: Professional outcomes

Start of Block: Cognitive outcomes

Q12.1
Section 10 / 13

Identify how participation as a mentor in the REU affected cognitive outcomes, including your:

	Decrease (1)	No Change (2)	Slight Increase (3)	Moderate Increase (4)	Good Increase (5)	Strong Increase (6)
1. Intellectual growth (1)	○	○	○	○	○	○
2. Frequency of explaining and answering questions about your work (2)	○	○	○	○	○	○
3. Perspective on your self (3)	○	○	○	○	○	○
4. Perspective on your academic field (4)	○	○	○	○	○	○
5. Awareness of different models or ways for mentoring (5)	○	○	○	○	○	○
6. Ability to teach undergraduates due to a better understanding of them (e.g., relating material to them) (6)	○	○	○	○	○	○
7. Assessment of the completeness of your work (7)	○	○	○	○	○	○
8. Acquisition of different perspectives (8)	○	○	○	○	○	○

9. Ability to think differently about a situation or topic (9)	○	○	○	○	○	○
10. Thinking through experimental designs more carefully (10)	○	○	○	○	○	○
11. Depth of understanding of your own work (11)	○	○	○	○	○	○
12. Recall of knowledge you might not otherwise have remembered (12)	○	○	○	○	○	○

End of Block: Cognitive outcomes

Start of Block: Challenges

Q13.1
Section 11 / 13

How challenging for you were each of the following aspects of the REU?

	Not at All Challenging (1)	Slightly Challenging (2)	Moderately Challenging (3)	Very Challenging (4)	Extremely Challenging (5)
1. Concern about UR-related gender-based issues (1)	○	○	○	○	○
2. Balancing UR work and professional work (2)	○	○	○	○	○
3. Balancing the	○	○	○	○	○

undergraduate's needs and your own needs (3)					
4. Gauging the undergraduate's knowledge and abilities (4)	○	○	○	○	○
5. Scheduling time with the undergraduate (5)	○	○	○	○	○
6. The balance between research productivity and education (e.g., course load) goals (6)	○	○	○	○	○
7. Emotional costs to you (7)	○	○	○	○	○
8. Establishing trust with the undergraduate (8)	○	○	○	○	○
9. General tensions between the undergraduate and the rest of the research group (9)	○	○	○	○	○
10. Changes in research productivity (10)	○	○	○	○	○
11. Amount of time and effort involved (11)	○	○	○	○	○
12. A personal lack of experience and knowledge in managing undergraduates (12)	○	○	○	○	○

13. Limited and/or unreliable resources for mentoring (13)	○	○	○	○	○
14. Limited and/or unreliable resources for doing UR (e.g., equipment availability or funding) (14)	○	○	○	○	○
15. An ambiguous mentorship structure among the undergraduate's mentors (e.g., whose directions take precedence) (15)	○	○	○	○	○
16. The amount of external value or recognition of efforts or contributions (16)	○	○	○	○	○
17. Conflict between organizational / institutional goals / methods for UR and those of your research group or department (17)	○	○	○	○	○

End of Block: Challenges

Start of Block: Block 15

Q14.1
Section 12 / 13

Please rate the following based on your experience as a mentor for undergraduate researchers in this program.

	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Neutral (4)	Slightly Agree (5)	Moderately Agree (6)	Strongly agree (7)
1. Participating as a mentor in this program is/was a valuable learning experience for me. (1)	○	○	○	○	○	○	○
2. Participating as a mentor in this program is/was a valuable life experience for me. (2)	○	○	○	○	○	○	○
3. I will mentor undergraduate researchers in the future. (3)	○	○	○	○	○	○	○

Q14.2 Are there any aspects of your mentoring experience in this program you'd like to mention that were not covered in this survey?

____
____
____
____
____

Q14.3 From your perspective as a mentor, what actions could be taken to improve this undergraduate research program or others like it?

____
____
____
____
____

End of Block: Block 15

Start of Block: Block 6

Q15.1 Section 13 / 13

This section asks about your experience mentoring undergraduates and other demographic information.

These questions are asked to develop an understanding of who participates in natural resources undergraduate research and will not be reported other than as generalities in publications. You have the option to not answer any of these questions.

Q15.2 How many semesters, or quarter equivalent, (including fall, spring, and summer) of prior experience do you have with mentoring undergraduates? *Enter "0" if none.*

____

Q15.3 How many times in the past have you participated in training on mentoring undergraduates, such as workshops or short courses? *Enter "0" if none.*

____

Q15.4 How many hours each week, on average, did you have in direct contact with your undergraduate researcher(s) that were part of this URE?

____

Q15.5 Not including yourself, how many other individuals mentored (i.e., they explicitly and intentionally formed a mentoring relationship with) your undergraduate(s) as part of this URE program for at least the duration of the experience? *Enter "0" for none.*

____

Q15.6 Please describe the general mentoring structure you were part of during this URE program. For example, 1 grad student mentoring 1 undergrad, 1 grad student and 1 professor mentoring 2 undergrads, etc.

____
____
____
____
____

Q15.7 Which best describes your position at work in the research group?

- Undergraduate student (1)
- Master student (2)
- Doctoral student (3)
- Assistant or Post-doctoral researcher (4)
- Assistant Professor or equivalent (5)
- Associate Professor or equivalent (6)
- Full Professor or equivalent (7)
- Other (Please identify) (8) ____

Q15.8 What is your gender?

- Male (1)
- Female (2)
- Other (3) ____
- Prefer to not answer (4)

Q15.9 What is your race / ethnicity? *Select "Yes" for all that apply.*

- ☐ Alaskan Native (1)
- ☐ American Indian or Native American (2)
- ☐ Asian (3)
- ☐ Black or African American (4)
- ☐ Hispanic or Latino/ Latina (8)
- ☐ Native Hawaiian or Pacific Islander (5)
- ☐ White or Caucasian (6)
- ☐ Other (please specify) (7) ____
- ☐ Prefer to not answer (12)

End of Block: Block 6

Start of Block: Block 8

Q16.1
As part of this research, we plan to look at a small number of specific natural resources REU programs for in depth study, and this will involve interviews with participants of those programs. If your program is selected, we would like to follow up with you.

If you are willing to be contacted for a follow up interview, please enter your contact email below:

____

Q16.2 You have reached the end of the survey. **To submit your responses, please click on the "Next" button below.**

Thank you! Your responses will be useful in helping establish the participant outcomes of natural resources undergraduate research experiences and will help future students who participate in them.

End of Block: Block 8

Appendix G. IRB Approvals

VirginiaTech

Office of Research Compliance
Institutational Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE:	June 13, 2012
TO:	John Bryan Kidd, John R Seiler
FROM:	Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)
PROTOCOL TITLE:	Intern Attitudes Toward Research
IRB NUMBER:	**12-535**

Effective June 13, 2012, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Exempt, under 45 CFR 46.110 category(ies) 2**
Protocol Approval Date:	**June 13, 2012**
Protocol Expiration Date:	**N/A**
Continuing Review Due Date*:	**N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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VirginiaTech

Office of Research Compliance
Institutational Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: March 5, 2014

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective March 5, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,7**
Protocol Approval Date:	**March 5, 2014**
Protocol Expiration Date:	**March 4, 2015**
Continuing Review Due Date*:	**February 18, 2015**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: February 9, 2015

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective February 9, 2015, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2015**
Protocol Expiration Date:	**March 4, 2016**
Continuing Review Due Date*:	**February 19, 2016**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

VirginiaTech

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Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: October 24, 2016

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective October 24, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2016**
Protocol Expiration Date:	**March 4, 2017**
Continuing Review Due Date*:	**February 18, 2017**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

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540/231-4606 Fax 540/231-0959
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website http://www.irb.vt.edu

MEMORANDUM

DATE: February 7, 2017

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective February 7, 2017, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2017**
Protocol Expiration Date:	**March 4, 2018**
Continuing Review Due Date*:	**February 18, 2018**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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website http://www.irb.vt.edu

MEMORANDUM

DATE: May 2, 2017

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective May 1, 2017, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2017**
Protocol Expiration Date:	**March 4, 2018**
Continuing Review Due Date*:	**February 18, 2018**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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VirginiaTech

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Blacksburg, Virginia 24061
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website http://www.irb.vt.edu

MEMORANDUM

DATE: February 21, 2018

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective February 21, 2018, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2018**
Protocol Expiration Date:	**March 4, 2019**
Continuing Review Due Date*:	**February 18, 2019**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

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540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE:	February 18, 2019
TO:	John F Munsell, John Bryan Kidd, John R Seiler
FROM:	Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)
PROTOCOL TITLE:	Outcomes from participation in a novel undergraduate research fellowship
IRB NUMBER:	**14-283**

Effective February 18, 2019, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

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All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2019**
Protocol Expiration Date:	**March 4, 2020**
Continuing Review Due Date*:	**February 19, 2020**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
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VIRGINIA TECH.

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300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE: March 2, 2020

TO: John F Munsell, John Bryan Kidd, John R Seiler

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires October 29, 2024)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective March 2, 2020, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2020**
Protocol Expiration Date:	**March 4, 2021**
Continuing Review Due Date*:	**February 11, 2021**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
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irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE:	February 23, 2021
TO:	John F Munsell, John Bryan Kidd
FROM:	Virginia Tech Institutional Review Board (FWA00000572, expires October 29, 2024)
PROTOCOL TITLE:	Outcomes from participation in a novel undergraduate research fellowship
IRB NUMBER:	**14-283**

Effective February 23, 2021, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

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https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2021**
Protocol Expiration Date:	**March 4, 2022**
Continuing Review Due Date*:	**February 11, 2022**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

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Blacksburg, Virginia 24061
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irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE: February 14, 2022

TO: John F Munsell, John Bryan Kidd

FROM: Virginia Tech Institutional Review Board (FWA00000572)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective February 14, 2022, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

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(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 5, 2022**
Protocol Expiration Date:	**March 4, 2023**
Continuing Review Due Date*:	**February 11, 2023**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

VIRGINIA TECH.

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE:	February 7, 2023
TO:	John F Munsell, John Bryan Kidd
FROM:	Virginia Tech Institutional Review Board (FWA00000572)
PROTOCOL TITLE:	Outcomes from participation in a novel undergraduate research fellowship
IRB NUMBER:	**14-283**

Effective February 7, 2023, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**February 7, 2023**
Protocol Expiration Date:	**February 6, 2024**
Continuing Review Due Date*:	**January 16, 2024**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

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MEMORANDUM

DATE: January 12, 2024

TO: John F Munsell, John Bryan Kidd

FROM: Virginia Tech Institutional Review Board (FWA00000572)

PROTOCOL TITLE: Outcomes from participation in a novel undergraduate research fellowship

IRB NUMBER: **14-283**

Effective January 12, 2024, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**January 12, 2024**
Protocol Expiration Date:	**January 11, 2025**
Continuing Review Due Date*:	**December 21, 2024**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.