University of Vermont
ScholarWorks @ UVM

Graduate College Dissertations and Theses | Dissertations and Theses

2017

Interdisciplinary Research Experiences For Undergraduates: Two Mixed-Methods Studies

Beth White
University of Vermont

INTERDISCIPLINARY RESEARCH EXPERIENCES FOR UNDERGRADUATES: TWO MIXED-METHODS STUDIES

A Dissertation Presented

By

Beth White

to

The Faculty of the Graduate College

of

The University of Vermont

In Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
Specializing in Educational Leadership and Policy Studies

January, 2017

Defense Date: November 18, 2016
Dissertation Examination Committee:

Barri Tinkler, Ph.D., Advisor
Jason Stockwell, Ph.D., Chairperson
Jill Tarule, Ph.D.
Simon Jorgenson, Ph.D.
Cynthia J. Forehand, Ph.D., Dean of the Graduate College

ABSTRACT

Despite the demand for a diverse STEM-educated population and workforce, college students have consistently turned away from these disciplines in large numbers, creating a persistent problem that many are trying to address. The aim of the National Science Foundation's Research Experiences for Undergraduates (REU) program is to inspire, attract, and retain STEM majors. Funding supports undergraduate STEM students' engagement in real-world research alongside STEM mentors. As colleges and universities compete for funding for REUs, it is important to understand the mechanisms within summer research programs that resonate most deeply with undergraduate STEM researchers. While many studies reveal strong correlations between research experiences and STEM aspirations, less is known about the mechanisms within REU programs that support these gains. My research used quantitative and qualitative self-reported data from 20 REU students, 18 of whom were underrepresented minorities in STEM. Over two summers, these students, in cohorts of ten, came to the University of Vermont to participate in a team-oriented, 10-week REU: *Interdisciplinary Research on Human Impacts in the Lake Champlain Ecosystem*.

Two mixed-methods studies, guided by the frameworks of the theory of possible selves, theory of self-efficacy for research, and social cognitive career theory, revealed four important program mechanisms that gave rise to gains in research skills, confidence and self-efficacy for research, and STEM career aspirations, particularly for individuals from underrepresented minority groups in STEM. Findings suggest that the program fostered student capacity building within a safe, inclusive, and positive setting where students experienced what it feels like to be an active participant in the world of research. Within this context, critical mechanisms that gave rise to gains in research skills, confidence and self-efficacy for research, and STEM career aspirations included: (1) experiential education through interdisciplinary research experiences, (2) student independence and ownership balanced with expert researcher guidance and support, (3) formal and informal mentoring networks where students were mentored and where they mentored others, and (4) the establishment of an intentional learning community that advanced leadership, research skill building, perseverance, and reflection.

Results from this research cannot be generalized beyond the context of the Lake Champlain REU, however, findings are in alignment with the body of literature that highlights the positive effects of REUs on STEM majors' research skills, confidence and self-efficacy for research, and STEM career aspirations. Using mixed methods to identify and understand the within-program mechanisms that support student gains is a valuable new research approach for this field. Recognizing programmatic mechanisms across REU programs can lead to expansion, replication, and application of these models beyond one institution, resulting in more positive gains for more undergraduate STEM researchers.

DEDICATION

I dedicate my dissertation to my parents, Denis and Joann White. Because of all that you do for me, I get to pursue my love of learning. Thank you for believing in me.

For the students of the Lake Champlain Research Experiences for Undergraduates program, and to all the students you will someday mentor.

And for those who are the first in their families to bravely step out and pursue education, I vow to dedicate my career to being your advocate.

ACKNOWLEDGEMENTS

I have not made this journey alone.

I acknowledge, with much gratitude, the faculty, staff, and colleagues in the Educational Leadership and Policy Studies program at the University of Vermont—thank you for being my mentors, advocates, and friends.

To my committee, you have made my work better. To Dr. Barri Tinkler, my advisor, for being my mainstay. To Dr. Jason Stockwell, for your infectious enthusiasm for science and learning, and for bringing me into the Rubenstein fold. To Dr. Jill Tarule, for introducing me to powerful ideas, like women's ways of knowing, and for being my unwavering advocate over the last five years. To Dr. Simon Jorgenson, for your palpable and contagious commitment to education, and for your deep thinking.

To Dr. Tammy Kolbe, with great appreciation for all that you taught me and for setting me on the journey of program evaluation. Thank you to the members of my UVM cohort and especially to those in my study group. I acknowledge a deep gratitude for the folks at the Rubenstein Ecosystem Science Laboratory, for all that you taught me and for your welcoming nature.

To my brothers, Donovan and Denis White, who were patiently and not so patiently my first students, and now are my friends. To my lifelong mentor and friend, Mrs. Suzanne

London, who first captivated and inspired me in ninth grade English and who continues to do just that 25 years hence. To Mrs. Gay Craig, my first and only female science teacher. To Ginger Wallis, my summer internship mentor who introduced me to the idea of graduate school. To Elise Guyette for encouraging me to pursue this doctorate at UVM and for connecting me with the EDLP program. To Dr. Jimmy Karlan, who has dedicated his career to putting students front and center in their education, may I follow in your footsteps.

And to my dearest friends. First, to the coven of women—to Jen Manwell, Judy Rubin, Joanne Farrell, Karen Scott, Dr. Beth Naylor, Dr. Kerry Lawrence, and Dr. Megan Munson-Warnken, you are my beloveds, my sisters, my champions. To Dr. Vincent Mugisha, who continues to inspire and be a role model for me. To the beings who opened their home and hearts to me at 492 Pratt Road. And to Romek Sypko, whose friendship surpasses time and space, thank you for the critical feedback on my graduate school entrance materials and for helping me get this ball rolling!

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1.Overview

Today, the need for a STEM-knowledgeable and skilled workforce is more important than ever (e.g. Business Roundtable, 2005; Committee on Science, Engineering, and Public Policy, 2007, 2012), yet the percentages of freshmen who declare majors in STEM are at the same proportions as they were in the 1970s (Hurtado, Eagan, & Chang, 2010). Policymakers and analysts who study government, academia, and industry recognize that environmental changes and globalization are spurring transitions in the economy, and stress the need for workers with STEM knowledge and skills (Mervis, 2015; NSF National Science Board, 2015). Despite the demand for a diverse STEM-educated population and workforce, college students have consistently turned away from these disciplines in large numbers, creating a persistent problem that many are trying to address (e.g. Hunter, Laursen, & Seymour, 2007; Hurtado, Eagan, & Chang, 2010; Seymour, Hunter, Laursen, & DeAntoni, 2004).

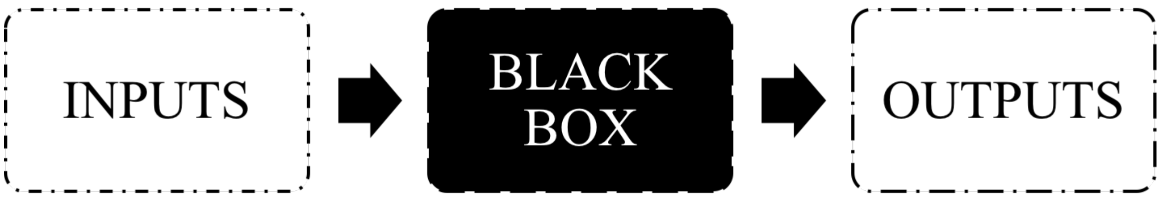
One federally supported program aimed at inspiring, attracting, and retaining STEM majors is the National Science Foundation's (NSF) Research Experiences for Undergraduates (REU) program (e.g. Hunter, Laursen, & Seymour, 2007; Roe, 1952; Russell, Hancock, & McCullough, 2007). REU funding supports undergraduate students' engagement in real-world research alongside STEM mentors (Lopatto, 2007; Russell et al., 2007; Seymour, Hunter, Laursen, & Deantoni, 2004). In addition to conducting hands-on research, students participate in professional development opportunities that strengthen content knowledge and skills and learn about post-undergraduate pathway options within their field (e.g. Adedokun et al., 2012; Alfred et al., 2005; Mau, 2003).

The programs "blur the interface between teaching and learning," (Hakim, 1998, p. 189) are highly motivating, and often leave students with a sense of belonging within the discipline.

In 2016, NSF earmarked $15 million for workshops aimed at attracting more women and non-Asian minorities into STEM (Mervis, 2015). Now, more than ever, the demand for STEM research experiences is unprecedented, particularly for individuals from underrepresented groups. In 2013, National Center for Science and Engineering Statistics (NCES) reported that the majority of the science and engineering workforce population is White and male; persons who make up smaller percentages within the STEM field than are represented in the U.S. population are referred to as underrepresented minorities. In STEM, women, persons with disabilities, and three racial/ethnic groups—Blacks, Hispanics, and American Indians are considered underrepresented (National Center for Science and Engineering Statistics, 2013). I included first-generation college students and persons from low socioeconomic backgrounds in this definition for this research study (Packard, 2016).

As more federal funding gets allocated to programs, it is important to know more about the nuances of the mechanisms within these research experiences that strengthen undergraduate STEM majors' research skills, ignite interests, and improve degree completion rates, especially for underrepresented minority students (e.g. NSF National Science Board, 2015; Thiry, Weston, Laursen, & Hunter, 2012; Trosset, Lopatto, & Elgin, 2008). The focus of my dissertation is to dig into the black box (Figure 1) of one REU program to discover more about the systems that give rise these important gains (Grubb, 2009). The first study (Chapter 4) investigated the programmatic contexts (experiences, events, and situations) of an REU that supported gains in STEM career aspirations. The second study (Chapter 5) illuminated the mechanisms that supported underrepresented minority students' (Blacks, Hispanics, women, first-generation to attend college, and Pell-eligible) gains in research skills, confidence and self-efficacy for research, and changes in thinking about career aspirations in STEM.

Figure 1: Measurable inputs and outputs of undergraduate research programs are often studied because they are relatively easy to measure, while the internal workings are more elusive and investigated less (Grubb, 2009; Ladd, Chalk, & Hansen, 1999; Tyack & Cuban, 2009). The programmatic contexts where implementation occurs is referred to as a black box, for it is often opaque and under examined. The porosity of this process is represented by the dashed lines.



1.2. Problem Statement

Studies of REUs reveal impressive findings, including increases in college completion rates for STEM majors who were REU participants (e.g. Mervis, 2015; Nagda, Gregerman, Lerner, von Hippel, & Jonides, 1998; Seymour, Hunter, Laursen, & DeAntoni, 2004) and enhanced degree and career aspirations (e.g. Hathaway, Nagda, & Gregerman, 2002; Hunter et al., 2007), particularly for minorities in STEM (e.g. Adedokun et al., 2012; Ong, Wright, Espinosa, & Orfield, 2011; Strayhorn, 2010). However, many studies of REUs are general and lack insight into the important processes that happen within the black box of the experiences.

A body of literature highlights the importance of mentoring in REUs, specifically the role of mentor-mentee interactions in relationship building, mentor preparation, and the interpersonal skills required of scientists who are the most successful mentors (e.g. Adedokun, Dyehouse, Bessenbacher, & Burgess, 2010; Dolan & Johnson, 2009; Wilson et al., 2012). Although valuable, much of the research on REUs is evaluation driven and focused on outcomes and program satisfaction (e.g. Lopatto, 2004; Sadler & McKinney, 2010; Thiry et al., 2012). Few studies offer rich descriptions of the most beneficial aspects of the research experience or explore ways to expand and scale up best practices across programs (e.g. Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2008; Packard, 2016; Taraban & Blanton, 2008).

1.3. Purpose of the Research

My research was guided by a conceptual framework that includes the theory of possible selves (Markus & Nurius, 1986), the theory of self-efficacy for research (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Bandura, 1977; Caprara et al., 2008), and the social cognitive career theory (Lent, Brown, & Hackett, 1994). I identified and analyzed key programmatic mechanisms within the black box of one REU program at the University of Vermont (UVM). The purpose of the two studies that emerged from my dissertation were to illuminate what Markus and Nurius (1986) refer to as “models, images, and symbols” within the program that resulted in students’ self-reported gains in research skills, confidence and self-efficacy for research, and research-related career aspirations. Essentially, I described key mechanisms that made salient the world of science for students, and the situations that activated or elicited a particular thought, feeling, or notion that resulted in students actively constructing, reconstructing, solidifying, or rejecting their ideas about their future-selves in STEM. Empirically, the mixture of quantitative and qualitative data from my studies provide important observations about keystone mechanisms within research experiences that add to the growing body of literature on the benefits of REUs for undergraduate STEM majors, especially for underrepresented minority students in STEM.

1.4. Research Questions

My research highlights key mechanisms that fostered research skill development, confidence and self-efficacy for research, and career aspirations for students from the UVM's Lake Champlain REU program: *Interdisciplinary Research on Human Impacts in the Lake Champlain Ecosystem*. Findings from analysis of self-reported data from two cohorts of undergraduate (*N*=20) students' post-programmatic surveys, exit focus groups, reflections, and blog entries are described in two articles (Chapters 4 and 5). The two studies were guided by the following research questions:

1. What did participants identify as important programmatic contexts (experiences, events, and situations) that helped them understand, conceptualize, and imagine or reinforce the image of their future selves in a STEM field, or not, after graduation?
2. What mechanisms supported underrepresented minorities (Blacks, Hispanics, women, first-generation in their families to attend college, and Pell-eligible) students'[1] to experience: (a) gains in research skills, (b) confidence and self-efficacy for research, and (c) changes in thinking about their career aspirations in STEM?

[1] I acknowledge that while a person may identify with one or more group, that does not automatically mean a shared or common experience within or across that group (Packard, 2016).

CHAPTER 2: COMPREHENSIVE LITERATURE REVIEW

2.1. Overview

Research experiences advance the development of agency as well as a sense of belonging within the discipline (Hakim, 1998). Findings from one of the first studies on undergraduate research experiences revealed that senior-year undergraduate internships provided students with the opportunity to crystallize their "higher levels of self-concept" (Brooks, Cornelius, Greenfield, & Joseph, 1995). Since this seminal work by Brooks et al., dozens of studies emerged that describe the impacts of undergraduate research experiences on research skills, confidence and self-efficacy for research, and STEM-oriented career aspirations—some of which focused specifically on research participants who identified as underrepresented minorities in STEM. A handful of studies explore the inner mechanisms of the Research Experiences for Undergraduates (REU) programs that impact participants.

My comprehensive review of the literature highlighted relevant research, which fell into the following thematic categories:

1. Research experiences: Research skills
2. Research experiences: Confidence and self-efficacy for research
3. Research experiences: Gains in STEM-oriented aspirations
4. Research experiences: Underrepresented minority STEM students
5. Research experiences: Prior studies that investigate mechanisms in the black box

The last two sections review:

1. The theoretical and conceptual frameworks that guide my study; and,
2. The justification for the research.

2.2. Research Experiences: Research Skills

One of the most frequently stated goals for REU programs is for students to gain research skills (e.g. Page, Abramson, & Jacobs-Lawson, 2004; Seymour, Hunter, Laursen, & DeAntoni, 2004; Taraban & Blanton, 2008). Studies of undergraduate research experiences revealed gains in a wide range of skills including: research-based processes (e.g. hypotheses testing, collecting and analyzing data, etc.) (e.g. Bauer & Bennett, 2003; Hackett, Croissant, & Schneider, 1992; Russell, Hancock, & McCullough, 2006), communication (e.g. Alexander, Foertsch, & Daffinrud, 1998; Seymour, Hunter, Laursen, & DeAntoni, 2004; Ward, Bennett, & Bauer, 2002), technical (e.g. specific computer programs) (e.g. Hackett et al., 1992; Kardash, 2000; Lopatto, 2004), team-oriented/interpersonal (e.g. Bauer & Bennett, 2003; Lopatto, 2004; Seymour, Hunter, Laursen, & Deantoni, 2004), and mathematical/statistical (e.g. Bauer & Bennett, 2003; Hackett et al., 1992; Kardash, 2000).

Lopatto (2004) designed a common assessment tool to evaluate summer research experiences in the sciences. In the first year, 1,135 researchers from 41 institutions administered the Summer Undergraduate Research in Engineering survey, which revealed average gains of above 3.0 (out of 5.0) for all 20 skill-related questions. The top three gains attributed to the summer research experiences were: "understanding the research process" (4.13), "readiness for more demanding research" (4.03), and "understanding how scientists work on real problems" (4.0) (Lopatto, 2008). In addition to technical and research skills, research experiences are associated with gains in skills related to thinking and working like a scientist, which also have been identified as a benefit for individuals who decide to pursue non-STEM careers (Lopatto, 2004;

Seymour, Hunter, Laursen, & DeAntoni, 2004; Taraban & Blanton, 2008). The majority (75%) of respondents from a survey of 3,298 randomly selected individuals from 210 active National Science Foundation award sites reported using the skills they gained in their research experiences (Russell et al., 2006).

2.3. Research Experiences: Confidence and Self-Efficacy for Research

Two interlinked qualities that are developed through independent scientific research are confidence and self-efficacy for research (e.g. Adedokun et al., 2013; Lopatto, 2003; Russell et al., 2006). Self-efficacy for research is a person's dynamic set of self-beliefs about their capabilities and capacity to realize goals within the field of research (Bandura, 1977; Caprara et al., 2008).

Kardash et al. (2008) measured the pre- and post-levels of self-efficacy of 189 research students who spent 12-hours a week in mentor laboratories over the course of 32-weeks. In the responses from the post-data, confidence and self-efficacy for research appeared as a theme in two of the three open-ended questions, which asked how the internship (1) influenced future goals, and (2) was personally beneficial and satisfying (Kardash et al., 2008). With regards to future career plans, 7.8% of participants expressed an increase in self-efficacy, 2.3% indicated a *decrease*, and more male (16%) and fewer female (2.6%) students reported gains. Regarding personal benefits, 29.3% of women expressed gains in perceived self-efficacy and independence, as compared with 4.3% of males (Kardash et al., 2008).

Using regression analysis, Berkes (2007) revealed strong links between research experiences and development of self-efficacy for research, and students' interests in continuing in the field. The number of semesters spent working in a wet lab was a statistically significant predictor of student desire to persist in life-science/biology (Berkes, 2007). Berkes (2007) described two key mechanisms for these gains: (1) access to resources from the research community in mastering laboratory skills and (2) familiarity with models and mentors. Adedokun et al. (2013) used structural equation modeling with post-program survey data from 156 students to study the mediating effects of self-efficacy for research on research skills and desire to continue in science; every one unit increase in research self-efficacy yielded a statistically significant 1.42 unit increase in research-related career aspirations (Adedokun et al., 2013).

2.4. Research Experiences: Gains in STEM-Oriented Aspirations

Undergraduate institutions often create research experiences to strengthen retention (e.g. Sadler, Burgin, McKinney, & Ponjuan, 2010; Seymour, Hunter, Laursen, & DeAntoni, 2004; Taraban & Blanton, 2008). Many research programs not only aid students with finishing their undergraduate degrees, but are also associated with gains in aspirations to pursue graduate school (e.g. Campbell, Skoog, Taraban, & Blanton, 2008; Henne et al., 2008; Locks & Gregerman, 2008). However, not all programs are successful. Lopatto (2008) found nearly equal percentages of students had not decided on a science career prior to their research experience and 4.7% changed their mind in the direction towards further involvement in the discipline, whereas 3.7% decided *against* pursuing a career in science. A glimpse into the mechanisms that worked or did not work to support students' gains would be helpful to investigate and was the focus of my studies.

While 34.4% expressed that participation in the research resulted in clarification of career pursuits, in Kardash et al.'s (2008) study, 12.5% reported *no effect* from undergraduate research experiences. In the same study, while 21.9% reported more interest in pursuing a science career, 22.7% expressed *decreases* in interest; and women were four times more likely (32.1%) to mention that participating in the research experience had *decreased* their likelihood of pursuing a career in science (Kardash et al., 2008). Again, this research begs the question: what mechanisms failed to work or were not in place in these research experiences?

In contrast, two controlled studies, which used longitudinal sampling, found that students who participated in research experiences had higher rates of attending graduate school than students who did not participate (Bauer & Bennett, 2003; Hathaway et al., 2002). Hathaway, Nagda, and Gregerman (2002) designed a stratified, random sampling protocol to select participants and non-participant "matches" for the undergraduate research program, which allowed comparisons of the impact of the experience between two groups, while controlling for background characteristics (Hathaway et al., 2002). Each randomly selected student was matched with three non-selected students (control and experimental groups) by field of study, race or ethnicity, graduation date, and cumulative GPA (Hathaway et al., 2002). Results from my study revealed that participants in undergraduate research were significantly more likely to pursue graduate education and conduct additional research than those not involved with the program (Hathaway et al., 2002).

Using a similar approach, Bauer and Bennett (2003) surveyed over 2,000 university alumni about a variety of topics, including whether they participated in research experiences and their perceived benefit from these experiences, as well as information about post-undergraduate endeavors, including whether they had enrolled in graduate school (Bauer & Bennett, 2003). When compared with alumni with no research experience, those who participated in research experiences (formal or otherwise) reported benefiting from the training, were significantly more likely to pursue post-baccalaureate education, and were about twice as likely to complete a doctorate (Bauer & Bennett, 2003). In a national survey conducted by Russell et al. (2006), researchers noted an increase in academic degree expectations after students participated in an undergraduate research experience; 29% expressed "new" desires to pursue a Ph.D. Furthermore, respondents from the follow-up survey who were in graduate school with the goal to obtain a Ph.D. expressed that their undergraduate experiences conducting research had a "strong influence" on their decision to pursue post-undergraduate studies (Russell et al., 2006).

2.5. Research Experiences: Underrepresented Minority STEM Students

Most students admitted to STEM programs carry with them invisible privileges that are often associated with race or ethnicity and gender (Fortenberry, 2016). When students from minority groups access advice, connections, and opportunities in the world of STEM, everyone benefits (Fortenberry, 2016; Packard, 2016). College completion and pursuit of post-undergraduate opportunities, like graduate school, not only require strong academic credentials, they often require personal connections. Research experiences support undergraduates with degree completion and provide leverage for post-undergraduate educational opportunities. In addition to gains students receive from conducting original research, these experiences provide funding and facilities as well as access to mentors who often assume the role of advocate and sponsor (e.g. Hunter et al., 2007; Lent et al., 2005; Seymour, Hunter, Laursen, & DeAntoni, 2004). Studies have shown the value of personalized research experiences, especially for individuals from non-majority groups, many of whom have less access to the privileges majority members enjoy.

In a phenomenological study of 65 underrepresented minorities in STEM who participated in research experiences, Hurtado et al. (2008) identified three elements that allowed students to see themselves as scientists: (1) early interests in science, (2) exposure to research, and (3) research career goals. In an ethnographic study of four liberal arts colleges that offered summer research experiences, Hunter et al. (2007) found a positive connection between the research experiences and science researcher identity, intellectual development, skills, competence, interests in science, and refined career goals. Nagda et al. (1998) studied retention rates for STEM majors who participated in research experiences and reported positive impacts for undergraduates involved in research, particularly for African Americans. In a study of self-reported data from minority students who participated in summer research through McNair, a federally-funded program to assist first-generation students and individuals from underrepresented groups on the path towards a doctoral degree, Strayhorn (2010) reported that research played an important role; nearly every minority student (96%) shared that their summer experience conducting research "encouraged," "sustained," or "increased" their STEM-oriented aspirations (Strayhorn, 2010).

Takeaways

After reviewing the literature on research experiences and students' gains in research skills, confidence and self-efficacy for research, and in STEM-oriented aspirations, particularly for underrepresented students in STEM, several questions remain. Are these programs simply providing a great experience for students who have already decided on graduate school and careers in STEM prior to participating, or are they helping those who may not have otherwise had an opportunity to be exposed to the world of STEM, like many underrepresented minority students? To what extent are these programs helping students create a vision of their future selves in STEM? Finally, what are the mechanisms within these programs that give rise to the important gains described in the literature and how can these best practices be replicated?

2.6. Research Experiences: Prior Studies that Investigate Mechanisms in the Black Box

Most studies reviewed in the literature focus mainly on output variables, like gains in research skills or career aspirations, that result from participating in undergraduate research experiences. Few, however, look at the mechanisms within these programs that support students' development of research skills, confidence and self-efficacy for research, or at the process by which students formulate ideas about their future selves in STEM, especially for those from minority groups (e.g. Adedokun et al., 2012; Adedokun & Burgess, 2011; Taraban & Blanton, 2008). Which implementation agents within programs are most effective for leveraging gains in the types of skills and attributes important for success in STEM?

Four indicators that allude to mechanisms that led to gains in students' STEM-oriented aspirations were displayed in Adedokun et al.'s (2013) study: (1) access to professional and academic networks and relationships, and community support; (2) gains in research confidence and the development of researcher identity; (3) opportunities to participate in research presentations and/or publications, and (4) access to awards/fellowships and letters of recommendations from faculty mentors. For programs that have a research component, access to professional opportunities (research, publication, presenting, and working professionals who modeled norms) were identified as important for minority students in several other studies (Gandara & Maxwell-Jolly, 1999; Summers & Hrabowski III, 2006; University of Maryland Baltimore County, 2016).

A body of research unveiled a few successful implementation mechanisms, however these were in year-long programs that extended across a students' entire undergraduate career (e.g. Bauer & Bennett, 2003; Jones, Barlow, & Villarejo, 2010; Terenzini, Yaeger, Bohr, Pascarella, & Amaury, 1997). One example is the Meyerhoff program, which is committed to involving students in research as early as possible. One mechanism in this program is offering students the opportunity to work alongside the "most effective" research faculty (Carter, Mandell, & Maton, 2009; Maton, Hrabowski, & Schmitt, 2000; University of Maryland Baltimore County, 2016). Other practices that were particularly beneficial were the organized monthly group activities (e.g. outings and team travel to conferences), which provided formal and informal time for students to get questions answered, bond with one another and program mentors, and build friendships (University of Maryland Baltimore County, 2016).

Gandara and Maxwell-Jolly (1999) reviewed twenty programs for minority students, including Meyerhoff, and identified five key mechanisms that wove across each: (1) mentoring, (2) financial support, (3) academic support, (4) psychological support, and (5) professional opportunities. Other studies have revealed successful best practices that lead to important gains, such as peer-to peer mentoring through formal (e.g.

cohorts) and informal channels (e.g. study groups, cohort grouping through shared-housing or laboratory assignments) (e.g. Bauer & Bennett, 2003; Hunter et al., 2007; University of Maryland Baltimore County, 2016). Researchers identified mentoring younger students from nearby grade schools supported content knowledge development, agency, and a sense of ownership in undergraduate STEM majors (Gandara & Maxwell-Jolly, 1999; University of Maryland Baltimore County, 2016).

Though some studies exist that unpack the mechanisms within programs that give rise to important gains, the field has yet to identify and extend best practices so that more students are afforded access to powerful learning opportunities. The purpose of my dissertation is to begin small, by illuminating what Markus and Nurius (1986) refer to the "models, images, and symbols" that resulted in students' self-reported gains in research skills, confidence and self-efficacy for research, and research aspirations within a single REU program at the University of Vermont.

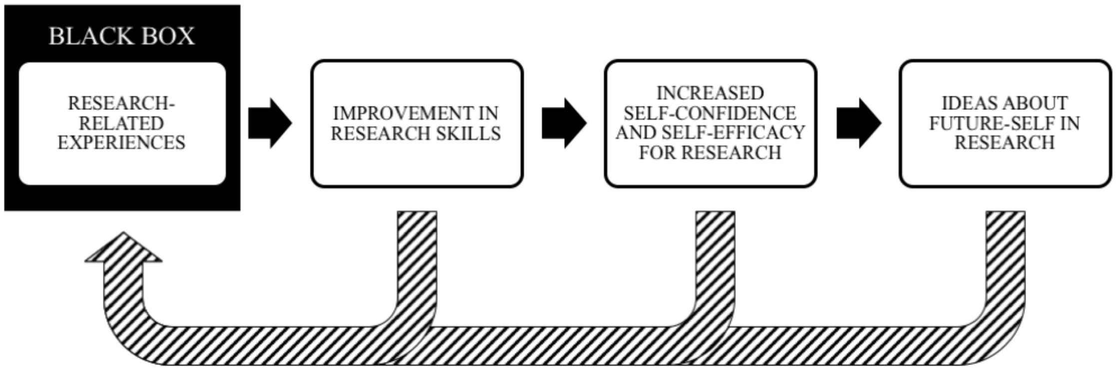
2.7. Theoretical Framework

> We guide our boys and girls to some extent through school, then drop them into this complex world to sink or swim as the case may be. Yet there is no part of life where the need for guidance is more emphatic than in the transition from school to work,—the choice of a vocation, adequate preparation for it, and the attainment of efficiency and success. (Parsons, 1909, p. 3)

While the process of guiding youth into careers can be traced back to the fifteenth century, more organized efforts to transition students from school to work did not emerge until the late 1800s (Brown, 2002). Social reformer Frank Parsons' seminal work on trait-and-factor-theory advocated for active engagement in choosing a vocation (Parsons, 1909). This early work is the foundation for many social theories of today. To guide the process of uncovering the mechanisms that resulted in students' self-reported gains in research skills, confidence and self-efficacy for research, and career aspirations in STEM, my study stitched together components of three theories to use as a framework: the theory of possible selves (Markus & Nurius, 1986), the theory of self-efficacy (Bandura, 1977; Caprara et al., 2008), and the social cognitive career theory (Lent et al., 2005; Lent, Brown, & Hackett, 2000, 2002).

Taking a backwards design approach, I identified key outputs which were then were used as indicators to understand the mechanisms (e.g. experiences or contexts) responsible for catalyzing or supporting that output. Three key outputs, (1) improvement in research skills, (2) levels of self-confidence and efficacy for research, and (3) changes in career aspirations, were identified from the literature on research experiences and from elements of each of the three social theories (theory of possible selves, theory of self-efficacy, and social cognitive career theory) (Figure 2). These theories helped pinpoint key variables (e.g. confidence with research) that were reinforced, enhanced, or fostered to shape students' ideas about what Markus and Nurius (1986) refer to as a possible- or future-selves.

Figure 2: The conceptual framework used three output areas (research skill improvement, self-confidence and self-efficacy for research, and conceptualizations of future-self) to trace back to the research-related experiences that gave rise to these outputs.



The theory of possible selves. In the 1980s, Markus and Nurius (1986) developed the theory of the "possible self," which offers a way to conceptualize the components that go into how individuals think about their past, current, and future selves. The authors asked over 200 college students about the role possibility played in defining their concept of self. Students had to respond to a list of words, mainly adjectives; one group of words in this survey included occupation-related images (e.g. scientist) and the other was connected to externally tied possibilities (e.g. needing/wanting to being appreciated by someone *else*). Students were asked to share whether the term: (a) described them, (b) if they would consider that as a possibility for them, and (c) how much they wanted the descriptor to be true. Many indicated meaningful endorsement of most of the questions, with a consistent bias towards the positive (Markus & Nurius, 1986).

To tease apart the role of the individuals' affect and motivational states, self-esteem, and perceived control in motivating the development of the sense of what is possible for themselves, Markus and Nurius' (1986) used stepwise regression with data from 136 individuals to study the interactions between the past, current, and future-selves. While past experiences influence the construction of one's future self, Markus and Nurius (1986) found that the current situation and construction of now self-motivated belief about what was possible for the future self, along with the level of importance assigned to that possibility. As social circumstances vary, new content can impact the current and future self-constructs. Situations that purposefully activate or elicit a thought, feeling, or experience may spark new notions about what is possible and may even result in action, change, or development (Markus & Nurius, 1986). How specific contexts empower individuals' current selves, such that they can imagine their future self within the world of science, is an important consideration for universities trying to recruit and retain STEM majors in the field (Dahlberg, 2001; Halstead, 1997; Hathaway et al., 2002; Kardash, 2000).

Markus and Nurius (1986) explained that the "pool of possible selves derives from the categories made salient by the individual's particular sociocultural and historical context and from the models, images, and symbols provided by the media and by the individual's immediate social experiences" (p. 954). Packard and Nguyen (2003) applied the theory of possible selves to science education. In their qualitative study of 41 adolescent girls and their images of themselves as "future scientists," Packard and Nguyen (2003) found that the individuals "negotiated career-related possible selves" when they were immersed in career-oriented internships with mentors (p. 251). Though research connecting this framework to science is scant, findings from Packard and Nguyen (2003) suggest that this theory is transferrable to STEM.

Self-efficacy and social cognitive career theory. Social cognitive career theory (SCCT) grew out of Bandura's (1977) seminal work with anxiety disorders and self-referent thoughts in guiding psychological functioning, motivation, and behavior (Lent et al., 1994). Eventually, Bandura's work extended beyond phobia and trauma to a co-authored analysis of self-efficacy in education with Caprara et al. (2008). Their study found a mediating effect of perceived self-efficacy for learning on academic achievement (Caprara et al., 2008). Like Caprara et al. (2008), developers of SCCT (Lent et al., 2002) emphasized the importance of (a) personal agency, (b) extra-personal factors (e.g. context and support systems), and (c) experiential factors, which enhance or constrain the formation, elaboration, and/or persistence of career interests and pursuits (Lent et al., 1994).

To consolidate the many competing explanations surrounding the process of career identification and choice, Lent, et al. (1994) conducted a meta-analytic review to theory-test several constructs and to identify the sociocognitive factors and mechanisms, including academic, that shape career-related interests and decisions for individuals in late adolescence and early adulthood. The meta-analysis found that the byproduct of the interaction between individuals and their environment is behavior (Lent et al., 1994). The interaction is multidirectional and dynamic—people can influence their environment and their environment can influence thought (Lent et al., 1994). The three main social cognitive mechanisms relevant to career development are: (1) self-efficacy, (2) outcome expectations, and (3) goal setting (described in detail in Table 1). Lent et al. (1994) wrote that "through repeated activity engagement, modeling, and feedback from important others, children and adolescents refine their skills, develop personal performance standards, form a sense of their efficacy in particular tasks, and acquire certain expectations about the outcomes of their performance" (p. 89).

Studies show that research experiences expose students to a wide variety of activities within the context of a research environment (e.g. Beninson, Koski, Villa, Faram, & O'Connor, 2011; Halstead, 1997; Thiry, Laursen, & Hunter, 2011), but which of the many activities provide the opportunity for STEM students to enhance agency as they form their interests, career expectations, and goals? Do these situations offer "repeated successful task experiences that have been reinforced and performed under conditions of varying challenge" (Lent et al., 1994, p. 102)?

Table 1: Social-cognitive agents that help shape the career development process (Lent et al., 1994).

Mechanism	**Description**	**Example of Self-Talk**
	PRIMARY LAYER	
Self-efficacy beliefs	The dynamic set of self-beliefs of capabilities (non-objective assessed skills) and capacity to realize goals. These are dynamic and change depending on environmental factors (e.g. situations and experiences that offer feedback). Self-efficacy beliefs are influenced by: (1) personal performance, (2) vicarious learning (observing others succeed/fail), (3) social persuasion, and (4) physiological states and reactions (e.g. feelings of exhilaration when performing a task). The ever-present contextual features, like family background or discrimination, may play a key role in self-efficacy beliefs, many of which vary across time.	"Can I do this?" or "I can do this!"
Outcome expectations	Beliefs about what is possible and imagined consequences, both intrinsic and extrinsic.	"If I do this, what will happen?"
	Self-efficacy → Outcome expectations → Formation of interests	
Goal setting around specific interests	The decision to engage in an activity to move towards a desired future outcome, which is often derived from a combination of personal experiences and values. Interests are influenced by relevant abilities but this is mediated by self-efficacy beliefs.	"I want to learn how to ___ because I am interested in becoming a scientist."

Lent et al. (1994) explored the psychological and social role that race, ethnicity, and gender play in career development, and the reactions the perception of race, ethnicity, and gender evoke within the sociocultural environment. Minority groups often perceive and/or experience discrimination in certain career-related contexts, and the field of STEM is no exception (e.g. Hurtado et al., 2008; Kardash et al., 2008; Packard, 2016). Access to career-related experiences is limited for certain groups, which results in an "internalization of these forces" (Lent et al., 1994, p. 105) and diminishes self-efficacy and outcome expectations. Admittance to learning experiences is all too often mediated by gender, race, and ethnicity, which can be detrimental to the development of positive self-efficacy, outcome expectations, or visions of one's future-self (Lent et al., 1994; Markus & Nurius, 1986). Students from underrepresented minority groups in STEM must have exposure to both role models and emotional support (e.g. scientists in a field of interest) (Fortenberry, 2016; Hurtado et al., 2008; Packard & Nguyen, 2003). They also must have access to financial support, such as stipends or grants, needed for conducting research (Fortenberry, 2016; Hurtado et al., 2008; Packard & Nguyen, 2003). Combined, these opportunity structures play a critical role in self-efficacy and outcome expectation formation (Fortenberry, 2016; Hurtado et al., 2008; Packard & Nguyen, 2003).

2.8. Conceptual Framework

The combination of Markus and Nurius' (1986) theory of possible selves, the self-efficacy theory, and the social cognitive career theory (Lent et al., 1994) guided the explorations into program-specific mechanisms that supported students' process of forming interests, making choices, and achieving success in the Lake Champlain REU program. These theories helped pinpoint key variables (e.g. confidence with research,) that were reinforced, enhanced, or fostered to shape students' ideas about what Markus and Nurius (1986) refer to as possible- or future-selves. The first theory helped with pinpointing mechanisms within the "immediate social experience" of the REU that influenced students' formation of ideas about their future selves. The second theory, self-efficacy (Caprara et al., 2008) for research, guided the research towards evidence of students' beliefs in their abilities to succeed at research and how these beliefs related to the likelihood that they could see themselves in that role again in the future. The third theory, social cognitive career theory (Lent et al., 2005, 2000, 2002), highlighted the importance between the development of interests and the act of making choices regarding one's future. Conceptually, this tri-legged framework offered a fresh look at the mechanisms within research experiences that impact underrepresented minority STEM students and explored ways to apply these understandings in other settings.

2.9. Justification for this Research

The findings from my studies will contribute to the growing understanding of the complex processes that happen within research experiences. The Lake Champlain REU program was unique in that it: (1) admitted a large proportion of students who were underrepresented minorities in STEM, and (2) was interdisciplinary in nature. The process of approaching research on REU programs from a new angle that intentionally investigates the mechanisms within the programs that support STEM students is important. My grand vision is that once the mechanistic archetypes are identified and evaluated, they may be refined, expanded, replicated, and applied more broadly, such that this model of learning becomes the norm.

.

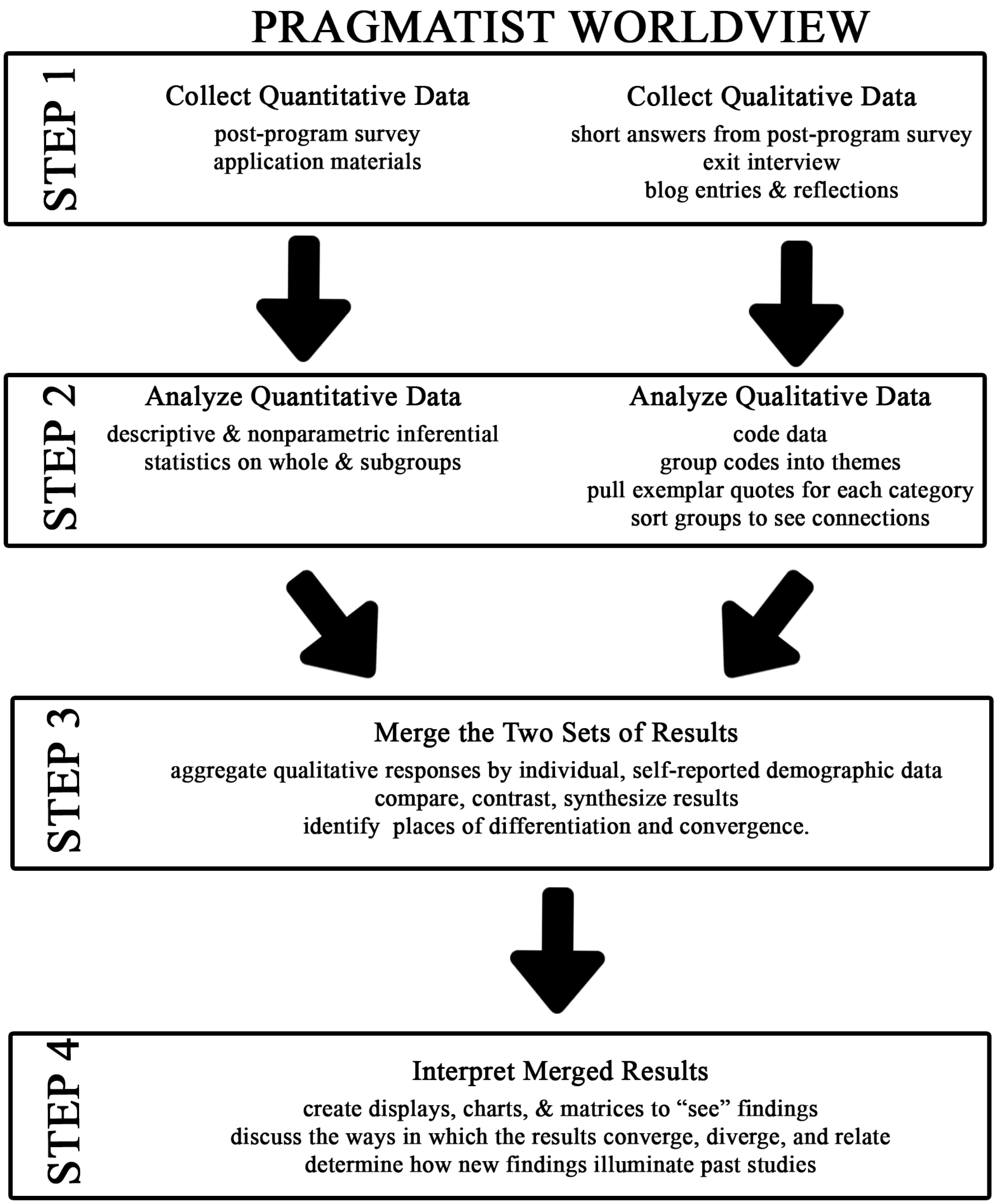
CHAPTER 3: COMPREHENSIVE RESEARCH DESIGN

3.1 Research Design

The purpose of my dissertation was to illuminate what Markus and Nurius (1986) refer to “models, images, and symbols” that resulted in students’ self-reported gains in research skills, confidence and self-efficacy for research, and research aspirations within a single Research Experiences for Undergraduates (REU) program at the University of Vermont (UVM). A convergent parallel mixed methods design was used because it provided an opportunity for qualitative data to compliment and illuminate the quantitative descriptive statistics (Plano Clark & Creswell, 2011). Mixed methods research combines research design with a philosophical worldview and theoretical lens (Plano Clark & Creswell, 2011). Quantitative and qualitative data was needed to access and unpack programmatic contexts that led to student gains (Small, 2011). The heart of my dissertation was pragmatic—with an aim to find what worked or what is useful in the real world of REUs (Plano Clark & Creswell, 2011; Small, 2011).

Both the quantitative and qualitative data were collected concurrently, and equal priority was given to both (Figure 3) (Plano Clark & Creswell, 2011). Each phase was independent of the other and the mixing of the data occurred during analysis and interpretation (Plano Clark & Creswell, 2011). The quantitative results were enhanced by the qualitative findings when, together, they were synthesized to capture the most complete description of students’ experiences.

Figure 3: Flow chart depicting the four steps of the convergent parallel mixed methods design.



3.2 Research Site

The research for my dissertation was conducted at UVM with two cohorts of participants from the REU: *Interdisciplinary Research on Human Impacts in the Lake Champlain* program. Over the course of 10-weeks during the summer, students designed, proposed, and conducted original research on important issues concerning Lake Champlain. In addition to the traditional research experience, students participated in "Thinking Like A Scientist" programming, where they attended short, weekly learning modules that covered foundational, capacity-building topics. Material ranged from critical reading and scientific writing to navigating graduate school and writing cover letters. Students also participated in a weekly journal club on the interdisciplinary approaches to research, and after dinner seminars held by mentors and university faculty who informally discussed their career paths. Each summer concluded with a formal presentation of student research and, in some cases, presentations at professional conferences or the submission of a manuscript. The program had four goals:

1. Provide interdisciplinary research experiences for undergraduates, including those from underrepresented groups;
2. Increase students' understanding of and capacity for conducting independent research; prepare rising 3rd and 4th year students for graduate school and rising 1st and 2nd year students for advanced undergraduate research;
3. Provide hands-on, research assistant experiences for local high school students including individuals from underrepresented groups; and
4. Develop communication and mentoring skills for REU participants when working with each other and with high school students (University of Vermont, 2016).

3.3 Participants

Students were recruited and selected into the Lake Champlain REU program based on strict criteria. Ten students each year were chosen from a national pool of applicants (Lake Champlain REU received 160 complete applications in both years). Recruitment efforts targeted students who self-identified as being from the following groups: Black, Hispanic, and American Indian, female, first-generation to attend college, Pell-eligible, persons with disabilities, rising first and second year students, and students from institutions with limited research opportunities. The program worked with Vermont Experimental Program to Stimulate Competitive Research's Center for Workforce Development and Diversity at St. Michael's College and forged partnerships at the national level to establish a network to meet the recruitment goals.

The application included voluntary, self-reported demographic information (including gender, ethnicity, race, first-generation status, and Pell-eligibility status), academic background, an essay component, project and mentor references, and two letters of recommendation. Applications were aggregated into two groups: (1) rising first and second year students and, (2) rising third and fourth year students. Initial screening was conducted by the Lake Champlain REU principal investigator (PI) who selected the top 50% of applicants based on specific criteria outlined in their application essays, academic records, and letters of recommendations. The top applicants from each group were forwarded to a selection committee of two faculty members and one post-doc or graduate student to select the top 10 candidates. Any applicant that made top five list for all three committee members was placed in potential acceptance pool for review and discussion. After discussion, each committee member ranked their top five remaining applicants and had the opportunity to argue for or against the rank order. The committee debated the merits of the applicants' rankings, and pondered whether the candidates who were not ranked high as others might bring something interesting program before arriving at a consensus of final rankings. With consensus on the top-three students per project, phone interviews were conducted by mentors. Names of candidates were then forwarded to the PI who made the final decision. Offers were presented and a waiting list was created in the event an applicant rejected the offer. This process was repeated until all ten positions were filled.

Seventy percent of the whole cohort (N=20) from both summers (2014 and 2015) self-identified as women, 15% as Hispanic or Latino/a, and 15% as Black or African American. Of the remaining students, 65% self-identified as White and 20% as Asian. Over half (60%) of the participants self-reported low-income status, as determined by Federal Pell grant eligibility. One quarter (25%) of the participants identified as first generation in their family to attend college. Participants were enrolled in a wide variety of majors and double majors at their undergraduate institutions that ranged from biology and environmental sciences to psychology and physics. The motivations participants selected in the exit survey for pursuing a research experience at UVM are detailed in Table 2.

Table 2: Motivation to pursue Research Experience for Undergraduates at UVM.

	% Yes
Gain hands-on experience in research	100%
Clarify which field I wanted to study	100%
Have a good intellectual challenge	100%
Enhance my resume	100%
Explore my interest in science	90%
Clarify whether graduate school would be a good choice for me	85%
Clarify whether I wanted to pursue a science research career	85%
Participate in a program with strong reputation	70%
Get good letters of recommendation	70%
Work more closely with a particular faculty member	65%

3.4 Data

My study used self-reported, retrospective quantitative and qualitative data from two cohorts of undergraduate students (*N*=20). Data were concurrently collected in the summers of 2014 (N=10) and 2015 (N=10) from self-reported post-program survey, focus-group interviews, the program's blog, and individual student reflections from four students who mentored high school students. Additional data sources included: application information and a detailed program schedule for both summers with descriptions of all sessions. All participants were invited and highly encouraged, via an online message and in person, to complete the questionnaire, write blog entries, and participate in the focus group interviews.

An online survey was developed and first employed in the summer of 2014. On the day before the last day of the program, each student received an email with a name and password to access a comprehensive, modified version of the post-survey instrument that evaluates student outcomes of research experiences in the sciences (Table 3). The Undergraduate Research Student Self-Assessment (URSSA) is required for NSF-sponsored REU programs. In addition to Likert-scale questions, the survey contained short-answer/open-ended questions.

Table 3: Overview of the categories of questions on the Undergraduate Research Student Self-Assessment (URSSA).

Question Category	Description of Category
Gains in application of knowledge of research work (i.e. thinking and working like a scientist)	Eight questions on a 5-point Likert scale (no gains to great gain) covered general and specific gains in skills and knowledge related to research (e.g. analyzing data for patterns, figuring out the next step in a research pattern, problem-solving in general, etc.).
Personal gains related to research work	Nine questions, on the same 5-point Likert scale (no gains to great gain), inquired about personal gains related to research work (e.g. confidence in ability to do research, contribute to science, do well in future science courses, etc.).
Gains in skills	Thirteen questions, on the same 5-point Likert scale (no gains to great gain), regarded gains in skills (e.g. writing scientific reports, conducting observations in the field, using statistics to analyze data, etc.).
Changes in attitudes or behaviors as a researcher	Eight questions required answers on a 4-point Likert scale (none to a great deal) that explored the extent to which students perceived changes in attitudes or behaviors as a researcher (e.g. engage in real-world science research, feel like a scientist, feel part of a scientific community, etc.).
The research experience	Six 4-point Likert scale (poor to excellent) questions asked participants about their research experience (e.g. the working relationship with the mentor, the amount of time spent doing meaningful research, the advice the mentor provided about careers or graduate school); this section had a short answer text box where students were invited to elaborate on their answers.
Accomplishments	Ten questions where students indicated their accomplishments (yes/no) from participating in the REU. These ranged from presenting a talk or poster to students and faculty to co-writing a paper to attending a conference.
The impact of the REU on future plans	There were several sections that addressed students' perception of the impact of the REU on their future plans. In one section, students responded using a 5-point Likert scale (not more likely to extremely more likely) on a series of questions regarding their future educational and career plans (e.g. enroll in a Ph.D. program in science, mathematics or engineering, pursuing certification as a teacher, working in a science lab, etc.). This section had a short answer text box with the following prompt: "Please state your intended degree and, compared to your intentions before doing research, how likely you are now to enroll in a graduate program leading to an advanced degree." An open textbox was available for students to add any "other gains" that were not already covered. The section concluded with a question addressing specific graduate school and career activities, where participants responded to a 4-point Likert scale (not at all to a great deal).

(Continued on next page.)

Question Category	Description of Category
Satisfaction with the experience	Twelve questions asked students for information on their level of satisfaction (4-point Likert scale, very dissatisfied to very satisfied) regarding specific aspects of the program (e.g. support or guidance from research mentor, financial support, research group meetings, etc.). The survey included specific questions about support with regards to training sessions (4-point scale, not at all to a great deal) (e.g. how much workshops on science writing, ethics, and safety supported learning.) One question asked about the amount of time students spent working on research-related activities and the number of hours on average per week spent talking with mentors. One question inquired about how important the stipend was in allowing the student to conduct research.
Motivation for pursuing Lake Champlain REU	Thirteen questions regarding motivation for research, 11 were yes/no and three were Likert scale ranging from not at all to a great deal. Responses ranged from "gain hands-on experience in research" to "enhance my resume."
Suggestions for program improvement	There were short answer sections where students could provide suggestions to improve the program and their personal research experiences.
Prior experience in research	One section asked participants to select the number of summers they had conducted research in the past (never to three summers).
Demographic information	The survey concluded with self-reported demographic information, including academic major/minor, year of study, gender, race, and ethnicity.

On the final day of the program, all students participated in a 45-minute semi-structured focus group interview in groups of three or four students. The focus group interview questions were pre-written, though flexibility to add or change questions was reserved, as needed, to follow interesting threads. Interview questions covered the following topics: (1) most significant gains, (2) feedback on the interdisciplinary focus, (3) the level of instruction and direction provided by mentors and staff, (4) the ways in which the experience differed from expectations, (5) whether students would recommend the Lake Champlain REU to others, (6) advice for future cohorts, and (7) open comment time. Interviews from both groups were conducted, digitally recorded, and later transcribed verbatim by the researcher.

For the blog, the program director prompted the students to write about how they were feeling and expectations for the program in the first week. In subsequent weeks, students were invited to reflect on how things were going, particularly in respect to their previous posts. On the last day, I invited the four students who mentored high school students form UVM's Upward Bound Program to write a short reflection on this aspect of their program experience.

3.5 Data Analysis

Quantitative and qualitative data were analyzed according to a backwards design (of tracing outcomes back to the black box, Chapter 1, Figure 1), and the meta-categories presented within the conceptual framework (Chapter 2, Figure 2). Quantitative and qualitative data were analyzed separately and then merged (Figure 3, steps two through four). The following questions guided this analysis process:

1. How do participant responses from the interview and short answer sections of the survey help illuminate the quantitative group data?
2. What did students say about particular contextual experiences that may illuminate the outcomes they describe in their post-survey responses?

Data from each instrument were catalogued based on student ID and uploaded into the mixed methods tool in HyperRESEARCH for coding. All identifying names were replaced with pseudonyms. The transcription protocol captured exact words used by participants, but removed all "uhs," "ers," and pauses, except in the instances where meaning would have been lost (Miles & Huberman, 1994; Plano Clark & Creswell, 2011). The interview transcripts were aggregated by individual participant and linked to self-reported demographic information. Cleaned data were read and re-read to get an overall sense of themes, ideas, and questions (Miles & Huberman, 1994).

Short answer response data were analyzed with qualitative coding techniques. The provisional start list of codes (Table 4) was established based on a combination of (1) the literature on STEM career aspirations, (2) the concept of the black box, (Chapter 1, Figure 1), (3) the meta outcome categories (research skills, confidence and self-efficacy for research, and career aspirations—Chapter 2, Figure 2), and (4) the three theories that undergirded the research (theory of possible selves, self-efficacy for research, and social cognitive career theory), (Hsieh & Shannon, 2005; Miles & Huberman, 1994). Sub-codes were made as needed, and everything was re-read and re-coded when new codes emerged (Miles & Huberman, 1994).

Table 4: Summary of start codes and emergent sub-codes.

Start Codes	Emergent Sub-codes

Self-concept or possible-selves exploration	Student unsure about post-undergrad educational path
	Program sparked new thinking about future plans
	    Student contemplates doing what you love, follow your passions and dreams
	Describes dissonance re: world of research and actual research
	Student experienced dissonance about future before-after REU
	Plan to pursue advanced degree
	    Student plans to pursue post-undergrad STEM
	    Student mentioned master's degree
	    Student mentions Ph.D.

Career-related experiences	Student mentions career-related research work
	Interdisciplinary approach provided participant access to new fields.
	Research experience prepared student for post-undergraduate path Student experienced "life of the scientist"
	    Student sees self as researcher
	    Student gained insight into of the world of research
	REU experience ignited excitement to conduct research

Exposure to vocational or post-undergraduate options	Program increased awareness about STEM careers
	    Student received general advice from mentors
	    Student described takeaways from dessert seminars
	    Student learned about career options through interactions w/ professionals
	Student gained info about graduate school

Changes in vocational commitment as a result of the internship experience	Student describes increase in STEM-related interests after REU
	    Program helped solidify future plans
	    Student plans to pursue post-undergrad STEM and credits REU
	Decrease/no effect in STEM-related interests after program
	Student plans to take "time off" between pursuits

All data were coded and grouped according to theme (Table 5) and were displayed with exemplars that offered descriptive evidence to support, contradict, or extend the theories identified in the literature (Hsieh & Shannon, 2005). Data were displayed in such a way that I could compare the quotes with statistics (percentages, means, standard deviations) with the responses to the quantitative questions.

Table 5: Final themes and with sub-theme codes.

Career-related experiences: explored, considered, or affirmed future education or career plans	
	Challenge-confusion
	Independence and ownership for the work
	Leadership
	Perseverance –persistence
	Preparedness – goal setting
	Support: mentoring and advising
	Workshops and seminars
	World of research ah ha
Career-related experiences = increases in confidence	
Research Skills: students honed research skills	
	Collaboration
	Communication
	Excitement for research
	Expectations
	First time
	General
	Importance of exploration
	Interdisciplinary
	Independence
	Past experiences
	Preparedness
	Problem solving
	Reading and understanding research
	Technical (specific laboratory skills)
	Time/Project management
Improvement in research skills = increases in confidence	
Overall	
Program expectations-exceeded or did not meet	
Changes in confidence and self-efficacy for research	
confidence was mentioned and pride	
Future self: plans for graduate education or a career, and details connected to that transformation.	
	Preparedness
	Value of future-self exploration
	More knowledgeable of opportunities
	Plans (including pre-post reflection on those plans), expectations, confirmations

3.6 Ethics and Political Considerations

To ensure that I was sensitive to the needs of my participants, the site I was working with, various stakeholders, and the publishers of research, I adhered to the following ethical and policy considerations, listed in order of research phases (Creswell, 2013).

- **Pre-research.** Prior to the study, I got approval to conduct the research from the university and the program director, as well as voluntary permission from participants. A submission was made to the university's Institutional Review Board on Human Subjects Research and was returned with the status of exempt (Creswell, 2013).
- **Research.** Throughout the data collection process, participants were aware of the purpose of the research. Students were invited to participate via an online email as well as through verbal communication and were given time to complete the surveys, blog entries, and exit interviews. I did my best to respect the potential power imbalances by building trust and providing rewards (mainly through homemade baked goods) for participating (Creswell, 2013).
- **Data analysis.** I protected the identity and privacy of the students by assigning aliases and developing composite profiles. I did my best to identify and report the multiple perspectives of the students (Creswell, 2013).
- **Publishing.** I will share my data with others and provide copies of the final dissertation to participants and stakeholders, and I will pursue publishing in a peer-reviewed journal. I will give credit for work done on the project and co-decide on author order, if needed. I will disclose the funders for this research (Creswell, 2013).

3.7 Personal Bias/Subjective I

Like all research, I bring positionality to my studies, and reflecting on this bias is important. My interest in the experiences of underrepresented individuals in STEM was fed by the fact that I personally identify as an underrepresented minority in STEM. I am a White female who studied science and taught high school science for nearly ten years before pursuing my Ph.D. The only child in my family to continue education beyond high school, I am particularly drawn to first-generation college students and their stories, and this biases my lens, as I tend to favor those who have overcome all that comes with being first generation to go to college.

McIntosh's (1988) writing on privilege helped me identify many of the advantages I carry around in my "invisible knapsack"—although I find more as I continue to grow and look inward. I am the oldest child from a strong-minded farming family from northern Vermont. My upbringing instilled a solid work ethic, an insatiable curiosity, and an intrinsic drive to improve. Almost everyone in our small town hailed from European ancestry, though there were exceptions, like my one friend from kindergarten, Grace, who had bi-racial parents. Many in my community were not very religious, my family included. Some in our town attended either the Catholic or Protestant church or one of the synagogues in the neighboring city of Burlington.

An uncle in the navy sent me dolls from his voyages around the world, which sparked my deep interest in collecting stories and learning all I could from people who were raised in culturally different places. This sparked years of pen pal correspondence with children throughout my adolescence, and we quickly became known as the family who hosted dozens of foreign exchange students. From age twelve on, my parents scraped together the means to send me to many of my friends' homes outside of Vermont. I traveled to places like Estonia and Germany, studied in Mexico and Finland, and, as a high school teacher, took my students on service-learning trips to Ecuador and Belize.

I remember my childhood and adolescent years filled with many deep friendships, a close family, and an insatiable love for nature and school. A social learner, I immediately embraced all that my rural public school had to offer. A pleasure and a privilege to attend school, I looked forward to it each day. Though I had to work very hard to do well, the support from my parents and my intrinsic drive, tenacity, and curious nature kept me positive and enabled me to thrive. My upbringing instilled a sense of resourcefulness and a determination never to give up, to always seek help, and to push myself.

In high school, I realized that I was a bit of an anomaly. As I got older, I started noticing that most of my classmates, and eventually my younger siblings, did not seem to enjoy their school days. In fact, at age seven or eight, my twin brothers came home day after day hating school. By early adolescence, I realized that my life experiences up to this point had tainted the way I viewed the world—particularly school. I took for granted that everyone loved school and was shocked when I realized this was a gross misconception. Questions about the role and purpose of school, and the spectrum of ways it impacts children's intrinsic curiosity, sprang forth in conversations with high school and then college classmates, teachers, and administrators, as well as with my parents, as I began to wonder what would happen to those for whom school was not a pleasure.

These queries were seeds that have grown into my research interests today. Throughout my master's program, during my tenure teaching high school, and most recently in my doctoral program, the following questions have remained on the forefront of my mind: Why does school work for some and not for others? What educational choices do students have and how do they decide what path they will venture on? Why do some students have voice and agency while others are left to drift, unsupported?

My background experiences have instilled in me a devotion to do things better for students. I believe that education is source of empowerment, freedom, upward mobility, a strong democratic society, and individual and collective inspiration and innovation. I am drawn to opportunities to study experiences that challenge students to engage in cooperative problem solving around authentic, community-based, real-world dilemmas that *students themselves* care about. I value experiences where members participate in a true democracy and curricula is exploration-based, interdisciplinary, and co-led by students, experts, and educators alike. My positionality towards wanting to see programs like the Lake Champlain REU succeed is strong, because the Deweyan part of me believes so deeply in this model. To mitigate the bias towards wanting to see good outcomes from my study, I checked for internal validity and maintained as much objectivity as possible.

3.8 Validating Data Findings

There are several strategies I employed to promote validity in my analyses (Johnson, 1997). These included:

- Researcher as detective: I developed an understanding of the data through a systematic search for evidence of cause and effect;
- Extended fieldwork: data were collected over an extended period of time (two summers);
- Low inference descriptors: I captured participants' accounts verbatim, as often as possible, to maintain validity in descriptions;

- Data triangulation: I validated, to the greatest extent possible, findings with data from multiple sources (e.g. surveys, focus group transcripts, blogs, etc.);
- Methodological triangulation: my study used mixed methods research methods to study the phenomenon;
- Reflexivity: I continually engaged in critical self-reflection regarding my biases and predispositions, which may have affected the ways I conducted the research. I tried to avoid "finding what [I] want[ed] to find" (Johnson, 1997, p. 3).

3.9 Limitations

The intention of my dissertation was to illuminate the programmatic elements that students identified as promoting an increase in research skills, confidence and self-efficacy for research, and interest in and excitement to pursue post-undergraduate STEM vocations. The study was not meant to be confirmatory. Limited to 20 participants, applicants underwent a rigorous selection processes, at both the university and individual levels. The REU entry requirements at this and many universities were robust, thus, the data were derived from a select sample of self-promoting, high achieving STEM majors who were likely to have a high sense of self-efficacy and ideas about future-selves from the outset. Students and mentors hailed from a variety of socioeconomic, ethnic, and geographical backgrounds and disciplines; each conducted research with varying technical sophistication and goals. I did not control for the many influences that might account for student responses about perception of gains in self-efficacy for research and career choices (academic achievement, pre-college experiences and ideas about future-selves, family circumstances, etc.). Students' decisions to pursue STEM are influenced by a myriad of factors, including everything from family attributes and individual personalities to dynamic interactions with peers and professors (Abraham, 2002; Taraban & Blanton, 2008).

The study was conducted at one university setting and is not generalizable; there was no control or comparison group. The size and nature of the data did not allow for an empirical approach. My study was reliant on self-reported data, which could be problematic, as some respondents may have wanted to cast the program in a particular light and thus offered biased answers (Bauer & Bennett, 2008). I relied on data that was captured by a survey (some sections of which were validated), exit focus group interview responses, blog entries, and reflection pieces (Critcher & Dunning, 2009; Linn, Palmer, Baranger, Gerard, & Stone, 2015; Weston & Laursen, 2015).

CHAPTER 4: JOURNAL ARTICLE 1

4.1 Article 1: Research Experiences for Undergraduates Program: Career-Related Contexts to Support College STEM Majors on STEM Pathways

Abstract

The U.S. is working hard to attract and retain majors in STEM, however, President Obama's Council of Advisors on Science and Technology found only 40% of undergraduate STEM majors complete their programs. As colleges and universities compete for funding from the National Science Foundation-sponsored Research Experiences for Undergraduates (REU) program, the mechanisms within summer research programs that resonate most deeply with undergraduate STEM researchers are important to identify and replicate. Using the framework of the theory of possible selves, I used a mixed methods approach to explore an interdisciplinary, team-oriented REU program that served two cohorts of STEM majors (*N*=20) from a wide range of socioeconomic, ethnic, and geographical backgrounds. Self-reported data from a post-experience survey and focus group interview revealed three important contexts where REU participants had experiences that informed, encouraged, or reinforced their sense of self regarding their career aspirations: (1) experiential education through interdisciplinary research experiences, (2) programming that builds student capacity, and (3) being mentored and mentoring. Results from this mixed methods study cannot be generalized beyond the context of this REU, however, findings are in alignment with the body of research on the positive effects of REUs on STEM majors' current and future self-conceptions. Research experiences that purposefully incorporate implicit (informal conversations and experiences in research alongside researchers at varying stages of their careers) and explicit (post-undergraduate pathway seminars) aspiration-focused opportunities help demystify the world of research and clarify the various pathways to a future in STEM. My study revealed the importance of transparency of programmatic goals and approaches, as well as first-hand experiences, to dispel the often inaccurate preconceptions of the life of the researcher and to enlighten the pathway to post-undergraduate options in STEM.

Keywords: Research Experiences for Undergraduates; Theory of possible selves; STEM career development; Post-undergraduate options; Mixed methods research

Introduction

With climate change and globalization disrupting access to resources and patterns in fossil fuel use (Pelling, 2011; Princen, Manno, & Martin, 2015), a supply of talented, transdisciplinary-trained scientists is needed to study human influences on the biosphere

(Doney, 2010; Millennium Ecosystem Assessment, 2005; Sala et al., 2000). Despite a tripling of enrollment and graduation rates for postsecondary education over the last 40 years, the percentage of individuals graduating with STEM majors continues to decline (e.g. Duncan & Martin, 2010; Maltese & Tai, 2011; Rask, 2010). Many STEM professionals credit participating in undergraduate research for setting their scientific careers in motion (Laursen, Seymour, & Hunter, 2012). In 1998, the Boyer Commission called for more undergraduate involvement in faculty-mentored, authentic research (Boyer, 1998).

The National Science Foundations' (NSF) Research Experiences for Undergraduates (REU) program funds research opportunities for STEM majors to engage in active, relevant, ongoing research projects alongside researcher-role models (e.g. Hunter et al., 2007; Lopatto, 2007; Russell et al., 2007). REU programs offer undergraduates interested in STEM the unique blend of research experiences with faculty, post-docs, graduate students, and technicians (e.g. Hu, Scheuch, Schwartz, Gayles, & Li, 2008; Hunter et al., 2007; Lopatto, 2008). Programming includes professional development opportunities aimed at strengthening research knowledge and skills, as well as providing time to explore post-undergraduate pathway options within the field (e.g. Page et al., 2004; Russell et al., 2007; Seymour, Hunter, Laursen, & Deantoni, 2004). REUs are effective at attracting and retaining STEM majors and enhancing degree aspirations in STEM research (e.g. Adedokun et al., 2012; Hathaway et al., 2002; Strayhorn, 2010). Students who complete REUs leave with positive outcomes, like gains in research skills and dispositions necessary to pursue a future in STEM (e.g. Alexander et al., 1998; Bauer & Bennett, 2003; Page et al., 2004). These programs "blur the interface between teaching and learning," are highly motivating, and leave many participants with a sense of belonging or membership within the discipline (Hakim, 1998, p. 189).

Colleges and universities interested in supporting early opportunities for undergraduate research can apply for funding from the NSF's REU program, though acceptance rates hover around 25% (National Science Foundation, 2016). As more institutions compete for REU funding, understanding the programming elements that promote an interest in and foster a desire for STEM majors to complete their degrees and pursue post-undergraduate education is needed (e.g. Bauer & Bennett, 2003; Jones et al., 2010; Thiry et al., 2012).

Purpose

I investigated the self-reported gains in understandings of and attitudes towards post-undergraduate education in STEM for two cohorts of undergraduates (*N*=20) who participated in the REU program: *Interdisciplinary Research on Human Impacts in the Lake Champlain Ecosystem.* Quantitative and qualitative data were analyzed through the lens of Markus and Nurius' (1986) theory of possible selves, a framework that helped identify the contexts within the many Lake Champlain REU program offerings that resulted in students' self-reported changes in post-undergraduate educational aspirations. My study was guided by the following research question: What did participants identify in the self-reported survey and exit focus groups as important programmatic contexts (experiences, events, and situations) that helped them understand, conceptualize, and imagine or reinforce the image of their future selves in a STEM field, or not, after graduation?

The conceptual contribution of our study may help other research-oriented programs identify and develop similar contexts that afford undergraduate researchers with opportunities to construct, reconstruct, solidify, or reject their place in the world of STEM—opportunities that demystify the dynamic and often confusing pathway to a STEM-career (Lopatto, 2008). Empirically, my study adds to the research on the benefits of undergraduate research experiences on students' understanding of research and post-undergraduate STEM options.

Theoretical Framework

In the 1980s, Markus and Nurius' (1986) developed the theory of "possible selves," which offered a way to conceptualize the components that go into how individuals think about their past, current, and future selves. The authors asked over 200 college students about the role possibility plays in defining one's self concept. The questions, listed mainly as adjectives, were grouped into six domains. One included occupation-related images (e.g. scientist) and the other was to externally-tied possibilities (e.g. being appreciated). Students were invited to share whether the descriptor (a) described them, (b) was considered as a possibility for them, and (d) how much they wanted this descriptor to be true. Most respondents indicated meaningful endorsement of many of the questions, with a consistent bias towards the positive (Markus & Nurius, 1986).

To tease apart the role of the individuals' affective and motivational states, self-esteem, and perceived control in developing a sense for what is possible, Markus and Nurius' (1986) used stepwise regression with data from 136 individuals to study the interactions between the past, current, and future-selves. While past experiences influence the construction of one's future self, Markus and Nurius (1986) found that the current situation and construction of one's "now-self" motivated beliefs about what is possible for the "future-self," along with the level of importance assigned to that possibility. In other words, as social circumstances vary, new content may impact "current" and "future" self-constructs. Situations that purposefully activate or elicit a particular thought, feeling, or experience may spark new notions about what is possible and may even result in refinement of that concept (Markus & Nurius, 1986).

The specific contexts that empower individuals' current selves to imagine their future selves within the world of science is an important consideration for universities that are trying to recruit and retain STEM majors in the field. Markus and Nurius (1986) explained that the "pool of possible selves derives from the categories made salient by the individual's particular sociocultural and historical context and from the models, images, and symbols provided by the media and by the individual's immediate social experiences" (p. 954). I found only one study where researchers applied the theory of possible selves to science. Using semi-structured interviews to explore 41 adolescent girls' images of themselves as "future scientists," Packard and Nguyen (2003) found that students "negotiated career-related possible selves" when they were immersed in career-oriented internships with mentors (p. 251). I became curious about which experiences, events, or situations the Lake Champlain REU students had that fostered their interests in and knowledge about STEM fields and careers.

To gauge students' self-reported "now" selves within the field of STEM, the descriptive statistics and short answers from a pre-program survey were examined, and the analysis of post-programmatic student-reported data offered a peek into what students thought about their “future” selves in STEM (Markus & Nurius, 1986). The aim was to uncover specific mechanisms in the students’ immediate social experience that catalyzed the construction, reconstruction, solidification, or rejection of plans to pursue post-undergraduate STEM career pathways (Lopatto, 2008).

Review of the Literature

Research on research experiences for undergraduates is relatively new (e.g. Adedokun & Burgess, 2011; Taraban & Blanton, 2008; Villarejo, Barlow, Kogan, Veazey, & Sweeney, 2008) and many questions remain. When do undergraduate students decide to pursue STEM? Do students who participate in research experiences as undergraduates do so because they are highly motivated, self-selected individuals who are already committed to a research trajectory? If research experiences influence students’ career aspirations, to what extent do they influence students’ construction of their future self (Adedokun et al., 2012)?

Studying research experience programs is challenging as many programs have a limited number of participants and are isolated to individual colleges or universities. Participation is often voluntary, and those who are selected were often rigorously screened before acceptance. The competitive nature of REU programs poses a challenge when trying to determine causality, as it is virtually impossible to use a comparison group (Villarejo et al., 2008). Consequently, relatively few systematic studies of REUs exist (Adedokun et al., 2012; Villarejo et al., 2008).

Two controlled studies used longitudinal sampling and found that students who participated in undergraduate research experiences had higher rates of attending graduate school than students who did not participate (Bauer & Bennett, 2003; Hathaway et al., 2002), however, neither study accounted for pre-existing interests. Adedokun et al.'s (2012) qualitative study of career decisions for undergraduate researchers revealed that increased awareness of career options were enhanced by: (1) access to professional and academic networks and relationships, (2) community support; (3) gains in research confidence and the development of research identity; and (4) opportunities to participate in research presentations and/or publications, and (5) access to awards/fellowships and letters of recommendations from faculty mentors. A subsequent study found research skills and self-efficacy for research beliefs were important predictors of undergraduates' research career aspirations (Adedokun et al., 2013).

The most studied aspects of undergraduate research experiences include the impact on student skill development and career aspirations. Researchers document student gains in technical and research skills, which range from data analysis to specific laboratory-oriented skills, as well as improvements in the ability to think and work like a scientist (e.g. Bauer & Bennett, 2003; Hunter et al., 2007; Russell et al., 2007). Some demonstrate the impact of research on preparation for careers in STEM, like increased enthusiasm about academic disciplines and continued engagement in independent research and scholarly activities (Seymour, Hunter, Laursen, & Deantoni, 2004). Others found positive correlations with retention rates (Adedokun & Burgess, 2011; Nagda et al., 1998). Independent research and scholarly activities are also linked with increased student self-concept and self-efficacy, sense of belonging, ownership of discipline and commitment to the work, confidence in problem solving, independence, and ability to assume leadership positions (Hunter et al., 2007; Russell et al., 2007; Thiry et al., 2011). Adedokun and Burgess (2011) found the role of student pre-experience preconceptions about undergraduate research experiences, which included traditional stereotypical views of research environments as being "stern and devoid of social interactions," were dispelled after participating in a research experience.

The process by which benefits are derived from research programming often falls into the rather obscure realm of the black box (Grubb, 2009; Ladd et al., 1999; Tyack & Cuban, 2009). The default for most research is to use readily available input and output variables (e.g. participant demographics and post-experience academic achievement) to study programs, because teasing apart the within-experience mechanisms is more difficult (Grubb, 2009; Ladd et al., 1999; Tyack & Cuban, 2009). The aim of my study is to peel back some of the layers of the black box of one REU to reveal elements of the programmatic mechanisms that supported students' thinking about their futures.

Methods

The research commenced with an analysis of students' pre-program levels of confidence within the world of research—their technical and scientific skills, expectations and concerns about participating in the Lake Champlain REU, and their ideas about their futures. Using a mixed methods approach, post-program data were then analyzed to reveal programmatic mechanisms (experiences, events, and situations) that helped students understand post-undergraduate options.

Participants

The participants came to the University of Vermont (UVM) in the summers of 2014 and 2015. Twenty undergraduate students (10 per cohort) were selected from 320 nationwide applicants over two years. Seventy percent of the Lake Champlain REU participants self-identified as underrepresented minorities in science. Individuals who constitute smaller percentages of degree recipients and of employed scientists as compared to the whole population are considered underrepresented minorities in STEM; these include women, persons with disabilities, and three racial/ethnic groups, Black or African American, Hispanics, and American Indians. Seventy percent of our students self-identified as women, 15% as Hispanic or Latino/a, and 15% as Black or African American (Table 6).

Table 6: Summary demographics for REU participants.

Category	Self-Selected Yes
Underrepresented minority groups[1]	70%
Gender	
Women	70%
Race	
Asian	20%
Black or African American	15%
White	65%
Ethnicity	
Hispanic or Latino	15%
Pell Eligibility	
Eligible for Federal Pell Grant	60%
First Generation to Attend College	
Self-Identified as First Gen	25%
Primary Majors	Environmental Studies (2)
Animal Sciences (1)	Environmental Sciences (6)
Aquatic Biology (1)	Environmental/Civil
Biology (6)	Engineering (3)
Communications (1)	Physics (1)
Economics (1)	Psychology (1)

Note**:** Some students selected more than one primary major (double major)

[1] **Underrepresented groups in STEM include**: individuals who constitute smaller percentages degree recipients and of employed scientists as compared to the whole population—these include women, persons with disabilities, and three racial/ethnic groups, Black or African American, Hispanics, and American Indians.

Lake Champlain REU Program Overview

The Lake Champlain REU program applied a team-based, interdisciplinary, cooperative research approach that promoted integrated thinking within and between the natural and social sciences. The Lake Champlain REU program had four goals:

1. Provide interdisciplinary research experiences for undergraduates, including those

from underrepresented groups.

2. Increase students' understanding of and capacity for conducting independent research; prepare rising 3rd and 4th year students for graduate school and rising 1st and 2nd year students for advanced undergraduate research.
3. Provide hands-on, research assistant experiences for local high school students including individuals from underrepresented groups.
4. Develop communication and mentoring skills for REU participants when working with each other and with high school students (University of Vermont, 2016).

Data and Analysis

A fixed, mixed methods, convergent parallel design strategy guided the direction of data collection and phases of analysis for my study (Onwuegbuzie & Leech, 2005; Plano Clark & Creswell, 2011). Equal priority was given to both the quantitative and qualitative forms of data. Convenience sampling was conducted with individuals who were available and willing to participate in the study (Onwuegbuzie & Collins, 2007; Tashakkori & Teddlie, 2003), this was a non-probabilistic technique, based on judgement and availability, not random selection (Plano Clark & Creswell, 2011). The process of naturalistic generalization of participants' personal experiences and perceptions was used to filter the study's conclusions (Stake, 2005). Given the small sample size ($N=20$), it was determined that there was insufficient statistical power to conduct analysis beyond frequency counts on the quantitative data. Onwuegbuzie et al. (2009) suggest between three and six groups as sufficient for studies that use focus group data, and my study meets the maximum threshold of six. The pre-survey data, which were used to construct an image of students' preconceptions about their now and future selves before the start of the program, were analyzed separate from post-survey data. Post-experience quantitative and qualitative data were analyzed separately; the qualitative data were then used to illuminate aspects of the quantitative data. Concurrent triangulation allowed one data set to compensate for the weaknesses of the other and offered both observations of the cohort as a whole as well as the voices of the individuals (Small, 2011). The quantitative data provided a generalized picture and the qualitative components provided more detail (Plano Clark & Creswell, 2011). This analysis strategy offered the richest source of material while taking into account the practical constraints of the short window in which data collection could occur.

Data

All Lake Champlain REU participants completed a pre-survey before the start of the program that contained mainly Likert-scale questions with two areas for comments. On the last day, each student completed a comprehensive modified version of the online post-survey instrument that evaluates student outcomes of research experiences in the sciences. The survey, known as the Undergraduate Research Student Self-Assessment (URSSA) is required for all NSF-sponsored REU programs. Students answered questions that fell into nine main categories: (1) thinking and working like a scientist; (2) personal gains related to research work, (3) gains in skills, (4) changes in attitudes or behaviors as a researcher, (5) accomplishments, (6) the role of REU on future plans, (7) satisfaction with the experience, (8) hours spent on activities with mentors, and (9) suggestions for program improvement. In addition to Likert-scale questions, the survey contained short-answer questions. Within 12-hours of completing the survey, all students participated in a 45-minute semi-structured exit interview in groups of three or four. The interview questions were pre-written though flexibility to add or change questions during the interviews was reserved, as needed, to follow interesting threads. The same researcher conducted all interviews and each session was digitally recorded.

Analysis

The analysis of the data was driven by the following question: How do participant views from the interview and short answer sections of the survey help illuminate the quantitative group findings from the URSSA and thus help to identify programmatic contexts that provided students opportunities to understand and conceptualize post-undergraduate options in STEM?

Means and standard deviations were calculated from the quantitative survey data and then were analyzed for whole-group trends. The qualitative data were transcribed with protocol that captured exact words from participants, but removed all "uhs," "ers," and pauses, except in the instances where meaning would have been lost (Miles & Huberman, 1994; Plano Clark & Creswell, 2011). All identifying names were replaced with pseudonyms. The interview transcripts were aggregated by individual participant and linked to self-reported demographic information. I read and re-read the cleaned data to get an overall sense of themes, ideas, and questions (Miles & Huberman, 1994). As recommended by Creswell (2013), I looked at the data with a pre-established list of categories. The provisional start list of codes came from the programmatic theoretical framework and the literature on STEM career aspirations, which gave rise to units of meaning (Miles & Huberman, 1994). Sub-codes were made as needed (Miles & Huberman, 1994) (Table 7). To maintain consistency in coding, I read and reread the transcripts to ensure that the updated codes were considered.

Table 7: Summary of start codes and emergent sub-codes.

Start Codes	Emergent Sub-codes
Self-concept or possible-selves exploration	Student unsure about post-undergrad educational path
	Program sparked new thinking about future plans
	Student contemplates doing what you love, follow your passions and dreams
	Describes dissonance re: world of research and actual research
	Student experienced dissonance about future before-after REU
	Plan to pursue advanced degree
	Student plans to pursue post-undergrad STEM
	Student mentioned master's degree
	Student mentions Ph.D.
Career-related experiences	Student mentions career-related research work
	Interdisciplinary approach provided participant access to new fields.
	Research experience prepared student for post-undergraduate path Student experienced "life of the scientist"
	Student sees self as researcher
	Student gained insight into of the world of research
	REU experience ignited excitement to conduct research
Exposure to vocational or post-undergraduate options	Program increased awareness about STEM careers
	Student received general advice from mentors
	Student described takeaways from dessert seminars
	Student learned about career options through interactions w/ professionals
	Student gained info about graduate school
Changes in vocational commitment as a result of the internship experience	Student describes increase in STEM-related interests after REU
	Program helped solidify future plans
	Student plans to pursue post-undergrad STEM and credits REU
	Decrease/no effect in STEM-related interests after program
	Student plans to take "time off" between pursuits

Findings

An overarching theme that wove together the quantitative and qualitative data was that the program sparked new thinking in participants about their future plans. The degree to which each person experienced new thinking varied with opportunities to construct, reconstruct, or solidify concepts of their post-program future selves. Three main Lake Champlain REU programmatic mechanisms that offered specific, research-related models, images, and symbols were: (1) experiential education through interdisciplinary-based research experiences, (2) programming that built capacity, and (3) being mentored and mentoring. While it was challenging to get specific details about these mechanisms without conducting further research, the findings provide a view into the internal workings that expand students' pool of possible selves (Markus & Nurius, 1986).

Post-Program Plans for Future-Self

When asked about their level of agreement as to the extent to which students feel prepared for future pursuits after completing the Lake Champlain REU, the majority (95%) strongly agreed or agreed that the experience "prepared me for graduate school." Some had not before contemplated the option of post-undergraduate education prior to this experience. One student said:

> Before participating in this program, I never seriously considered graduate school of any type and certainly not directly after graduating from undergraduate. This program helped me to determine that I enjoy doing research and want to obtain a Ph.D.…[it] has helped me to solidify the belief that I would like to go to graduate school. Also, it has taught me that I really enjoy conducting research and I would like to conduct research as a part of my long-term career.

One student declared the REU provided a "life changing experience," and commented on how it had an impacted on his/her plans. The student wrote, "[It] has helped me decide what I want to do in graduate school and perhaps the early part of my life."

Over half (60%) strongly agreed or agreed that the experience clarified the field they wanted to study and 55% said it confirmed their interest in that field (Table 8). One student said:

> I was fairly likely beforehand to enroll in a master's program but now I am certain that I want to thanks to this program. It helped me decide that I wanted to go to graduate school for modeling based on the project I did this summer.

For eight of the 20 participants, the experience spurred a shift in thinking about the future. These individuals expressed that they were much more likely to "enroll in an advanced degree program," that the program "reinvigorated their curiosity and passion for research," and that it clarified the "graduate school pathway."

Table 8: Students' self-reported ideas about Lake Champlain REU's role in preparing them for their future plans on a 4-point scale (strongly disagree - strongly agree).

Areas of Preparation	% agree and strongly agree	Mean	S.D.
My research experience has prepared me for graduate school.	95%	3.60	0.60
My research experience has prepared me for a job.	95%	3.35	0.59
My research experience has prepared me for advanced coursework or thesis work.	90%	3.40	0.68
Doing research clarified for me which field of study I want to pursue.	60%	2.75	0.97
Doing my research confirmed my interest in my field of study.	55%	2.80	0.83

At the end of the program, 75% of participants said they were more likely than before the research experience to enroll in a master's program in science, engineering, or mathematics; 55% expressed an increased likelihood to work in a lab (Table 9). One student shared:

> I am much more knowledgeable about what opportunities are available to me right out of my undergraduate degree and I am much more likely now to take a few years to work in research technician positions or similar opportunities and then go to graduate school to attain a master's degree.

Table 9: Students' self-reported intentions after completing the Lake Champlain REU as compared to their pre-program plans on a 5-point Likert scale (not more likely – extremely more likely).

Post-program intentions	% somewhat-extremely more likely
Enroll in a master's program in science, mathematics or engineering?	70%
Work in a science lab?	55%
Enroll in a Ph.D. program in science, mathematics or engineering?	50%

Half of the program participants expressed new plans to pursue a Ph.D. in science, engineering, or mathematics after finishing the program. One student talked about how the program opened her/his mind up to the possibility of a Ph.D. and a career in STEM:

> I was already pretty set on enrolling in post-undergrad education, but this research experience definitely set it in stone for me. It has definitely opened my eyes to the job possibilities available in the world of science. I have a much better idea of what working in science entails.

Another student noted the importance of having informal time to interact with individuals who were already on or had completed the post-undergraduate educational path:

> Before, I wanted to get only a master's degree in engineering. Now, I have the intention of pursuing a Ph.D. This research experience allowed me to learn more about graduate school by allowing me to interact with graduate students and professors.

Several students expressed mixed feelings about their plans for themselves. For one student, the experience shifted his/her interests towards the social sciences. Two students finished the program feeling undecided about their future-selves and were still considering options. One student shared:

> My intended degree is [in] biology. This program has made me think of pursuing some sort of chemistry in the future...though I am not sure where that would lead...biochemistry? I have also thought about pursuing computer science after this program. I liked coding in R and biological models in Java. Before the program I wanted to go straight [into] a Ph.D. program in some sort of biology. Now I think I want to work as a lab/field technician and figure out what I am

> interested in. Then I might go on to a masters and then Ph.D. Or I might do a master's instead of a lab/field technician. Anyways...I'm definitely not going straight to a Ph.D. anymore.

Others were more clear about a master's degree and still not certain about the Ph.D. One student was leery about entering academia, especially after seeing how hard his/her mentor had to work. This student shared:

> I plan to get at least a master's degree, but I am still undecided as to the specifics or whether to get a Ph.D. There are parts of research that I really like, and parts that I really don't. I remain unsure what my future career and graduate school plans are.

In looking at the programmatic mechanisms that supported students thinking about their future selves, three characteristics rise to the top: (1) experiential education through interdisciplinary research experiences, (2) programming that builds student capacity, and (3) being mentored and mentoring.

Experiential Education Through Interdisciplinary-Based Research Experiences

Lake Champlain REU students developed, proposed, and conducted research on original, self-generated questions. These were grounded in an authentic dilemma facing the wellbeing of Lake Champlain, and represented many different disciplines from economics to biochemistry. The program's interdisciplinary, experiential focus provided the opportunity for every student to finish the program with an "understanding of what everyday research work is like," and the majority (95%) of students expressed gains in "engaging in real-world science research" (Table 10). Students appreciated that the interdisciplinary component mirrored what exists in scientific research. One student noted, "I think if you're focused on just that one—your own aspect of research—you're going to miss out on so many different connections, and new paths that your research can take, collaboration that you could do with somebody."

Students said that the interdisciplinary nature of the research experience helped with meaning making and that "conducting [a] hands-on experiment is an excellent way to apply what you'd learned in the world." Many shared that this focus allowed them to have deeper relationships and more complex interactions with their peers as well as with the diverse range of topics that impacted the lake ecosystem. This approach brought together individuals from different fields and offered opportunities to "interact with scientists from outside your school" (80% gain). One student noted, "One of my biggest gains was learning how to problem solve." Ninety-five percent of students expressed moderate to great gains in "feeling like a scientist" and "feeling part of a scientific community."

Table 10: Students' self-reported gains as result of Lake Champlain REU according to a 5-point scale (no - great gains).

Areas of gain	% Moderate-great gain	Mean	S.D.
Understanding what everyday research work is like.	100%	4.90	0.37
Feel responsible for the project.	100%	4.90	0.37
Understanding the relevance of research to my coursework.	95%	4.10	0.91
Engage in real-world science research	95%	4.50	1.00
Feel like a scientist.	95%	4.20	0.95
Feel a part of a scientific community.	95%	4.30	0.97
Think creatively about the project.	90%	4.20	1.14
Work extra hours because you were excited about the research.	90%	4.10	1.10
Confidence in my ability to do well in future science courses.	85%	4.20	1.24
Interact with scientists from outside your school.	80%	4.00	1.41
Try out new ideas or procedures on your own.	75%	3.60	1.23
The amount of time I spent doing meaningful research.	75%	3.20	0.81

Programming That Builds Student Capacity

At the start of the program, students designed an independent research project and proposed it to the Lake Champlain REU community during the third week to receive feedback. In addition to traditional research, students participated in "Thinking Like A Scientist" programming where they attended short learning modules each week that covered foundational, capacity-building topics such as critical reading and scientific writing, and career-oriented topics such as navigating graduate school and writing cover letters. Students also participated in a weekly journal club on interdisciplinary approaches to research and after dinner seminars held by Lake Champlain REU mentors and university faculty who informally discussed their career paths. Each summer concluded with a formal presentation of student research and, in some cases, the submission of a manuscript. For some, the seminar topics were new, for others they were a review. For many, the seminars were a mere taste of topics that left many students wanting more. Table 11 details the extent of the capacity-building programs.

Table 11: Research-skills and career-related seminar topics and activities of the 2014-2015 Lake Champlain REU program. (Note: Some seminar topics were only offered in one year or the other—indicated in italics).

Short Learning Modules	Weekly Workshops & Facilitated Mentoring Opportunities
Effective Elements of Collaboration (*2014 cohort only*)	Scientific Writing
Leading and Participating in Effective Discussions	All Hands on Deck Days (*2015 only*)
Information Literacy	Partner Shadow Days and Debrief Seminar (*informal in 2014, formalized in 2015*)
Plagiarism (*combined with Info Literacy in 2015*)	Critical reading
Ethics	Whole Group Project
Sociology	Peer-to-Peer Mentoring Check-ins
Effective Talks	Open Statistics and Writing Days
Basic Statistics	Journal Club
Data figures (*combined with to Journal Club in 2015*)	Dessert Seminars
GIS	Project Proposal Symposium
Communicating Science to the Public	Research Progress Presentation
Navigating Graduate School	Public Presentations to ECHO visitors
Publishing Process (*2014 only*)	Research Symposium
Preparing for a Panel Discussion	Manuscript Writing & Submission
Preparing for Careers in Science: The Job Search, Building a Resume/CV, and Cover Letter	Individualized one-on-one training with mentors
Effective Posters	
Public Presentations	
Ecological Economics	
Aquatic Ecology	
Cross-Discipline Workshop	

Reading, writing, and understanding literature. The weekly journal and writing clubs offered the chance for students to "read about other people's research that are not necessarily [in] my field—[thus gaining] a little bit more of knowledge," and to work on manuscripts. Students appreciated having access to a broad range of faculty as part of these programming modules, and acknowledged how the extra supports helped with critical thinking and writing skills. One student noted that the clubs:

> Changed the way I thought about the writing as well and the way we were tailoring it to an audience—scientific writing in general, or science work is not necessarily well communicated—and the fact that it was interdisciplinary led to that translation of your work to people who you're ultimately aiming to present it to.

The writing opportunities resulted in a manuscript, a poster session, and in a whole group interdisciplinary project, which in the first year was a movie and the second year was a "zine."

After dinner seminars. Every Thursday evening over about eight of the 10-weeks, students attended a formally-organized, but open-structured, seminar where researchers, postdocs, deans, and graduate students shared the stories of their career pathways. In this casual setting, over dessert, students and invited guests spent an hour or more in open dialogue about various topics. One student noted, "My future is a big question mark for me, so it's nice to talk to people who've been there before." In the post-program survey every participant (100%) expressed enjoyment for what they sometimes referred to as "dessert seminars," and agreed that they should be continued in future years. One student said they were, "extremely interesting and helpful, and it's nice to get to know the mentors in a more informal setting."

One evening, the seminar was exclusively dedicated to navigating the sometimes confusing path towards graduate school. Program organizers brought in the dean of the graduate college to answer questions and clarify misconceptions. One student noted, "[F]rom a professional standpoint, I learned so much about graduate school. I didn't even know how to apply or anything before this program."

The intention behind the after dinner seminars was to introduce students to the many possible paths available to them within the ever-widening field of STEM. One student noted that the seminars introduced a new way of thinking:

> It has been a wonderful and inspiring training that has helped all of us as a whole consider new career paths and consider important factors when deciding what we

> want to do. Listening to the career paths of different mentors and faculty is extremely exciting and is something that I look forward to doing every week.

The open-nature of the seminars allowed students to ask questions they would not normally feel comfortable posing—they offered new and exciting prospects and advice that students could add to the treasure-trove of ideas about their possible future selves. One student said, "I got a lot of useful life/professional advice from the dessert seminars...stuff that I feel like no one really talks about, I loved how unfiltered everyone was."

Being mentored and mentoring. Students shared that they had positive interactions with mentors for the most part. On average, this time was when students received both instruction and support, particularly at the beginning of the program. The majority (90%) of the students reported having an "excellent" or "good" working relationship with their mentors. A unique component of this program was the opportunity for students to mentor one another, which happened for students who were part of research teams, during "shadow days," informally, and for the four students who worked with high school students from the university's Upward Bound Program.

The assigned mentor(s). Mentoring was especially important at the onset of the experience. One theme that emerged was that after students became more comfortable with their roles in the laboratories, mentors intentionally starting giving students more independence. One student explained:

> My hand was held for the first week, and then I was left to my own devices, and that was really scary at first…but it ended up working out well, because it made me figure it out myself.

As the program progressed, many stated that they felt empowered and supported to pursue independent work within the structure of the program. One student shared:

> I was given a fair amount of instruction, but I also felt like I had the room to ask what I wanted too…I feel like it was a fair balance between instruction in that regard…in terms of how things played out or how you go about achieving those goals and answering those questions, I felt like I had a lot of room to think and do things.

By mid-summer, many shared that they felt that clear expectations and roles within the mentor-mentee relationship were established. For the most part, mentors were available for guidance and questions, and students could work independently in-between formal meetings.

Most students reported that mentors were assessable and approachable, however there were several mentors who were less available. One student said, "I would have liked to spend more time with my mentor but I understand why his/her other obligations made that impossible." A different student took partial responsibility for the infrequent opportunities to interact because s/he said s/he did not "reach out to my full capability." Two students had particularly challenging experiences. One student related that:

> There was just no collaboration—like absolutely zero, and I think that made it kind of difficult…[and that the mentor] would be a really great mentor if [she/he] had more time—every time I met with [him/her], [she/he] was extremely helpful, but I only met with [her/him] for maybe five or six times and I had an hour to share with the other intern. What ended up happening, each meeting [he/she] would tell us what we needed to do before our next meeting, and we had to go

> figure out how to do it ourselves, which has been a good experience in terms of learning to figure out things on your own and finding your own resources, but in the meantime, I do wish [she/he] was more easily available.

A fundamental point is that it is important that mentors are available over the 10-week period to meet with and support students. Some mentors may have to travel during the program period, however regular and consistent meetings are vital for establishing deep connections and opportunities for collaboration.

The "other" mentors. Due to the interdisciplinary nature of the program, students made connections with faculty other than their assigned mentors. In the focus group, one student noted that s/he "made a lot of connections with faculty members who have been able to mentor me in various ways." When one student's mentor was not available s/he said, "There were other people to ask, just not my mentor, because [she/he] deliberately stepped back a) because [he/she] had important stuff to do and b) because [she/he] wanted to let me work on my own, which I appreciated."

A member of the faculty who was paid by the program was available to the students, and he was praised time and time again for providing support and expertise. The students found him to be patient, relatable, and easy to converse with. Others praised the UVM graduate students for their support and help. One student mentioned that "There were a couple of grad students and they were working in things that wasn't related to my work, but they were very helpful—they know a lot."

Reciprocal mentoring. Many students experienced a reciprocal mentor-mentee relationship, where they got and gave advice and interacted with their mentors more as equals. This quote articulated the degree to which this participant's mentoring arrangement had reciprocity:

> It felt more like an apprenticeship...like s/he was showing me how to live life as a scientist (this wasn't a bad thing...I liked it). It was a great experience to have so much interaction with my mentor. We worked on our respective projects in his/her office at UVM and I got to see what s/he was working on and vice versa. It felt like we were both learning from each other as s/he edited my work and I edited his/hers.

Along a similar vein, one student said, "The relationship that I had with my research partner was great. I really felt like the three of us (my mentor, partner, and I) were a research team. We got along great and frequently worked together and collaborated." Another student noted:

> [Name of mentor] was great as a mentor, [he/she] really let me work independently, but was always there if I needed [her/him]. I thought [his/her] level of instruction was perfect. [He/she] kind of worked with me as more of an equal because [she/he] was just starting this project too—so [he/she] would bounce ideas off of me and ask me what I thought we should do.

Mentoring high school students. In addition to peer-to-peer mentoring, two students from each cohort worked directly with high school students from UVM's Upward Bound Program. Students found that the Upward Bound mentoring experience helped them engage with their research in a new way. One student shared that:

> Getting high school students to mentor helped a lot because it made me get my stuff down really well. Because in order to teach someone you have to know and

> be confident in what you do. So once I got high school students to teach, I felt better about my own way of doing the lab methods.

Another student shared:

> This experience was incredibly rewarding for me because it forced me to speak about my project and complex process using basic language and simple explanations. Reiterating in this way helped me to better understand my research and my goals for the summer.

The Upward Bound connection was important, a sentiment that was echoed by every REU student-mentor. REU students assumed the role of active leaders and set goals and took the role very seriously. One student wrote in his/her reflection:

> [We] [a]imed to personalize the students' experiences with us by incorporating their interests into our projects. Over the 5 weeks, we introduced the students to scientific literature, critical thinking, experimental design, interpreting statistics, creating figures and posters, and presenting work, all while talking about college life in general. Their experience with [other REU student] and I culminated in a poster that they created and presented about how skills developed through research are applicable to their daily lives and future careers!

The Lake Champlain REU Upward Bound mentors emphasized discussing post-high school opportunities with their Upward Bound students. One REU student noted that s/he:

> [F]ound that giving younger students advice about college and how to make decisions about future education was a good opportunity for me to reflect on the

> choices I have made in my academic career thus far. This has been helpful as I make decisions about my future from this point onward.

Undoubtedly, the Upward Bound mentoring opportunity, although more time consuming for the students and the REU organizers, was valuable and rewarding.

Discussion

My study illuminated the contexts of the Lake Champlain REU program that ignited students' new thinking about their plans. Three key programmatic mechanisms were identified: (1) experiential education through interdisciplinary research experiences, (2) programming that builds student capacity, and (3) being mentored and mentoring through the mixed methods approach (e.g. Linn, Palmer, Baranger, Gerard, & Stone, 2015; Mau, 2003; Sadler, Burgin, McKinney, & Ponjuan, 2010). These three mechanisms provided students with gains in skills, confidence and self-efficacy for research, and insight into the world of research. The opportunity to experience the life of the scientist and gain exposure to ideas about post-undergraduate options were also gains from the program's cross-disciplinary emphasis and structure of the seminars. Ample opportunities for direct experiences with individuals from a variety of fields and backgrounds offered participants further insight into a variety of STEM-oriented pathways and occupations.

Findings from this study support the growing body of literature on the role of research experiences on post-undergraduate career preferences and aspirations (e.g. Adedokun et al., 2012; Mau, 2003; Strayhorn, 2010). The results cannot be generalized beyond the context of the Lake Champlain REU, however this investigation provides insight into the importance of structuring research experiences that offer experiences, events, and situations that inform, encourage, and reinforce students' self-conceptualizations (Lopatto, 2008; Markus & Nurius, 1986).

Experiential education is an incredibly valuable way to ignite passion for STEM, and is further enhanced by an interdisciplinary, real-world focus, robust capacity-building programming, and a diverse array of mentor and mentoring opportunities. Opportunity to collaborate on authentic problems offers a chance for students to dispel inaccurate preconceptions and stereotypes of the life of the researcher by immersing new students head first into the world of research (e.g. Adedokun & Burgess, 2011; Russell, Hancock, & McCullough, 2007; Taraban & Blanton, 2008) Capacity-building programming, formal and informal, is a powerful mechanism for filling in content gaps, as well as for dispelling confusion about graduate school or the pathways to STEM careers (Adedokun & Burgess, 2011). Regarding mentoring, I strongly encourage REU program leaders to have an open dialogue with mentors of all types, from researchers to post-docs to REU students themselves, about the powerful role mentoring plays in the learning process and to be explicit about successful strategies for collaborating.

Areas for future research include investigating the nature and quality of mechanisms within the black box of students' hands-on experiences in research; to unpack the formal and informal interactions themselves, and also investigate the content within seminars. In particular, it would be useful to identify what made the "Think Like A Scientist" programming, particularly the after dinner and navigating graduate school seminars, such important access points which allowed students to entertain the possibility of vocational options in STEM.

Implications

As colleges and universities compete for funding to support programs that recruit and retain STEM majors, education professionals might consider using interdisciplinary contexts with real world challenges—learning opportunities that allow students to think like and experience the world of a scientist. The more information students have about the nature of the work and the pathways towards a career in STEM, the more likely we will be adequately prepared to meet the challenges of climate change and globalization.

Limitations

The findings of this mixed-methods study are limited in several ways. First, as my study had only 20 participants who hailed from a variety of socioeconomic, ethnic, and geographical backgrounds. This study was not meant to be confirmatory. Secondly, students' decisions to pursue STEM are influenced by a myriad of factors (e.g. prior work/research experiences) for which I could not control (Abraham, 2002; Taraban & Blanton, 2008). Further, mentors hail from a variety of backgrounds and disciplines and each conduct research with varying technical sophistication and goals, potentially impacting students' habits and experiences. Third, my study was entirely drawn from self-reported data, which may be problematic as some respondents may have wanted to cast the program in a particular light (Bauer & Bennett, 2008). Finally, the rigorous selection process on both the university and individual levels confounds my study further, for REU entry requirements at this and many universities are robust, essentially resulting in a group self-selected, high achieving STEM majors who likely have a high sense of self-efficacy and ideas about future-selves from the outset.

Acknowledgments

This work was supported by the National Science Foundation under award #1358838 and the Rubenstein School of Natural Resources at the University of Vermont.

References

Abraham, L. (2002). What do high school science students gain from field-based research apprenticeship programs? *Clearing House*, *75*(5), 229–232.

Adedokun, O. A., Bessenbacher, A. B., Parker, L. C., Kirkham, L. L., & Burgess, W. D. (2013). Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *Journal of Research in Science Teaching*, *50*(8), 940–951.

Adedokun, O. A., & Burgess, W. D. (2011). Uncovering students' preconceptions of undergraduate research experiences. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 12.

Adedokun, O. A., Zhang, D., Parker, L. C., Bessenbacher, A., Childress, A., Burgess, W. D., & Adedokun, B. O. A. (2012). Understanding how undergraduate research experiences influence student aspirations for research careers and graduate education. *Journal of College Science Teaching*, *42*(1), 82–90.

Alexander, B. B., Foertsch, J., & Daffinrud, S. (1998). The spend a summer with a scientist program: An evaluation of program outcomes and the essential elements for success. *Madison, WI: University of Madison-Wisconsin, LEAD Center*.

Bauer, K., & Bennett, J. (2003). Alumni perceptions used to assess undergraduate research experience. *The Journal of Higher Education*, *74*(2), 210–230.

Bauer, K., & Bennett, J. (2008). Evaluation of the undergraduate research program at the University of Delaware: A multifaceted design. *Creating Effective Undergraduate Research Programs in Science: The Transformation from Student to Scientist*, 81–111.

Boyer, E. (1998). The Boyer commission on educating undergraduates in the research university, reinventing undergraduate education: A blueprint for America's research universities. *Stony Brook, NY*, *46*.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: SAGE.

Doney, S. (2010). The growing human footprint on coastal and open-ocean biogeochemistry. *Science*, *328*(5985), 1512–1516.

Duncan, A., & Martin, C. (2010). *A blueprint for Reform: The reauthorization of the Elementary and Secondary Education Act*. Washington, D.C.: US Department of Education Office of Planning.

Grubb, W. (2009). *The money myth: School resources, outcomes, and equity*. Russell Sage Foundation.

Hakim, T. (1998). Soft assessment of undergraduate research: Reactions and student perspectives. *Council on Undergraduate Research Quarterly*, *18*(4), 189–192.

Hathaway, R., Nagda, B., & Gregerman, S. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study. *Journal of College Student Development*, *43*(5), 614–631.

Hu, S., Scheuch, K., Schwartz, R., Gayles, J. G., & Li, S. (2008). Reinventing undergraduate education: Engaging college students in research and creative activities, *33*(4), 1–103.

Hunter, A., Laursen, S., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36–74.

Jones, M. T., Barlow, A. E., & Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in biology. *The Journal of Higher Education*, *81*(1), 82–115.

Ladd, H., Chalk, R., & Hansen, J. (1999). *Equity and adequacy in education finance: Issues and perspectives*. National Academies Press.

Laursen, S., Seymour, E., & Hunter, A.-B. (2012). Learning, teaching and scholarship: Fundamental tensions of undergraduate research. *Change: The Magazine of Higher Learning*, *44*(2), 30–37. https://doi.org/10.1080/00091383.2012.655217

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate Research Experiences: Impacts and opportunities. *Science*, *347*(6222), 1261757.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE-Life Sciences Education*, *6*(4), 297–306.

Lopatto, D. (2008). Exploring the benefits of undergraduate research: The SURE survey. *Creating Effective Undergraduate Research Programs in Science*, 112–132.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877–907.

Markus, H., & Nurius, P. (1986). Possible selves. *American Psychologist*, *41*(9), 1-954.

Mau, W.-C. (2003). Factors that influence persistence in science and engineering career aspirations. *The Career Development Quarterly*, *51*(3), 234–243.

Miles, M., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: biodiversity synthesis*. Island Press.

Nagda, B., Gregerman, S., Lerner, J., von Hippel, W., & Jonides, J. (1998). Undergraduate student-faculty research partnerships affect student retention. *The Review of Higher Education*, *22*(1), 55–72.

National Science Foundation. (2016, June). National Science Foundation: About Funding. Retrieved from https://www.nsf.gov/funding/aboutfunding.jsp

Onwuegbuzie, A., & Collins, K. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report*, *12*(2), 281–316.

Onwuegbuzie, A., Dickinson, W., Leech, N., & Zoran, A. (2009). A qualitative framework for collecting and analyzing data in focus group research. *International Journal of Qualitative Methods*, *8*(3), 1–21.

Onwuegbuzie, A., & Leech, N. (2005). On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies. *International Journal of Social Research Methodology*, *8*(5), 375–387.

Packard, B., & Nguyen, D. (2003). Science career-related possible selves of adolescent girls: A longitudinal study. *Journal of Career Development*, *29*(4), 251–263.

Page, M. C., Abramson, C. I., & Jacobs-Lawson, J. M. (2004). The National Science Foundation Research Experiences for Undergraduates program: Experiences and recommendations. *Teaching of Psychology*, *31*(4), 241–247.

Pelling, M. (2011). *Adapting to Climate Change, from Resilience to Adaptation*. Routledge, New York, NY, USA.

Plano Clark, V., & Creswell, J. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications.

Princen, T., Manno, J. P., & Martin, P. L. (2015). *Ending the fossil fuel era*. MIT Press.

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review*, *29*(6), 892–900.

Russell, S., Hancock, M., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*(5824), 548–549.

Sadler, T. D., Burgin, S., McKinney, L., & Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, *47*(3), 235–256.

Sala, O., Chapin, F., Armesto, J., Berlow, E., Bloomfield, J., Dirzo, R., … Kinzig, A. (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*(5459), 1770–1774.

Seymour, E., Hunter, A., Laursen, S., & Deantoni, T. (2004). Establishing the benefits of Research Experiences for Undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493–534. https://doi.org/10.1002/sce.10131

Small, M. L. (2011). How to conduct a mixed methods study: Recent trends in a rapidly growing literature. *Sociology*, *37*(1), 57-86.

Stake, R. (2005). Qualitative Case Studies. In N. Denzin & Y. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 443–466). Thousand Oaks, CA: SAGE Publications.

Strayhorn, T. (2010). Undergraduate research participation and STEM graduate degree aspirations among students of color. *New Directions for Institutional Research*, *2010*(148), 85–93.

Taraban, R., & Blanton, R. (2008). *Creating effective undergraduate research programs in science: The transformation from student to scientist*. Teachers College Press.

Tashakkori, A., & Teddlie, C. (2003). *Handbook of mixed methods in social & behavioral research*. Sage.

Thiry, H., Laursen, S., & Hunter, A. (2011). What experiences help students become scientists?: A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *The Journal of Higher Education*, *82*(4), 357–388.

Thiry, H., Weston, T., Laursen, S., & Hunter, A. (2012). The benefits of multi-year research experiences: Differences in novice and experienced students' reported gains from undergraduate research. *CBE-Life Sciences Education*, *11*, 260–272.

Tyack, D., & Cuban, L. (2009). *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

University of Vermont. (2016). University of Vermont Rubenstein Ecosystem Science Laboratory NSF Research Experiences for Undergraduates. Retrieved from http://www.uvm.edu/~ecolab/?Page=REU.html

Villarejo, M., Barlow, A., Kogan, D., Veazey, B., & Sweeney, J. (2008). Encouraging minority undergraduates to choose science careers: career paths survey results. *CBE-Life Sciences Education*, *7*(4), 394–409.

CHAPTER 5: JOURNAL ARTICLE 2

5.1 Article 2: Research Experiences for Undergraduates Program: Mechanisms that Support Underrepresented Minority College STEM Majors

Abstract

The National Science Foundation supports STEM majors' participation in active research experiences by funding universities and colleges through the Research Experiences for Undergraduates (REU) programs. A multitude of studies of REUs reveal strong correlations between students' research experiences and STEM aspirations, however less is known about the mechanisms within the programs that support these gains. In this article, I argue the importance of digging into the black box of these research experiences to discover more about the systems that give rise to research skills, confidence and self-efficacy for research, and STEM career aspirations. This mixed methods study explored self-reported gains of 18 underrepresented minority STEM students who participated in an interdisciplinary, team-oriented, 10-week REU. Data from surveys, focus group interviews, and blog entries were analyzed through the theory of possible selves, theory of self-efficacy for research, and social cognitive career theory. Findings revealed four mechanisms that resulted in gains. The program (1) balanced student independence and ownership with expert researcher guidance, (2) established formal and informal mentoring networks, (3) fostered a learning community that advanced leadership, perseverance, and reflection, and (4) offered a positive, interdisciplinary research setting for students to experience what it feels like to be an active participant in the world of research. Results from this mixed methods study cannot be generalized beyond the context of this REU. By zeroing in on the within-program implementation factors, my study offers a new direction for the research field that focuses on best practices. Identifying programmatic mechanisms from more REUs will allow models to be expanded, replicated, and applied beyond a single university. To facilitate this process, I recommend regional REU programs form cohorts to learn from and improve research-based teaching and learning such that it holds the most benefits for the most students.

Keywords: Research Experiences for Undergraduates; STEM education; Mixed methods research; Black-box; Theory of possible selves; Theory of self-efficacy for research; Social cognitive career theory; Underrepresented minorities in STEM

Introduction

Despite 50 years of federally funded programming to advance individuals into the

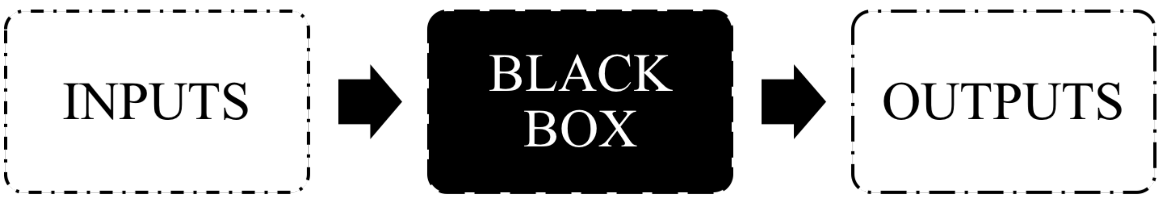
STEM workforce, the percent of students graduating with STEM majors continues to decline (e.g. Maltese & Tai, 2011; President's Council of Advisors on Science and Technology, 2010; Rask, 2010). This is particularly true for underrepresented minorities (Jones et al., 2010; National Center for Science and Engineering Statistics, 2013; Summers & Hrabowski III, 2006). U.S. postsecondary institutions struggle to recruit and retain talented interdisciplinary-trained individuals who are interested in pursuing STEM pathways (e.g. Maltese & Tai, 2011; President's Council of Advisors on Science and Technology, 2010; Rask, 2010), and, as a result, the majority of the science and engineering workforce population is White and male (National Center for Science and Engineering Statistics, 2013). Gross disparities in representation in STEM magnify as the U.S. becomes increasingly multiracial.

The National Center for Science and Engineering Statistics report (2013) defines persons who make up smaller percentages within a field than are represented in the U.S. population as underrepresented minorities. In STEM these include: women, persons with disabilities, and three racial/ethnic groups—Blacks, Hispanics, and American Indians (National Center for Science and Engineering Statistics, 2013). However, some scholars also include first-generation college students and persons from low socioeconomic backgrounds in this definition (Packard, 2016). While individuals from African American, Hispanic, Native Hawaiian, American Indian minority groups comprise 28% of the U.S. population, they hold a mere 15% of the highest degrees in science and engineering, as compared to Whites, who represent 68% of the population but hold 72% of the highest science and engineering degrees (NSF National Science Board, 2015). Asians, who represent 5% of the U.S. population, hold 14% of the highest science and engineering degrees. Women, despite comprising half of all college graduates in the U.S. population, represent only 28% of the STEM workforce (National Science Board, 2010).

One federally funded program designed to improve these numbers is the National Science Foundation's (NSF) Research Experiences for Undergraduates (REU). Though costly to implement, and often limited to top students, REUs offer the opportunity for students to develop interests, confidence and self-efficacy for research, and career aspirations in STEM (e.g. Hunter et al., 2007; Roe, 1952; Russell et al., 2007), particularly for individuals from diverse backgrounds (e.g. Hurtado et al., 2008; Jones et al., 2010; Summers & Hrabowski III, 2006). After considering the plethora of research on the positive benefits of REUs, the question still unanswered is: What are the mechanisms within REU programs that support these gains?

In this article, I argue the importance of digging into the black box (Figure 1) of these research experiences to discover more about the systems that give rise to important gains, specifically in research skills, confidence and self-efficacy for research, and STEM career aspirations. My larger vision is twofold. First, I emphasize the importance of establishing a new approach to research on REUs that considers key inputs and outcomes of these experiences while illuminating the mechanisms within the programs that support STEM students. Ideally, once the mechanistic archetypes that support students are identified in individual settings, they can be expanded, replicated, and applied more broadly, such that this model of learning becomes the norm. Second, with an eye towards programmatic sustainability and the desire to see best practices expanded beyond a single program, I propose that REU programs organize and come together annually as regional cohorts to share information and strengthen the organization. Other NSF-funded programs, like the Robert Noyce Studentship program, use this cohort model and gather together programs from specific regions on an annual basis to share work (National Science Foundation, 2016). REU program administrators and students alike could participate in roundtables, poster sessions, and even panel discussions around important topics, and meet other students and scholars in similar fields. A small step towards this vision, my study examines the black box of one such REU program.

Figure 4: Measurable inputs and outputs of undergraduate research programs are often studied because they are relatively easy to measure, while the internal workings are more elusive and investigated less (Grubb, 2009; Ladd et al., 1999; Tyack & Cuban, 2009). The programmatic contexts where implementation occurs is referred to as a black box, for it is often opaque and under examined. The porosity of this process is represented by the dashed lines.



Research Questions

My study used quantitative and qualitative sources to describe as many details as possible about the contexts within the black box of one summer research program. The following research question guided this research: What mechanisms supported underrepresented minorities (Blacks, Hispanics, women, first-generation students, and Pell-eligible) students'[2] to experience: (1) gains confidence and self-efficacy for research, (2) gains in research skills, and (3) changes in thinking about their career aspirations in STEM?

[2] I acknowledge that while a person may identify with one or more group, that does not automatically mean a shared or common experience within or across that group (Packard, 2016).

Related Literature

A plethora of studies exist that describe gains in students' research skills and STEM-oriented career aspirations because of their undergraduate research experiences, particularly for underrepresented minorities in STEM. Undergraduate research experiences move beyond traditional learning by fostering student-directed research alongside faculty, post-docs, graduate students, and other peers (Lopatto, 2007; Russell et al., 2007; Seymour, Hunter, Laursen, & Deantoni, 2004); an approach that advances the development of agency as well as a sense of belonging within the discipline (Hakim, 1998). In addition to student-driven research, research experiences offer professional development opportunities that strengthen content knowledge, skills, and understanding about the many post-undergraduate pathway options in STEM (Lopatto, 2007; Russell et al., 2007; Seymour, Hunter, Laursen, & Deantoni, 2004).

Research Experiences: Positive Outputs for Minority STEM Students

Studies have shown the value of personalized research experiences, especially for individuals from non-majority groups. In a phenomenological study of 65 ethnically and racially diverse women and men, exposure to research afforded the opportunity for individuals to view themselves as scientists and understand more about research careers—both deemed necessary elements to becoming a scientist (Hurtado et al., 2008). Nagda et al. (1998) examined retention rates for STEM majors who participated in research experiences and reported positive impacts for all undergraduates, especially African Americans. In an ethnographic study of four liberal arts colleges that offered summer research experiences, Hunter et al. (2007) found positive connections between the experience and science researcher identity, intellectual development, skills, competence, interests in science, and refined career goals.

The federally-funded McNair Students program, offered at 151 U.S. universities and colleges, assists first-generation students and individuals from underrepresented groups on the path towards doctoral degrees. In a study of self-reported data from minority students who participated in McNair summer research at one of three universities in the summer of 2008, Strayhorn (2010) reported that research played an important role in promoting aspirations for graduate school. Nearly every minority McNair scholar (96%) shared that their summer experience conducting research "encouraged," "sustained," or "increased" their STEM-oriented aspirations (Strayhorn, 2010).

Research experiences can be powerful pathways for entrance to post-undergraduate educational opportunities, as they offer funding and access to facilities to conduct original research with the support of a mentor who often takes on the role of a advocate and sponsor that helps students negotiate the many pathways into STEM (e.g. Hunter et al., 2007; Lent et al., 2005; Seymour, Hunter, Laursen, & DeAntoni, 2004). But what are the mechanisms that happens within these programs that produces, in many cases, these incredible results?

The Unexamined Middle

Most studies of REUs focus on output variables, like gains in research skills or career aspirations that result from participating in undergraduate research experiences, and a handful explicitly address the role research experiences play in supporting recruitment and retention of minority students in STEM (e.g. Adedokun et al., 2012;

Adedokun & Burgess, 2011; Taraban & Blanton, 2008). Even fewer describe implementation agents or mechanisms (e.g. mentoring or study groups) within programs (e.g. Hunter et al., 2007; Jones et al., 2010; Villarejo et al., 2008). Inputs and outputs (e.g. participant demographics and post-experience academic achievement) are most easily defined and therefore more frequently measured. But capturing what happens within experiences, and the extent to which the complex network of interactions impacts students' self-conceptions or skills, is more difficult and therefore is much less studied (Grubb, 2009; Ladd et al., 1999; Tyack & Cuban, 2009). Little is known about the mechanisms that give rise to these important gains because few researchers (e.g. Gandara & Maxwell-Jolly, 1999; Jones et al., 2010; Summers & Hrabowski III, 2006) aim their studies at the inner workings of the experience.

Prior Research into the Black Box of Programs that Emphasize Research Experiences

Of the research that scrutinizes the black box of implementation, most studies are of yearlong programs that extend across the four undergraduate years, some of which offer research opportunities as one of many program components (e.g. Bauer & Bennett, 2003; Jones et al., 2010; Terenzini et al., 1997). For example, inside the Meyerhoff program, researchers described a culture of "positive peer pressure" (e.g. study groups), a commitment to involving students in research as early as possible in their undergraduate experience, a 6-week summer acculturation program with course offerings, and yearlong support and assistance in preparing graduate school applications (Carter et al., 2009; Maton et al., 2000; University of Maryland Baltimore County, 2016). Other students found similar components. Gandara and Maxwell-Jolly (1999) reviewed twenty of programs for minority students, including Meyerhoff, and identified five key threads that wove across each: (1) mentoring, (2) financial support, (3) academic support, (4) psychological support, and (5) professional opportunities.

Some studies have focused exclusively on the element of mentoring, most are descriptive, and few test the effectiveness across a control sample. A study of the Meyerhoff program revealed the importance of recruiting the "most effective" research faculty to work with students and frequent, "high quality" contact between mentor and mentee (University of Maryland Baltimore County, 2016). In other studies, these factors were positively associated with development of intellectual and academic interactions, job recommendations, and degree completion (Jones et al., 2010; Terenzini et al., 1997; Villarejo & Barlow, 2007).

Some research highlighted the importance of programs that promote peer-to peer mentoring through formal (e.g. cohorts) and informal channels (e.g. study groups, organized housing arrangements, laboratory assignments, etc.) (e.g. Bauer & Bennett, 2003; Hunter et al., 2007; University of Maryland Baltimore County, 2016). The Meyerhoff program offered monthly group activities intended to actively build sense of community within its cohort of students—a safe space to discuss everything from classes and research to experiences with mentors to home and family situations (University of Maryland Baltimore County, 2016). They also offered team building activities and in group travel to conferences (University of Maryland Baltimore County, 2016). With programs that have a research component, access to professional opportunities (research, publication, presenting, and working professionals who modeled norms) were important for minority students (Gandara & Maxwell-Jolly, 1999; Summers & Hrabowski III, 2006;

University of Maryland Baltimore County, 2016). Other programs encouraged the mentoring of younger students, which resulted undergraduates reporting increases in content knowledge, agency, and a sense of ownership within the discipline (Gandara & Maxwell-Jolly, 1999; University of Maryland Baltimore County, 2016).

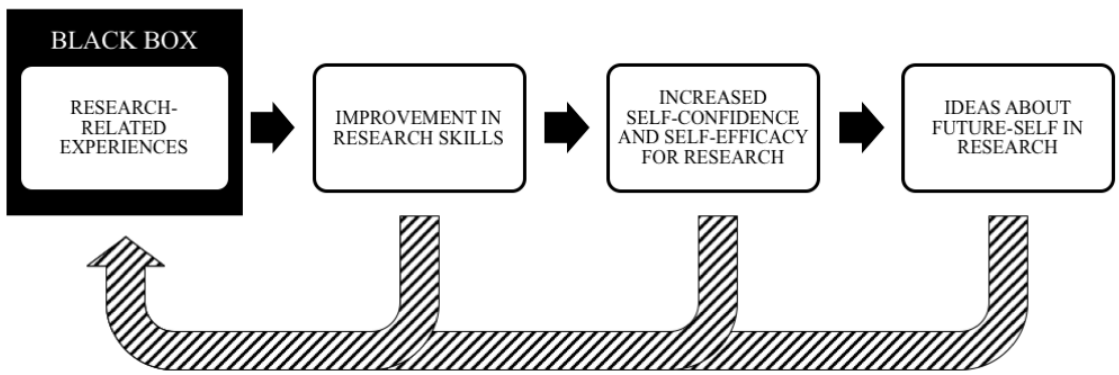
Research by Hunter, Larsen, and Seymour (2007), one of a few studies that looked specifically at summer research programs, revealed that students who received support from faculty, peers, and science professionals experienced improvements academically, practically, and professionally. Others who studied university-wide programs found that some institutions offered counseling and advice beyond mentoring, (e.g. workshops, pre-college bridge orientations, learning centers, tutoring, etc.), though little is known about the effectiveness of these interventions (Gandara & Maxwell-Jolly, 1999; University of Maryland Baltimore County, 2016).

As is detailed in this review of the literature, most research on minority students relied on output variables that captured gains in research skills, confidence and self-efficacy for research, and decisions about graduate school or careers in STEM. Past qualitative studies have used students' voices to call attention to important issues. However, few studies have uncovered the nuances that come with employing both qualitative and quantitative data.

Conceptual Framework

Taking a backwards design approach, my study began by identifying areas where students self-reported gains. These areas were then used as indicators to identify mechanisms (e.g. experiences or contexts) responsible for catalyzing or supporting that gain. Three key outputs were identified through a review of literature on research experiences as well as a combination of three theories: the theory of possible selves (Markus & Nurius, 1986), the theory of self-efficacy for research (Adedokun et al., 2013; Bandura, 1977; Caprara et al., 2008), and social cognitive career theory (SCCT) (Lent et al., 1994). Outputs identified were: (1) improvement in research skills, (2) levels of self-confidence and efficacy for research, and (3) changes in career aspirations (Figure 5).

Figure 5: The conceptual framework used three output areas (research skill improvement, self-confidence and self-efficacy for research, and conceptualizations of future-self) to trace back to the research-related experiences that gave rise to these outputs.



The combination of Markus and Nurius' (1986), Caprara (2008), and Lent et al.'s (2002) theories guided my thinking about the process students take with regards to forming interests, making choices, and achieving success. Markus and Nurius (1986) explained that the "pool of possible selves derives from the categories made salient by the individual's particular sociocultural and historical context and from the models, images, and symbols provided by the media and by the individual's immediate social experiences" (p. 954). Markus and Nurius' (1986) theory helped with pinpointing mechanisms within the "immediate social experience" of the REU that influenced students' formation of ideas about their future selves. The second theory, self-efficacy (Caprara et al., 2008) for research, is predicated on the understanding that one's belief in one's abilities affects the degree to which one succeeds in a situation, in this case in the world of research. The degree to which one believes in one's abilities can play a significant role in how one approaches challenges related to that situation and the likelihood of seeing oneself in that role again in the future. The third theory, social cognitive career theory (Lent et al., 2005, 2000, 2002), considers how interests develop, how choices regarding career trajectories are made, and how success is obtained. This theory is anchored also in the theory of self-efficacy, as well as on the role of outcome expectations and goal setting—processes that vary depending one's context and support systems and the extent to which experiential factors enhance or constrain one's process (Lent et al., 1994).

Conceptually, this framework offers a fresh look at the mechanisms within research experiences that impact underrepresented minority STEM students. I explored ways to apply this framework in other settings. Empirically, my study offers new quantitative and qualitative data to compliment and enrich the plethora of studies on the benefits of REU programs.

Data

My study used self-reported, retrospective quantitative and qualitative data from two cohorts of undergraduate students (*N*=18) who participated in the NSF-sponsored REU: *Interdisciplinary Research on Human Impacts in the Lake Champlain Ecosystem* in the summers of 2014 and 2015. Though questionnaire, focus group interview, reflections, and blog data were collected from 20 students in total, findings are drawn only from students who self-identified as underrepresented minorities (Black, Hispanic, female, first-generation college students, and Pell-eligible). Additional data sources included application information and a detailed program schedule for both summers with descriptions of seminars. All students were invited and highly encouraged, via an online message and in person, to complete the questionnaire, write blog entries, and participate in the exit interviews.

A modified version of the national post-survey instrument that evaluates student outcomes, the Undergraduate Research Student Self-Assessment (URSSA), was used. This survey is required for NSF-sponsored REU programs. On the day before the last day of the program, each student received an email with a name and password to access the questionnaire. Students answered questions that fell into 12 categories: (1) gains in application of knowledge of research work (i.e. thinking and working like a scientist), (2) personal gains related to research work, (3) gains in skills, (4) changes in attitudes or behaviors as a researcher, (5) the research experience overall, (6) accomplishments, (7) the impact of the REU on future plans, (8) satisfaction with the experience, (9) motivation for pursuing Lake Champlain REU, (10) suggestions for program improvement, (11) prior experience in research; and, (12) demographic information. In addition to Likert-scale questions, the survey contained short-answer questions.

On the final day of the program, all students participated in a 45-minute semi-structured interview in groups of three or four. The interview questions were pre-written, though flexibility to add or change questions during the interviews was reserved, as needed, to follow interesting threads. Interview questions covered the following topics: (1) most significant gains, (2) feedback on the interdisciplinary focus, (3) the level of instruction and direction provided by mentors and staff, (4) the ways in which the experience differed from expectations, (5) whether students would recommend the Lake

Champlain REU to others, (6) advice for future cohorts, and (7) open comment time. All interviews were recorded using a digital recording device and transcribed verbatim.

For the blog, the program director prompted the students to write about how they were feeling and expectations for the program in the first week. In subsequent weeks, students were invited to reflect on how things were going, particularly in respect to their previous posts. As this information was to be displayed publically (on the program website), some may have filtered their responses. Lastly, I asked the four students who mentored high school students form the Upward Bound Program for a short reflection on this aspect of their program experience.

Participants

Students were recruited and selected into the Lake Champlain REU based on strict programmatic criteria. Ten students each year were selected from a national pool of applicants (Lake Champlain REU received 160 complete applications in both years). Recruitment efforts targeted students from underrepresented groups (Black, Hispanic, and American Indian, female, first-generation, and Pell-eligible, and persons with disabilities), rising first and second year students, and students from institutions with limited research options. The program worked with Vermont Experimental Program to Stimulate Competitive Research's Center for Workforce Development & Diversity at SMC and forged partnerships at the national level to establish a network to meet these recruitment goals.

The application included voluntary, self-reported demographic information (including gender, ethnicity, race, first-generation to attend college status, and Pell-eligibility status), academic background, an essay component, project and mentor preferences, and two letters of recommendation. Applications were aggregated into two groups: (1) rising first and second year students and, (2) rising third and fourth year students. Initial screening was conducted by the Lake Champlain REU principal investigator (PI) who selected the top 50% of applicants based on specific criteria outlined in their application essays, academic records, and letters of recommendations. The top applicants from each group were forwarded to a selection committee of two faculty members and one post-doc or graduate student to select the top 10 candidates. Any applicant that made top five list for all three committee members was placed in potential acceptance pool for review and discussion. After discussion, each committee member ranked their top five remaining applicants and had the opportunity to argue for or against the rank order. The committee debated the merits of the applicants' rankings, and pondered whether the candidates who were not ranked high as others might bring something interesting program before arriving at a consensus of final rankings. With consensus on the top-three students per project, phone interviews were conducted by mentors. Names of candidates were then forwarded to the PI who made the final decision. Offers were presented and a waiting list was created in the event an applicant rejected the offer. This process was repeated until all ten positions were filled.

Seventy percent of the whole cohort from both summers (*N=20*) self-identified as women, 15% as Hispanic or Latino/a, and 15% as Black or African American. Of the remaining students, 65% self-identified as White and 20% as Asian. Over half (60%) of the participants self-reported low-income status, as is determined by Federal Pell grant eligibility. One quarter (25%) of the participants identified as first generation to attend college. Participants were enrolled in a wide variety of majors and double majors at their undergraduate institutions that ranged from biology and environmental sciences to psychology and physics. The motivations participant described in the exit survey for pursuing a research experience at UVM are detailed in Table 12.

Table 12: Motivation to Pursue REU at UVM.

	% Yes
Gain hands-on experience in research	100%
Clarify which field I wanted to study	100%
Have a good intellectual challenge	100%
Enhance my resume	100%
Explore my interest in science	90%
Clarify whether graduate school would be a good choice for me	85%
Clarify whether I wanted to pursue a science research career	85%
Participate in a program with strong reputation	70%
Get good letters of recommendation	70%
Work more closely with a particular faculty member	65%

Research Site

This research was conducted at the University of Vermont (UVM), where the Lake Champlain REU students participated in a 10-week summer program where they designed, proposed, and conducted original research on Lake Champlain. In addition to the traditional research experience, students participated in "Thinking Like A Scientist" programming where they attended short learning modules each week that covered foundational, capacity-building topics such as critical reading and scientific writing, and career-oriented topics such as navigating graduate school and writing cover letters and resumes. Students also participated in a weekly journal club on interdisciplinary approaches to research and after dinner seminars held by Lake Champlain REU mentors and university faculty who informally discussed their career paths. Each summer concluded with a formal presentation of student research and, in some cases, the submission of a manuscript. The Lake Champlain REU program had four goals:

1. Provide interdisciplinary research experiences for undergraduates, including those

from underrepresented groups;

2. Increase students' understanding of and capacity for conducting independent research; prepare rising 3rd and 4th year students for graduate school and rising 1st and 2nd year students for advanced undergraduate research;
3. Provide hands-on, research assistant experiences for local high school students including individuals from underrepresented groups; and
4. Develop communication and mentoring skills for REU participants when working with each other and with high school students (University of Vermont, 2016).

Sampling Design

Convenience sampling was conducted with individuals who were available and willing to participate in the study (Onwuegbuzie & Collins, 2007; Tashakkori & Teddlie, 2003), a non-probabilistic technique, based on judgment and availability, not random selection (Plano Clark & Creswell, 2011). Conclusions were therefore derived through internal generalization from the sample as a whole (Maxwell, 1992), and naturalistic generalization of participants' personal experiences and perceptions were used to filter the conclusions (Stake, 2005). Given the small sample size (*N=18*), it was determined that there was insufficient statistical power to conduct analysis beyond frequency counts on the quantitative data. Onwuegbuzie et al. (2009) suggest between three and six groups as sufficient for studies that use focus group data, and my study meets the maximum threshold of six.

Analysis

Using the mixed methods model of convergent parallel design, quantitative and qualitative data were collected concurrently, with equal priority given to both (Plano

Clark & Creswell, 2011). Each phase was independent of the other and the mixing was conducted in the last stage (Plano Clark & Creswell, 2011). Using a concurrent, mixed methods design strategy offered the richest source of material while considering the practical constraints regarding the window of time that data collection could take place. All analysis was conducted through the conceptual framework of Markus and Nurius' (1986) theory of possible selves, self-efficacy for research (Caprara et al., 2008; Packard & Nguyen, 2003), and social cognitive career theory (Lent et al., 2002).

Concurrent triangulation allowed one data set to compensate for the weaknesses of the other (Small, 2011). The quantitative data from the Likert scale response questions provided information about areas where students experienced gains (or not) in skills and confidence as a result of their summer research experience, and qualitative data from students' exit interviews, short answer statements to the survey, blog entries, and written reflections provided rich descriptions of the internal workings within the program that gave rise to these gains. The heart of the study was to discover what works, or what was useful in the real world of this summer research program, a philosophy that is borne out of a pragmatic worldview (Plano Clark & Creswell, 2011; Small, 2011).

Means and standard deviations were calculated from the quantitative survey data and then were analyzed for whole-group trends. The qualitative data were transcribed with protocol that captured exact words from participants, but removed all "uhs," "ers," and pauses, except in the instances where meaning would have been lost (Miles & Huberman, 1994; Plano Clark & Creswell, 2011). The interview transcripts were aggregated by individual participant and linked to self-reported demographic information and uploaded into the mixed methods tool in HyperRESEARCH where I coded all the data. All identifying names were replaced with pseudonyms. I read and re-read the cleaned data to get an overall sense of themes, ideas, and questions (Miles & Huberman, 1994) and looked for reoccurring responses within the initial coding categories and added sub-codes where needed (Table 13).

Table 13: Summary of start codes and emergent sub-codes.

Start Codes	Emergent Sub-codes
Research skills	Communication Interdisciplinary Problem solving
Career-related experiences	Exploration of personally-relevant topics Independence and ownership for the work Support: mentoring and advising World of research aha
Confidence/ Self-efficacy for Research and Future-self	Value of future-self exploration More knowledgeable of opportunities Plans (including pre-post reflection on those plans), expectations, confirmations

Investigator Positionality

I acknowledge my own background in the context of this research and the significance of the role it has played. Like many of the participants in my study, I come from a humble, rural upbringing. With only a high school diploma, both of my parents worked a variety of blue-collar and domestic jobs to make ends meet.

As the first and only child in my family to have the privilege and honor to attend and graduate from college with a degree in science, I was immediately drawn to the Lake Champlain REU program's philosophy, mission, and goals. Like many who participate in research, I too had a powerful summer internship experience at the Montshire Museum of Science in the summer of my junior year, where I met Ginger Wallis who mentored me and introduced me to the idea of graduate school—a notion I had never considered.

The great Dewey (1916) believed that we “learn best what we live,”—that individualized, first-hand experiences offer opportunity for individuals to develop deep understandings and interests. For me, an ideal learning environment is where transdisciplinary partnerships support personalized learning in STEM. These are places that offer both implicit and explicit experiences, events, and situations that inform, encourage, and reinforce students’ self-conceptualizations of their futures. I am particularly dedicated to efforts that support underrepresented minorities in STEM. My experience implementing personalized learning programs with high school students began 15 years ago as a high school teacher-advisor. The Met School’s motto “One Student at a Time” resonated deeply with my educational philosophy, and has transcended across my teaching career and into my work as a doctoral scholar.

While my role initially began as the Lake Champlain REU program’s evaluator, I found myself drawn in by the students and their research, and by year two, I co-mentored a student who studied the public’s perception and understanding of invasive species in Lake Champlain. I relate to many of the struggles, to the feelings of isolation and doubt that surfaced from underrepresented minority students in the literature and in my own participants’ testimonials. I am partial to programs that actively support marginalized students, and I advocate for improving and expanding this model so that more underrepresented individuals in STEM can find support to be successful.

Findings

The research question invited me to look closely at the elements of the students’ research-related experiences that resulted in self-reported (1) gains in confidence and self-efficacy for research, (2) gains in research skills, and (3) STEM-oriented aspirations.

Three meta-categories emerged from the data: (1) situations where students had research-related experiences that led to gains in confidence (discussed in Part I), (2) experiences that led to gains in research skills (discussed in Part II), and (3) the combination of these experiences that led to gains in students' thinking about their futures (discussed in Part III). The quantitative and qualitative responses were hand-grouped into the meta-categories; however, it could be argued that some of the questions could fit into either category as there is a great deal of crossover. (Note: I included the underrepresented minority qualifying demographic characteristics after quotations in parentheses for reference.)

Part I: Exposure to Research and Career Contexts

A main objective of the Lake Champlain REU program was to increase students' understanding of and capacity for conducting independent research, to increase confidence, and to introduce them to the possibility of attending graduate school. The survey had eight questions that explored students' gains in confidence (Table 14).

Table 14: Means for underrepresented minorities in STEM or URMs (N=18) on confidence and self-efficacy for research from the URSSA survey on two scales.

Areas of Confidence and Self-Efficacy	URMs N=18	
	Mean	**S.D.**
Feel responsible for the project. [1]	4.89	0.38
Confidence in my ability to do research. [1]	4.39	0.77
Confidence in my ability to do well in future science courses. [1]	4.22	1.26
Feel like a scientist. [2]	4.22	0.94
Feel a part of a scientific community. [2]	4.17	0.99
Comfort in working collaboratively with others. [1]	4.17	1.04
Comfort in discussing scientific concepts with others. [1]	4.00	0.84
Confidence in my ability to contribute to science. [1]	3.72	1.08
[1] **5-point Likert Scale (No gain - Great gain)** [2] **5-point Likert Scale (None - A great deal)**		

There were 15 questions on the survey that fell into the meta-category of research-related contexts within the black box of the experience. The quantitative and qualitative data revealed three sub-indicator categories where students experienced exposure to research and career-like experiences: (1) exploration of personally-relevant topics and feeling a sense of ownership and independence, (2) receiving support through mentoring and advising, and (3) experiencing the aha moments of realization, inspiration, and insight into the world of research. Tables 15 and 16 detail the quantitative mean gains (separated out by their 4- and 5-point Likert scales, for clarity) for the survey questions, along with their sub-indicator categories. These data points are discussed in the subsections below.

Table 15: Means for underrepresented minorities in STEM or URMs (N=18) on career-related experiences from the URSSA survey on a 5-point Likert scale (None – A great deal).

Career-related Experiences	URMs N=18		Sub-indicator categories
	Mean	S.D.	
Understanding what everyday research work is like.	4.83	0.38	World of research aha
Engage in real-world science research.	4.39	1.04	
Ability to work independently.	4.39	0.92	Independence/Ownership
Work extra hours because you were excited about the research.	4.11	1.02	
Interact with scientists from outside your school.	4.06	1.39	World of research aha
Developing patience with the slow pace of research.	4.00	1.72	
Understanding the relevance of research to my coursework	4.00	0.91	Exploration and personally-relevant topics
Try out new ideas or procedures on your own.	3.72	1.25	Independence/ Ownership

Table 16: Means for underrepresented minorities in STEM or URMs (N=18) on quality career-related experiences from the URSSA survey on a 4-point Likert scale (Poor – Excellent).

Quality of Experiences	URMs N=18		Sub-indicator Categories
	Mean	S.D.	
The research experience overall.	3.56	0.62	World of research aha
My working relationship with research group members.	3.39	0.74	Support: Mentoring and Advising
My working relationship with my research mentor.	3.28	0.81	
The amount of time I spent doing meaningful research.	3.11	0.86	World of research aha
The advice my research mentor provided about careers or graduate school.	2.83	1.17	Support: Mentoring and Advising
The amount of time I spent with my research mentor.	2.78	1.22	

(1) Exploration of personally-relevant topics and feeling a sense of ownership and independence. REUs offer students immersion in day-to-day research, first hand experiences that connect to academics and beyond. One student said, “My first two years of undergraduate coursework have explored a considerable breadth of material but have thus far presented limited opportunities to dive really deeply into specific topics" (Pell-eligible). The balance between fostering a sense of independence and providing enough guidance is subtle and varies depending on mentor, student, and the nature of the research. When asked about what advice she would give to a future REU student, one student said, "Be prepared to motivate yourself independently." The mean gain for the question "ability to work independently" was 4.39 out of 5.00; many shared details about the extent to which they were "allowed" to govern their own research. One student said, "I think that maybe if my mentor was more hands on and directing me step-by-step, I would have had less independent development, which I think was really valuable" (Pell-eligible).

The question on the confidence table regarding the extent to which students "feel responsible for the project" had a mean of 4.89 out of 5.00, a topic that came up time and time again. One student shared, "I am grateful to have had so much control over my project. From developing my research question to designing my methods, my mentor has encouraged me to explore these processes on my own while still offering insightful advice and support" (female, first-generation, Pell-eligible). The mean gain for survey question "confidence in my ability to do research" was 4.39 out of 5.00, a process that varied from student to student—some slowly worked their way towards self-sufficiency, as is highlighted by this quote: "Now that we have gone through two full cycles of data collection I can seamlessly work on any part of this cycle independent of my mentor" (Black, first-generation, Pell-eligible). The blog entry below highlights the degree to which one student had to be self-motivated, and invested:

> I think I can best describe the first five weeks of this program as "research boot camp." I've been pushed to my limits and at times been unsure whether I could achieve all that is expected of me. Sometimes I feel that I've been thrown in the deep end as I strive to work productively alongside graduate students and post-docs on my own research project. But I can see now that the amount of independence I've been given has been instrumental in allowing me to rapidly develop the basic skills of a research scientist (Pell-eligible).

One student noted, "Now that I have gotten fairly acclimated to the field and lab work of my project I am finding time to draw conclusions and make sense of the data we are collecting" (Black, first-generation, Pell-eligible). Another student directly linked self-confidence with growth in research skills, "The more I learn the more confident I have grown in my abilities to produce a final product at the end of the summer and meet the expectations of those I am working with" (female, Pell-eligible).

(2) Receiving support through mentoring and advising. Half of the students had truly excellent mentoring experiences, two had good mentoring experiences, and the remaining six expressed disappointments in their mentoring experience, which largely had to do with one-on-one mentor availability. In these cases, support often came from others who assumed a mentor role.

Excellent mentoring. For individuals who had excellent mentoring, many described having access to support and advice, while at the same time being trusted and free to take the lead in their research. One student described it as the best mentoring experience he has had. Others in this category felt like the relationship with their mentors was collaborative and team-like. For example, one student shared: "The relationship that

I had with my research partner was great. I really felt like the three of us (my mentor, partner, and I) were a research team. We got along great and frequently worked together and collaborated" (Black, first-generation, Pell-eligible). Students were surprised about how available their mentors were and how quickly they would respond with specific directions and ideas. One student said she and her mentor discussed everything from future/career plans to questions about the research project and that she was looking forward to keeping in contact with her mentor in the future. Another student who had an excellent mentor said:

> When I've needed assistance, instruction, or any other form of support it has been readily available. I am deeply grateful to my mentor not only for providing direct input and resources but also for connecting me with a vibrant community of bright and energetic fellow researchers who daily impress me with their generous sharing of skills and knowledge. Early on I realized that there were more resources and opportunities available to me than I could possibly exhaust (Pell-eligible).

Students described how surprised they were by the outpouring of help, interest, and support by those that were in the world of research. Students who had excellent mentors expressed feeling as if they were "future members of the scientific community" (first-generation, Pell-eligible) and they felt supported. Half way through the summer experience, one student realized that mentoring went beyond the person to which he was assigned. He wrote, "I realize that I've begun to understand what it means to go into this field. I'm making more and more connections each day with people that could end up being future mentors or even colleagues" (first-generation, Pell-eligible).

Good mentoring. Two students, both for whom English was not their first language, experienced good mentoring. These students spoke at length about how hard it was at times to understand what their mentor was trying to convey. One said, "My mentor's expectation of me to understand everything s/he taught me was very high, and sometimes it could be difficult to understand everything the first time" (female, first-generation, Pell-eligible). Despite the challenges one student shared how much she learned from her mentor. She said, "S/he was really patient in explaining stuff to me, and I learned a bunch of stuff that I was never exposed to before." The students shared that the graduate students at their lab were helpful and able to answer questions as they made their way in the new environment.

Disappointing mentoring. Six Lake Champlain REU students enjoyed the time they got to interact with their mentors, but as it turned out, the mentors were not on campus enough to meet with students. One student wrote:

> I only met with him/her for maybe five or six times and I had an hour to share with the other intern. What ended up happening, each meeting s/he would tell us what we needed to do before our next meeting, and we had to go figure out how to do it ourselves, which has been a good experience in terms of learning to figure out things on your own and finding your own resources, but in the meantime, I do wish s/he was more easily available (female).

The level of expectation the students had for their mentors were high, as one student noted that they met 5-6 times, which may seem like a lot from an outside perspective, but expressed that this was not frequent enough. While these highly-structured meetings were helpful, the infrequency of contact left one student feeling isolated. Many in this situation shared important advice about persistence, independence, and resilience. One student said:

> Take ownership of your own work. Don't be afraid to be your own boss. Don't be afraid to reach out to your mentor…I quickly learned that you have to be persistent in your emails and things like that and not be afraid to ask others for help and just take ownership of your work (female, first-generation, Pell-eligible).

Students experienced mentors who were friendly and tried to be supportive, but the lack of physical proximity trumped these efforts and students felt the repercussions in the quality of their work.

(3) Experiencing the aha moments of realization, inspiration, and insight into the world of research. The Lake Champlain REU offered the opportunity for students to "engage in real-world science research," a question on the survey that had a mean gain of 4.39 out of 5.00. Over the 10-weeks, students had first-hand experiences that allowed them to develop and further hone numerous research skills. The question that assessed the extent to which students "feel like a scientist" had a mean of 4.22 out of 5.00. Students were invited to reflect on the extent to which they experienced the world of research, from the excitement and newness of it all to the slow pace. The mean for the survey question "amount of time doing meaningful research" was 3.11 out of 4.00.

Every student walked away with a personal picture of what "everyday research is like," a question that had an average gain of 4.83 out of 5.00. This image likely impacted how students thought about their futures. In the end, some expressed clarity about sticking with the type of research in the future similar to the type they conducted over the summer, and others were curious and enticed by other types of research experiences they witnessed or heard about and wanted to explore those options for the future. One student said,

> I have learned so much already about the nature of research and possible options for the future and I am excited to continue learning from all the individuals…This experience has taught me so much about conducting research from the start to finish of a project and I now feel confident in my ability to design, develop and conduct research projects in the future" (female, Pell-eligible).

After experiencing most the summer on the computer instead of out in the field, one student noted that, "It kind of made me realize that maybe that's the not best way to go about what I want to do" (female). Another student, after witnessing the research-life of her mentors in academia and hearing about other professors' career experiences in the after dinner seminars, wrote:

> I am not sure that I want to go into academia anymore because of seeing how hard my mentors work and learning more about other careers. I think I would like to work for a federal agency more now after applying to a doctoral program (female, Latina, Pell-eligible).

Several students had never done research before and described the experience as eye-opening. One student shared:

> I [have] a much clearer understanding of what's involved in scientific research in a lot more concrete way, in a hands-on way, in kind of detail-to-detail [way]: this is how you formulate a question, this is how you gather the background information to formulate the question—and these are testable hypotheses versus just sort of interesting ideas you're talking about (Pell-eligible).

Especially prominent were students' sense of surprise about the amount of time it took to gather and analyze data. The question "developing patience with the slow pace of research," had a mean of 4.00 out of 5.00. One student said, "I think this process is definitely teaching me patience, and I'm realizing that research doesn't go as quickly as you imagine for a lot of factors outside your control at times" (female, Pell-eligible). Another student shared:

> I was humbled by how much work goes into everything, and I came in with a false expectation that I am a really diligent person, so I can just bite off however much and I'll get everything done what I think I can get done—I got just half the laboratory analysis that I thought I was going to do and like one-week of statistical analysis (Pell-eligible).

Part I takeaways. Overall, students described a vast array of contexts where they were exposed to research, many of which cultivated interest through the exploration of personally-relevant topics where students experienced agency, autonomy, and support from faculty and peer mentors. The day-to-day experiences in the world of research were experiential and contained formal and informal opportunities to interact and collaborate. A theme that rose to the surface was the program's emphasis on having a collaborative learning community that promoted a culture of growth, reflection, and hard work that lead to aha moments. The daily experience of being exposed to research and career related topics over 10-weeks played a powerful role in students' understanding of the sometimes mysterious world of research, which is important for development of confidence and self-efficacy for research, and ideas about future-selves.

Part II: Self-Reported Gains in Research Skills

Of the survey responses, 22 questions fell into the meta-category "research-related skills" (Table 17). Responses were on a 5-point Likert scale (no gain–great gain). To understand the contexts that targeted specific skill gains in research, I created tables that placed question response averages or percentages alongside program elements, like seminars and symposia (Table 18). For the first meta-category, research-related skills, the merging of the qualitative and quantitative data revealed overlap in several sub-indicator categories: (1) communication skills, (2) interdisciplinary skills, and (3) problem solving skills. Again, categorization was subjective, there were areas where the groups overlapped.

Table 17: Means for underrepresented minorities in STEM or URMs (N=18) on research-related skills from the URSSA survey on a 5-point Likert Scale (No gain - Great gain).

Research Skills	URMs N=18	
	Mean	**S.D.**
Preparing a scientific poster.	4.50	0.86
Problem-solving in general.	4.39	0.70
Taking greater care in conducting procedures in the lab or field.	4.33	0.97
Working with computers.	4.28	0.97
Understanding journal articles.	4.28	0.99
Think creatively about the project.	4.22	1.18
Understanding the connections among scientific disciplines.	4.17	0.79
Analyzing data for patterns.	4.17	0.92
Identifying limitations of research methods and designs.	4.17	0.79
Explaining my project to people outside my field.	4.11	0.99
Figuring out the next step in a research project.	4.11	0.83
Conducting database or internet searches.	4.11	1.23
Understanding the theory and concepts guiding my research project.	4.06	0.90
Making oral presentations.	4.00	0.73
Formulating a research question that could be answered with data.	3.94	0.87
Writing scientific reports or papers.	3.89	1.00
Managing my time.	3.72	1.22
Defending an argument when asked questions.	3.44	1.25
Using statistics to analyze data.	3.44	2.17
Keeping a detailed lab notebook.	3.41	1.77

Table 18: A comparison of Lake Champlain REU formal program elements and research-related skills from the questions on the URSSA survey, grouped by categorical theme.

Research-Related Skills	Formal Program Elements	Sub-indicator Categories
Preparing a scientific poster (μ = 4.50).	Research symposium	Communication Skills
Explaining my project to people outside my field (μ = 4.11).	Effective talks; Peer-to-peer sharing; Proposal symposium, Public presentation at ECHO science museum, Research symposium	
Making oral presentations (μ = 4.00).	Communicating science to the public seminars; Effective posters seminar; Effective talks seminar; Mentor meetings; Poster peer review I & II seminars; Proposal symposium; Public presentations; Research symposium	
Defending an argument when asked questions (μ = 3.44).		
Writing scientific reports or papers (μ = 3.89).	Weekly journal club; Weekly scientific writing seminars	
Understanding journal articles (μ = 4.28).	Weekly journal club; Weekly scientific writing seminars	
Understanding the theory and concepts guiding my research project (μ = 4.06).	Content seminars (aquatic ecology, ecological economics, ethics, plagiarism, sociology, GIS, etc.); Mentor meetings; Weekly journal club; Weekly scientific writing seminars	
Formulating a research question that could be answered with data (μ = 3.94).	Mentor meetings; Weekly journal club; Weekly scientific writing seminars	
Understanding the connections among scientific disciplines (μ = 4.17).	Content seminars (sociology, aquatic ecology, ecological economics, GIS); Interdisciplinary focus of the program; Mentor meetings; Partner shadow days; Research symposium; Weekly journal club	Interdisciplinary Skills

(Continued on next page.)

Research-Related Skills	Formal Program Elements	Sub-indicator Categories
Think creatively about the project (μ = 4.22).	Combined elements of research experience	Problem-solving Skills (e.g. technical, laboratory, statistical, time and project management, etc.)
Problem-solving in general (μ = 4.39).	Combined elements of research experience	
Identifying limitations of research methods and designs (μ = 4.17).	Mentor meetings; Weekly journal club; Weekly scientific writing seminars	
Figuring out the next step in a research project (μ = 4.11).	Mentor meetings; Weekly scientific writing seminars; Weekly journal club	
Conducting database or internet searches (μ = 4.11).	Information literacy seminar	
Working with computers (μ = 4.28).	Mentor meetings	
Analyzing data for patterns (μ = 4.17).	Mentor meetings; Open stats days; Statistics seminar; Weekly journal club	
Using statistics to analyze data (μ = 3.44).	Mentor meetings; Open stats days; Statistics seminar; Weekly journal club	
Conducting observations in the lab or field (μ = 3.00).	Mentor meetings	
Calibrating instruments needed for measurement (μ = 2.50).	Mentor meetings	
Managing my time (μ = 3.72).	Effective elements of collaboration seminar; Leading and participating in effective discussions seminar	
Keeping a detailed lab notebook (μ = 3.41).		

(1) Communication skills. Sharing knowledge with others through writing, collaboration, and presenting were three subthemes that emerged in this category. Students spoke about the communication skills they developed from collaborating with outside organizations, like museums, municipalities, state agencies, and nearby colleges/universities, as well as with students from within the Lake Champlain REU and various other academic departments at UVM. The summer program offered three opportunities for students to prepare and conduct public presentations, each of which resulted in meaningful gains.

Reading, writing, understanding, and communicating research. Students read extensively before and during the REU. Most mentors sent students journal articles to read in advance of the program, a practice that students identified as beneficial and worth continuing in the future. Students who received and read project-specific journal articles before the start of the program had much to share about the importance of digesting material in advance of the research experience. Those who did not get articles to read, despite contacting mentors, were disappointed. One student said, "I feel like I would have done more had I done a little bit before I came and had a clear idea…I didn't have any preparation" (female, Pell-eligible.) Many shared that the articles were varied and gave them a feel for the expansiveness of their topics.

To improve students' reading and understanding research skills, Lake Champlain REU program leaders held two weekly seminars, journal club and scientific writing, where together as a learning community, they read and unpacked two articles per week from a pool of literature submitted by Lake Champlain REU mentors. Based on feedback from the first cohort, REU leaders tailored journal club in the second year to knit closely with the writing seminars and the interdisciplinary focus. Each week, program organizers focused on the sections of journal articles students were working on for their manuscripts. The structure was student-directed, with students taking turns leading each session in interdisciplinary pairs. Year two students seemed pleased with the improvements and content in both the journal club and writing seminars, for many, the journal club helped identify the ways in which their topics were interconnected and helped unite the cohort. Out of 5.00, the average gain on the question "understanding journal articles" was 4.28. One student described the challenge she faced as the co-discussant for that week's journal club. At first, she and her partner struggled to synthesize articles on two very different, but interrelated topics they were assigned. She said:

> It kind of made more sense to me as the program went on. I remember our first journal club when [student name] and I was [leading] together and I was like, "Okay, environmental economics and zooplankton! What? How does this even jibe?" And now I am like, "Well, obviously, I totally see the connection now" (female).

There were several students who were less comfortable with writing and, though they found it difficult, they felt very supported by the programmatic structures. One student said, "I haven't taken many science classes, so learning how to do scientific writing will definitely help me later on, especially with my desire to do graduate level studies" (female, Pell-eligible). The ever-present challenges with writing and evolution of this skill are reflected in the low mean gains on the question "writing scientific reports or papers," which was 3.80 out of 5.00. Slightly higher, however, was the question "understanding the theory and concepts guiding my research project," which was 4.06. A more difficult aspect of research "formulating a research question that could be answered with data" had a mean of 3.94 out of 5.00.

The challenge of writing a manuscript generated excitement in two students who said, "I am excited to continue working on this project as I write my final manuscript and I am hopeful to have similar science translation research opportunities in the future" (female, Pell-eligible), and "I am looking forward to writing up my final manuscript and submit it to be published in some form" (female, first-generation, Pell-eligible). Though it may not have been the highlight of most Lake Champlain REU students' weeks, the students expressed the benefit of participating in a scientific writing seminar that offered individual attention and feedback. One student, eager to submit his manuscript for publication said:

> I am very pleased that I was able to make arrangements with my mentor to allow me to continue working on my project in the coming months. There's a real possibility that the end result of this collaboration could be the publication of my research in a peer-reviewed journal before the end of my junior year. This is a thrilling goal to strive for and one which I feel well prepared by my experience this summer to achieve (Pell-eligible).

Collaborating. The short answer sections of the survey, exit interview, and blog revealed students' appreciation for the opportunities to refine their collaboration and communication skills as they worked closely with mentors, peers, colleagues in their labs, outside organizations, and high school students from the university's Upward Bound program. The question "comfort in working collaboratively with others," on the confidence table, had a mean gain of 4.17 out of 5.00, as most students found collaboration to be a positive experience. One student particularly enjoyed working with his high school interns:

> Not only am doing field work all week, but I'm also going to be receiving a couple of Upward Bound students to mentor that will help me with my project. It will definitely be a great growing experience for the students as well as me (first-generation, Pell-eligible).

Some students got the opportunity to work directly with professionals from a variety of fields and enjoyed how the opportunities provided a diversity of viewpoints. This student said, "When you have people from physics, environmental engineering, environmental science—you just get a whole new interaction and a lot of new ideas and opinions and I thought it was really useful" (female, Latina, Pell-eligible). Another student said, "It is interesting to see how people with different background[s] and expertise are joining for a common good and each brings a little knowledge, it's exciting" (African American, Latino, Pell-eligible).

Students enjoyed how the merging of ideas yielded stronger research. Most students from year two spoke about how much they enjoyed helping their two teammates collect data on the three field days, and were impressed by their peers' projects, as well as their abilities to lead the whole group in data collection. Though there was a great deal of learning that came out of the collaborative process, some expressed how their skills, like communication and planning, were challenged as they worked in partnership with others, especially with folks from outside organizations.

Presenting. In addition to the proposal and research symposia, the Lake Champlain REU program offered several seminars on communicating science through formal and informal means, from communication strategies for working with mentors and colleagues to communicating directly with the public. Several workshops targeted poster design, which was important for the culminating research summit that happened the final week of the program. Out of 5.00, the mean gain for survey question "preparing a scientific poster" was 4.50 and the mean gain on the survey question, "explaining my project to people outside my field" was 4.11. On the collaboration table, the question "comfort in discussing scientific concepts with others" had a mean gain of 4.00.

During the second week, all students delivered their research project proposals at a symposium open to REU students and mentors, where they had to introduce and defend their research agendas. The mean gain for "making oral presentations" was 4.00 out of 5.00. While communicating one's research can be a daunting challenge, the formal venues within the Lake Champlain REU provided a safe environment for students to have successful experiences. The proposal and final research symposia generated energy and excitement for research amongst the students. One student noted that it was "A great experience—it was awesome to see everyone's posters that we all worked so hard on, and it was really nice to get to talk one on one with people about my research" (female). Another student researcher said that the research symposium, "Went well and it was exciting to present our research to people. Seeing all of our research come together has been such a rewarding experience" (female, Latina).

These contexts highlighted the interdisciplinary focus of the research experience as well as the opportunity for students to explore their interests and actively engage in imagining possibilities for their future-selves. One student shared about the symposium:

> It was hard for me to explain internal nutrient loading a lot of time to a room of people who were doing varying things. It was also weird being in the poster session and having internal nutrient loading right next to different topics…I liked it. It made me realize there a lot of options that I can pursue—even if I don't like biogeochemistry there's some cool GIS stuff—that sounds cool! Why don't I try that? Or some social science stuff (Black, first gen, Pell-eligible)?

Some students described the importance of having the "tangible" poster and the opportunity to "field the tough questions asked by various academics." These events built self-confidence. One person called the symposium the "fruit of our productivity" (female, first gen, Pell-eligible) and expressed how proud she felt. Another student who was thinking ahead said:

> I hope to even present my poster at a conference in the future! It is motivating to know that, even after the program ends, there will be many opportunities for me to expand upon the skills I developed this summer and to share my work. Without a doubt, I would recommend this program to any student interested in exploring scientific research as a potential career (female, first gen, Pell-eligible)!

Most students expressed plans to present a talk or poster to other students and faculty in the future (Table 19). Where one student found the structure of the workshops to be overbearing and called for more independence, another felt the opposite and wanted more guidance. Many, however, had responses that resonated with this statement: "Now, I am more confident about writing research paper[s] and reading scientific articles" (female, first gen, Pell-eligible). In the end, each produced and presented an original manuscript and poster.

Table 19: Percentages of underrepresented minorities in STEM or URMs (N=18) who expressed research-related plans for the future.

Future Plans within Research	URM N=18 % Yes
I will present a talk or poster to other students and faculty.	83.3
I will present a talk or poster at a professional conference.	44.4
I will write or co-write a paper to be published in an academic journal.	33.3
I presented a talk or poster at a professional conference.	22.2
I will write or co-write a paper to be published in an undergraduate research journal.	22.2

(2) Interdisciplinary skills. A main goal of the Lake Champlain REU was to promote integrated thinking across disciplines within and between the natural and social sciences. The mean gain for "understanding the connections among scientific disciplines" was 4.17 out of 5.00. The exit interviews specifically asked students to remark on the interdisciplinary component of the program. Some students had experienced an interdisciplinary approach to their STEM studies at their home institutions, however few had previously had the opportunity to dive so deeply into the topics covered in this program. One student captured this sentiment in the following quote:

> I found the reality that a lot of scientists face where it's like when you come in and you're kind of green and you're like, "Oh, everything is connected, I can see where this fits in the big picture," and then you dive deep into something…that's what the summer was about—having a narrow focus and diving deep into something (Pell-eligible).

Another student remarked on the importance of having projects that overlap and that interdisciplinary research is important. One student shared, "The world is interdisciplinary—it's not just like you're a molecular cell in a vacuum—you have to connect with other people and I think that prepared us more for the real world" (female, Latina, Pell-eligible). A different student noted that, "Especially in the real world, when making decisions, you're not just looking at one thing—it's very complicated and you have to look at it from a holistic standpoint. Having that in this REU was definitely eye-opening for me" (Pell-eligible).

Many appreciated how the Lake Champlain REU connected the sciences with social sciences, some wished it was even more of an emphasis. Many were surprised by the diversity of projects they were exposed to over the summer and how the interdisciplinary nature of the program allowed them to apply their skills to unique challenges. Part of the interdisciplinary focus involved participating in a shadow day experience with a peer whose research was housed in a different field. In addition, in year two, the entire cohort assisted two students with data collection over a period of three days throughout the summer, which not only gave students more hands-on experiences with two very different forms of data collection, it provided an opportunity for two students to take on leadership roles as they explained their studies and guided their peers through the data gathering protocol. A student who assisted her peers in these days remarked, “I was a big fan of the shadowing experience and of James’ (pseudonym) water sampling and Beatrice’s (pseudonym) sampling—that was one of the best ways that the interdisciplinary picture manifested itself.” Beatrice, one of the two Lake Champlain REU students who received help with data collection, shared how this endeavor was one of the most demanding of the summer, yet yielded the most satisfaction for her:

> Leading it was really stressful—that was really hard—just trying to think of everything to put together—it was stressful, but it was really awesome—that was one of the most awesome parts of my project—[it] was like you design it, you create it, you put it all together—and then you’re also part of the implementation and everything—that was really worthwhile (Pell-eligible).

Several students expressed gains in their ability to communicate interdisciplinary projects to others, and one decided to pursue a field that combines interdisciplinary science and communication after her summer experience. When asked in the exit interview about his opinion on the interdisciplinary nature of the REU, one student remarked, “It made me really uncomfortable, in a good way.” (Black, first-generation, Pell-eligible). Another student noted in a blog entry:

> I am very interested in the relationships between scientific research and social change, and I have not had the opportunity to study any sort of policy at my home institution…As a biology and sociology double major, it is super exciting to be part of an interdisciplinary program that allows me to explore both sociology and biology. It was amazing to see how everyone's projects, including my own, came together! I have learned so much this summer and I look forward to applying all the skills I have learned to future endeavors (female, Pell-eligible)!

The interdisciplinary approach to the Lake Champlain REU offered students with a depth of experience across many subject areas, which afforded rich, diverse perspectives. One student noted, "I really liked how not everyone is in the same field, so sometimes when you are in the same field you get a lot of similar viewpoints about how they view science and other aspects…I really liked it" (female, Latina, Pell-eligible). Several students noted the importance of having diverse cohort and faculty members. One student said:

> We have different people from different backgrounds working together for this larger picture…everyone has his or her own role…and then after we combined everything together and from that process, I think we all learned about what other people are doing and from that way we can enrich our knowledge even more (female, first-generation, Pell-eligible).

The interdisciplinary emphasis of the program allowed for the cohort to get to know each other better and bond. One student said:

> I saw how James (pseudonym) and Greg's (pseudonym) projects went into Jane's (pseudonym) project which went into my project—you could see the line—but if you were only studying one, you'd never see that relationship, you'd never know

what else was going on because you're just focused on that particular thing. It's good to get a broader aspect of what you're looking at…Being an upcoming sophomore in college, I came into the REU program relatively void of experience. Never in my life have I been in such a place with an environment that promotes research to this extreme level (Black, female, first-generation, Pell-eligible).

At the end of the program, the cohorts were challenged to come up with a creative project that linked and presented each of their research studies. The first cohort created a film that highlighted the intersections of each of their topics, and the second cohort wrote and published a "Zine." In her blog entry, one student wrote:

> Everyone is doing a great job of condensing the biological/ economic/ physics-related jargon and making projects communicable and broadly relevant. Having a diverse and interdisciplinary range of projects happening on a similar time-scale with close collaboration is fostering connections that might not otherwise exist. Hopefully these connections will continue to grow and help to create multi-faceted, widely applicable outcomes from each of these projects (female).

Students enjoyed finding connections between their disciplines and research topics. Many expressed their excitement for these connections to further develop and for the relationships to extend beyond the summer experience.

(3) Problem solving skills. Two main sub-categories were borne out of this theme: technical skills and time and project management. Stories about working through technical and statistical challenges were prevalent and many described the outpouring of support from peers, mentors, others in their laboratory environments. Many portrayed how much time and effort it took to problem solve, but as one student pointed out, these

"Extra efforts yielded enormous benefits to me personally and professionally" (Pell-eligible). Throughout the qualitative data were examples of the "ups and downs" of the research experience. Students expressed gratitude for opportunities to improve their critical thinking and research skills.

The question "problem solving skills in general" had a mean gain of 4.39 out of 5.00. In short-answer responses students coupled problem solving with other skills, like communication. A student said, "One of my biggest gains was learning how to problem solve on my own and learning about good methods of communication and communicating with other people—like following up, being persistent with emails" (female, first gen, Pell-eligible). Others spoke about the connections between problem solving and having to be creative, the question "think creatively about the project" had a mean gain of 4.22 out of 5.00.

Technical skills. Throughout the summer students engaged in problem solving, which often required technical skillsets. Many student testimonials linked problem solving skills with technology, persistence, and excitement for research. Students spoke and blogged about troubleshooting that involved technology new to them; it was not surprising that out of 5.00, the questions "working with computers" had a high mean gain of 4.28 and that "figuring out the next step in a research project" had a mean of 4.10. One student shared:

> This week we were able to fix all the bugs in our code, and get the model to start giving us outputs. It was a great success and we are both happy to have solved through all the problems…we are continuing to figure the issues out in order to best get our model to represent Missisquoi Bay…I am learning a lot about the

inner workings of the model, and am starting to feel more and more comfortable with all the files and how they are run. I also feel more comfortable with the four different computer languages we are using, and am realizing how much I have learned so far (female).

Solving computer-based problems resulted in high levels of satisfaction, though many students expressed struggling, especially with statistics. Out of 5.00, average mean gain for “analyzing data for patterns” was 4.17. One student expressed the feelings she had after experiencing a success with her software:

> This week I ran into some challenges on ArcGIS—I was having a hard time figuring out how to make certain measurements, but after struggling for a few days and asking around (to not much avail), I finally had a breakthrough on Friday which felt SO GOOD. A nice surprise about my project is the amount of freedom I have—it’s a lot of independent work on my part so I can set my own schedule. The independence also means that sometimes I’ve had to struggle through problems, but it’s been a great learning experience since I realize that I can always figure things out by having patience and being resourceful (female).

Students took real pride in trying to figure things out on their own, the question “conducting database or internet searches” had a mean of 4.11 out of 5.00, which was a skill highlighted in the seminars and practiced by each of the students throughout the summer. One student described her approach to solving a technical problem by scouring journal articles on the topic before turning to her mentor:

> After reading numerous papers on the subject throughout the week, on Friday my mentor introduced me to some of the first steps I needed to do in ArcGIS and sent

> me to go figure out how to do it. Largely it was pretty straightforward, but wrestling with (and googling around for) the tasks which were less familiar to me was a rewarding experience because I felt such a feeling of accomplishment every time I learned a new way to do something (female)

Other students talked about specific lab-oriented skills they gained that will be useful beyond this research experience. One student said:

> I've learned so much and done things that I never could before like extracting lipids, going on mountain hikes, and giving presentations. I'm gaining some serious lab skills that I know I will use in the future, and I'm learning how the science community works (Black, first-generation, Pell-eligible).

These reflections overwhelmingly illuminate the importance of problem solving, in these instances with technical or computer challenges. They highlight the importance of having time to tinker and figure out solutions from a variety of sources, but more importantly, they underscore how the act of solving problems generates excitement and confidence.

Time and project management. When participants were asked in the exit interviews about what advice they would give to future REU participants, almost everyone brought up the topic of time. The main sentiment was that the 10-weeks went by quickly and students stressed the importance of being organized and mindful of goals. One student said, "Prepare as much as you can ahead of time because 10-weeks is really short and really solidifying your plan for what you're doing as early as possible will allow you to get more done" (female, Pell-eligible). Another student struggled with managing his time. He shared, "I would say that they should plan their time good, because I really had a hard time doing my own schedule. Don't leave things to the last minute," (Black, Latino, Pell-eligible).

Students had many opportunities to practice managing projects and timelines, a skill that is developing for many. The following quote captures this sentiment as the student describes the intensity of balancing the many aspects of research:

> Processing my results has been a lengthy process that has been going on since last week and will continue for the next week. I don't even know where the time has been going! This week I have been busy balancing different parts of my research project. It is definitely a good representation and preparation for the future. In the next week-and-a-half we will be preparing for a presentation to the public, a research symposium, and a panel discussion on top of processing data and finishing up our manuscript (female, Latina, Pell-eligible).

There were many quotes like the one above that came in the final two weeks of the program. What was interesting about students' reflections on this time was fact that they described it both as the most stressful point in the program and the most gratifying. This paradox is best captured in the participant's own words—one wrote, "[These] two weeks have been very stressful, we have had a lot of work. Despite all the work, I think that these past two weeks have been the most that I have enjoy[ed] (Black, Latino, Pell-eligible)." Another student shared, "The last week has been especially frantic, as we had to finish creating our zine, submit our posters, present our posters at the symposium, and finish packing. However, it was also the most rewarding" (female, Pell-eligible).

Part II takeaways. From the combination of quantitative and qualitative data, the Lake Champlain REU afforded students extensive opportunities to practice and improve communication, interdisciplinary, and problem solving skills, which resulted in feelings of pride and excitement for research. The interdisciplinary nature of the program provided the opportunity for students to get a broad look at research while diving deep into their own studies where they demonstrated growth in skills and integrated thinking. Students wore many hats over the 10-weeks and developed skillsets necessary to match the roles they assumed. It would be interesting to see how these skills transfer to post-experience situations—to survey students longitudinally after they applied these skills in a new research environment and reflected on the extent to which the Lake Champlain REU experience influenced their know-how and confidence.

Part III: Conceptualizing a Future in Research

The act of becoming familiar with or better at something has an impact on the levels of self-efficacy and confidence with that given subject or skill, and ultimately plays a role in future planning (Caprara et al., 2008; Lent et al., 2002; Markus & Nurius, 1986). Despite the limitations of this research, due to sample size and other factors described earlier, the data revealed that the experiences helped students expand and refine their skills and levels of confidence, which may influence future aspirations. Tables 20 and 21 highlight the extent to which students perceived the Lake Champlain REU as having a role on their future plans. In the qualitative comments, students shared how the program ignited newfound interests and skills, and influenced their plans for pursuing post-undergraduate education.

Table 20: Students' level of agreement for underrepresented minorities in STEM or URMs about statements regarding the impact of Lake Champlain REU on specific future plans on a 4-point Likert Scale (Strongly disagree – Strongly agree).

Specific Future Plans	**URMs N=18**	
	Mean	**S.D.**
My resume has been enhanced by my research experience.	3.78	0.55
My research experience has prepared me for graduate school.	3.61	0.61
My research experience has prepared me for advanced coursework or thesis work.	3.33	0.69
My research experience has prepared me for a job.	3.33	0.59
Doing research introduced me to a new field of study I want to pursue.	2.78	0.73
Doing my research confirmed my interest in my field of study.	2.67	0.77
Doing research clarified for me which field of study I want to pursue.	2.67	0.97

Table 21: Likelihood that Lake Champlain REU affected underrepresented minorities in STEM or URM students' specific future plans on a 5-point Likert Scale (Not more likely – Extremely more likely).

Specific Future Plans	**URMs N=18**	
	Mean	**S.D.**
Compared to your intentions before doing research, how likely are you now to:		
Enroll in a master's program in science, mathematics or engineering?	2.94	1.47
Work in a science lab?	2.72	1.49
Enroll in a Ph.D. program in science, mathematics or engineering?	2.44	1.34
Enroll in a combined M.D/Ph.D. program?	2.33	1.53
Enroll in a program to earn a different professional degree (i.e. law, veterinary medicine, etc.)	1.78	1.99
Enroll in medical or dental school?	1.44	1.89
Pursue certification as a teacher?	1.33	0.77

Several students described how their new interests and gains in skills will be beneficial for the future. One student spoke about how the program introduced him to a world outside of his biology major, "This experience has pushed me towards the paths of chemistry and geology. This was excitingly unexpected and I cannot wait to broaden my knowledge in the sciences beyond biology" (Black, first-generation, Pell-eligible). Others discovered new technology that will serve them well into their post-undergraduate and professional careers. One student said:

> I am so grateful that this exposure to so many different topics has opened my eyes to all of the possibilities of topics to pursue in the science and technology field. I

> feel that I have met great professors, students, and advisors who are all helping to prepare me to make decisions about my future (female).

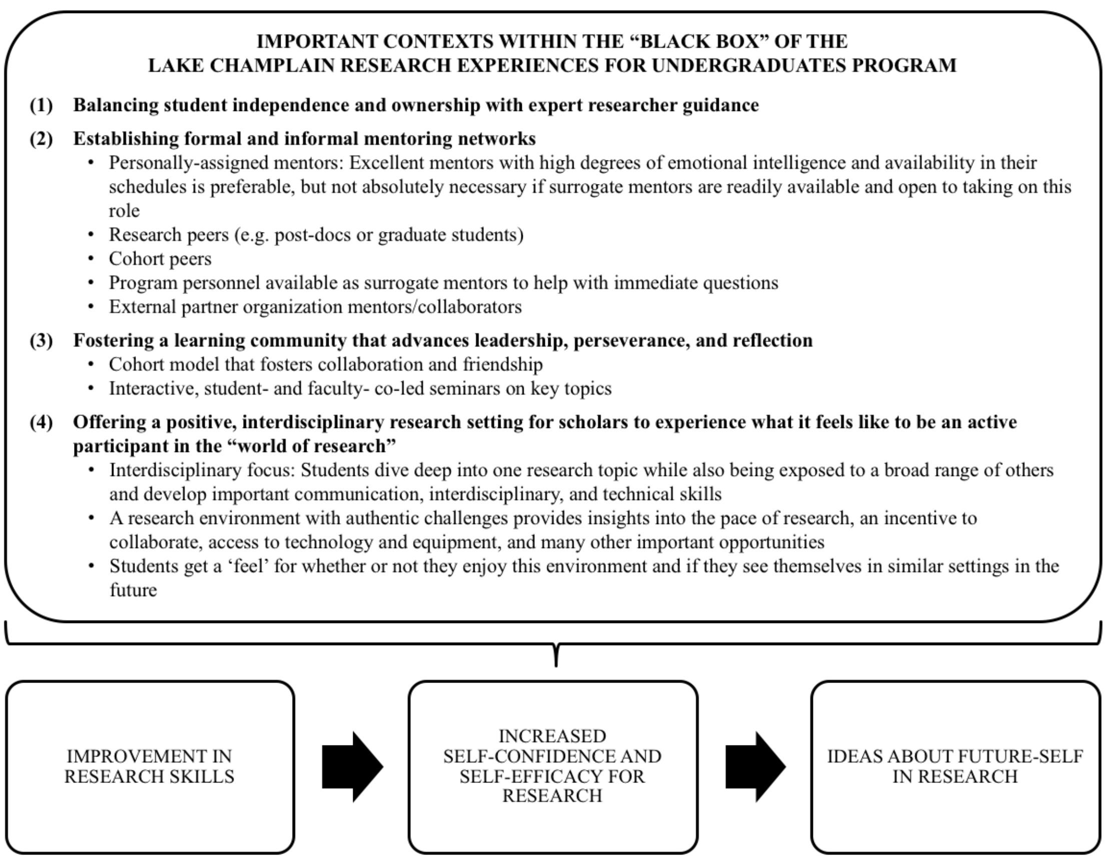
Several students spoke directly about their growth as researchers and all they learned about graduate school. Students described a feeling of preparation, especially after the after dinner seminars. One student described how she will be making "informed decisions" about her future, and another said she felt equipped for graduate school because she "realized how research works" (female, Pell-eligible). Most directly credited this experience as having great influence on their skill development, which directly impacts their future plans. One student said, "This REU is preparing me with skills I will continually use during my final year of college, onto my time as a graduate student" (female, Latina, Pell-eligible). The general sentiment of most of the students is captured in one student's quote:

> This has definitely been one of the most rewarding experiences of my life. As for research side of things, though it can be frustrating at times, the feeling you get after everything is completed is amazing, so I'm going to continue exploring my options (female, Pell-eligible).

Discussion

Using a mixed methods approach, my study examined a rich range of quantitative and qualitative sources to discover and describe the mechanisms about the contexts within the black box of the Lake Champlain Research Experiences for Undergraduates (REU) program that supported underrepresented minorities to experience: (1) gains in research skills, (2) confidence and self-efficacy for research, and (3) changes in thinking about their career aspirations in STEM. Four main themes emerged as important components, that when cultivated, can lead to successful experiences for undergraduate STEM majors: (1) balancing student independence and ownership with expert researcher guidance, (2) establishing formal and informal mentoring networks, (3) fostering a learning community that advances leadership, perseverance, and reflection, and (4) offering a positive, interdisciplinary research setting for students to experience what it feels like to be an active participant in the world of research (Figure 6) (e.g. Haen, Raman, Polush, & Kemis, 2012; Hathaway, Nagda, & Gregerman, 2002; Lent et al., 2005).

Figure 6: Four important mechanisms inherent the Lake Champlain REU program that supported underrepresented minority students' gains in research skills, confidence and self-efficacy for research, and conceptualizations about their post-undergraduate futures in STEM.



Independent Student Research

Independent research by students was cultivated in the Lake Champlain REU program. The combination of mentor direction, programmatic structure and guidance, along with high expectations offered the opportunity for Lake Champlain REU students to struggle and find independence. The path towards independence was not without toil or even failure, but the structure and culture of the program helped students get back on their feet and try again.

Mentoring and Advising

From the outset, the program cultivated an inclusive, welcoming environment where everyone was viewed as valuable contributors to the learning community as is extant in the literature (e.g. Adedokun et al., 2013; Carter et al., 2009; Maton et al., 2000). Having excellent mentors with emotional intelligence and availability in their schedules is preferable, but not absolutely necessary if surrogate mentors are readily available and open to taking on this role. The program prioritized mentoring and selected mentors were trained prior to the start of the REU. The training stressed collaboration, communication, and reciprocity, which made a real impact on students (e.g. Adedokun et al., 2010; Dolan & Johnson, 2009; Packard, 2016). Overall, students felt and appreciated that mentors had positive intentions, and for some who were not around as much, students reported that there was still an expression of genuine support (e.g. Berkes, 2007; Jacobi, 1991; Packard, 2016).

A surprising finding was that despite some students reporting of disappointing mentoring experiences, the Lake Champlain REU still had a profound effect on their gains in research skills, confidence and self-efficacy for research, and aspirations (e.g.

Berkes, 2007; Brooks et al., 1995; Brown, 2002). Anecdotes from these students highlight why it is vital to employ many types of data to study these programs. If I were to look only at the quantitative data, I would have seen a student rating of "poor" under the "working relationship with my mentor" question and would never have known about the depth of that experience, or about any of the positive gains that emerged for those students who had so much independence (e.g. Onwuegbuzie & Leech, 2006; Small, 2011; Tashakkori & Teddlie, 2003). What is fascinating is that this is not isolated to this one survey question or data point; most of the students, when they expressed frustration or disappointment, generally followed with a piece of wisdom that highlighted the bright side and the deeper learning.

A Learning Community Culture and Cohort Model

When students shared details about the challenges they faced, many followed up with a statement about the positive gains from that experience, the silver lining, a practice cultivated across the learning community (Carter et al., 2009; Lam, Ugweje, Mawasha, & Srivatsan, 2003; Tinto, 1987). For example, a student who described disappointment in her mentoring experience concluded with thoughts about how she developed independence and perseverance because of that experience. She described how she has more efficient and concise communication strategies, and how she walked away feeling resourceful and confident. This learning community fostered the practice of finding the silver lining within research-related challenges (e.g. Adedokun et al., 2013; Alexander et al., 1998; James, 1998).

The journal and writing clubs were one mechanism where the community gathered on a weekly basis to learn from each other. The purposeful paring of interdisciplinary teams to lead discussions in these work sessions played an important role in cultivating community, as did the shadow days and "all hands on deck" days (e.g. Bauer & Bennett, 2003; Taraban & Blanton, 2008; Thiry et al., 2011) These experiences provided opportunities for students to take on leadership roles, to explain their work to a new audience, to help out with each other's projects, to get feedback, to share challenges, to be receptive of ideas for improvement, and to build relationships (Bauer & Bennett, 2003). Further adding to this dynamic is the fact that the cohort members lived in the same dormitory, where they cooked, ate, and spent time traveling and being outdoors together, an element of the experience worth unpacking in further research.

The learning community culture also promoted the practice of self-reflection, which happened formally through the writing of the online blogs and informally in program gatherings (e.g. at the BBQ after the proposal symposium). At first I thought that because the blogs were public they might not have rich descriptions of students' inner thoughts, but as I began to read, I realized that this medium provided a platform for students to reflect on and express feelings about the many Lake Champlain REU-related experiences. Again, especially in the blogs, students explored challenges and then considered the bigger picture, which likely helped develop the practice of self-reflection. Not surprisingly, students complained at length about having to post to the blog and the first cohort especially wanted this practice discontinued, most likely because the process of reflection is hard. After getting this feedback, program coordinators changed the blog posts from weekly to one in the beginning, middle, and end of the REU.

The Interdisciplinary Focus

The emphasis on interdisciplinary studies brought the interactions of the learning community to a whole new level. The integration of this idea provided formal and informal opportunities for students to collaborate. The interdisciplinary focus also meant that although they had independent studies, students were not researching in isolation. Furthermore, the interdisciplinary focus provided challenges which required deep thinking and the commitment of time, as well as a certain degree of messiness. This structure afforded the opportunity for students to synthesize and defend their work, learn about their place in the larger ecosystem of research, collaborate in data collection, and actively engage in meaning making; tasks that push everyone to a whole new level.

Implications

Studying the mechanisms inside a research experience can be daunting, however the opportunity to discover as much as possible about the systems that give rise to important gains is vital if we want to identify and disseminate the best possible mechanistic archetypes to support students in STEM. Therefore, I support a new research agenda that asks tough questions about best practices, one that gets at elements of programs that work and that can be expanded, replicated, and applied more broadly—even beyond summer research programs and into everyday STEM undergraduate classrooms. To actualize this effort, I encourage REU programs to consider utilizing the cohort model on a macro-level, so that colleges and universities can learn from one another to improve this very important modality such that it holds the most benefits for the most students.

Limitations

While my study illuminated the programmatic elements that students identified as promoting an increase in research skill gains, confidence and researcher self-efficacy, and interest in and excitement to pursue post-undergraduate STEM vocations, it is not meant to be in any way confirmatory. The sample was limited to 18 participants who first self-selected via the application and then underwent a rigorous selection process at the university. REU entry requirements at this and many universities are robust, thus, the data is derived from a select sample of self-promoting, high achieving STEM majors who are likely to have a high sense of self-efficacy and ideas about future-selves from the outset.

Students and mentors hail from a variety of socioeconomic, ethnic, and geographical backgrounds and disciplines; each conduct research with varying technical sophistication and goals. I did not control for the many influences that might account for student responses about perception of gains in self-efficacy and career choices (e.g. academic achievement, pre-college experiences and ideas about future-selves, family factors, etc.). Students' decisions to pursue STEM are influenced by a myriad of factors, including everything from family attributes and individual personalities to specific interactions with professors (Abraham, 2002; Taraban & Blanton, 2008).

The study was conducted at one university setting and is not generalizable; there was no control or comparison group. The size and nature of the data do not allow for an empirical examination of the mediating effects on students' possible-selves formation. My study is reliant on self-reported data, which could be problematic as some respondents may want to cast the program in a particular light (Bauer & Bennett, 2008).

I relied on data that were captured by a survey (some sections of which are validated), blog entries, and exit interview responses (Critcher & Dunning, 2009; Linn et al., 2015; Weston & Laursen, 2015).

Acknowledgments

This work was supported by the National Science Foundation under award #1358838 and the Rubenstein School of Natural Resources at the University of Vermont.

References

Abraham, L. (2002). What do high school science students gain from field-based research apprenticeship programs? *Clearing House*, *75*(5), 229–232.

Adedokun, O. A., Bessenbacher, A. B., Parker, L. C., Kirkham, L. L., & Burgess, W. D. (2013). Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *Journal of Research in Science Teaching*, *50*(8), 940–951.

Adedokun, O. A., & Burgess, W. D. (2011). Uncovering students' preconceptions of undergraduate research experiences. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 12.

Adedokun, O. A., Dyehouse, M., Bessenbacher, A., & Burgess, W. D. (2010). Exploring faculty perceptions of the benefits and challenges of mentoring undergraduate research. *Online Submission*.

Adedokun, O. A., Zhang, D., Parker, L. C., Bessenbacher, A., Childress, A., Burgess, W. D., & Adedokun, B. O. A. (2012). Understanding how undergraduate research experiences influence student aspirations for research careers and graduate education. *Journal of College Science Teaching*, *42*(1), 82–90.

Alexander, B. B., Foertsch, J., & Daffinrud, S. (1998). The spend a summer with a scientist program: An evaluation of program outcomes and the essential elements for success. *Madison, WI: University of Madison-Wisconsin, LEAD Center*.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

Bauer, K., & Bennett, J. (2003). Alumni perceptions used to assess undergraduate research experience. *The Journal of Higher Education*, *74*(2), 210–230.

Bauer, K., & Bennett, J. (2008). Evaluation of the undergraduate research program at the University of Delaware: A multifaceted design. *Creating Effective Undergraduate Research Programs in Science: The Transformation from Student to Scientist*, 81–111.

Berkes, E. (2007). *Practicing biology: Undergraduate laboratory research, persistence in science, and the impact of self-efficacy beliefs*.

Brooks, L., Cornelius, A., Greenfield, E., & Joseph, R. (1995). The relation of career-related work or internship experiences to the career development of college seniors. *Journal of Vocational Behavior*, *46*(3), 332–349.

Brown, D. (2002). *Career choice and development*. John Wiley & Sons.

Caprara, G. V., Fida, R., Vecchione, M., Del Bove, G., Vecchio, G. M., Barbaranelli, C., & Bandura, A. (2008). Longitudinal analysis of the role of perceived self-efficacy for self-regulated learning in academic continuance and achievement. *Journal of Educational Psychology*, *100*(3), 525.

Carter, F. D., Mandell, M., & Maton, K. I. (2009). The influence of on-campus, academic year undergraduate research on STEM Ph. D. outcomes: Evidence from the Meyerhoff Scholarship Program. *Educational Evaluation and Policy Analysis*, *31*(4), 441–462.

Critcher, C. R., & Dunning, D. (2009). How chronic self-views influence (and mislead) self-assessments of task performance: self-views shape bottom-up experiences with the task. *Journal of Personality and Social Psychology*, *97*(6), 931.

Dewey, J. (1916). *Democracy and Education: An Introduction to Philosophy of Education*. Macmillan.

Dolan, E., & Johnson, D. (2009). Toward a holistic view of undergraduate research experiences: An exploratory study of impact on graduate/postdoctoral mentors. *Journal of Science Education and Technology*, *18*(6), 487–500.

Gandara, P., & Maxwell-Jolly, J. (1999). Priming the pump: A review of programs that aim to increase the achievement of underrepresented minority undergraduates. *College Board, New York.*

Grubb, W. (2009). *The money myth: School resources, outcomes, and equity*. Russell Sage Foundation.

Haen, K. M., Raman, D. R., Polush, E., & Kemis, M. (2012). Training the next generation of creative, innovative and adaptive scientists and engineers: The NSF Engineering Research Center for Biorenewable Chemicals (CBiRC) Research Experience for Undergraduates. *Education for Chemical Engineers*, *7*(4), e230–e240.

Hakim, T. (1998). Soft assessment of undergraduate research: Reactions and student perspectives. *Council on Undergraduate Research Quarterly*, *18*(4), 189–192.

Hathaway, R., Nagda, B., & Gregerman, S. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study. *Journal of College Student Development*, *43*(5), 614–631.

Hunter, A., Laursen, S., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36–74.

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2008). Diversifying science: Underrepresented student experiences in structured research programs. *Research in Higher Education*, *50*(2), 189–214.

Jacobi, M. (1991). Mentoring and undergraduate academic success: A literature review. *Review of Educational Research*, *61*(4), 505–532.

James, P. (1998). Progressive development of deep learning skills through undergraduate and postgraduate dissertations. *Educational Studies*, *24*(1), 95–105.

Jones, M. T., Barlow, A. E., & Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in biology. *The Journal of Higher Education*, *81*(1), 82–115.

Ladd, H., Chalk, R., & Hansen, J. (1999). *Equity and adequacy in education finance: Issues and perspectives*. National Academies Press.

Lam, P. C., Ugweje, O., Mawasha, P. R., & Srivatsan, T. S. (2003). An assessment of the effectiveness of the McNair Program at the University of Akron. *Journal of Women and Minorities in Science and Engineering*, *9*(1).

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*(1), 79–122.

Lent, R. W., Brown, S. D., & Hackett, G. (2000). Contextual supports and barriers to career choice: A social cognitive analysis. *Journal of Counseling Psychology*, *47*(1), 36.

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. *Career Choice and Development*, *4*, 255–311.

Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., … Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically Black universities. *Journal of Counseling Psychology*, *52*(1), 84.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate Research Experiences: Impacts and opportunities. *Science*, *347*(6222), 1261757.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE-Life Sciences Education*, *6*(4), 297–306.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877–907.

Markus, H., & Nurius, P. (1986). Possible selves. *American Psychologist*, *41*(9), 1–954.

Maton, K. I., Hrabowski, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. *Journal of Research in Science Teaching*, *37*(7), 629–654.

Maxwell, J. (1992). Understanding and validity in qualitative research. *Harvard Educational Review*, *62*(3), 279–301.

Miles, M., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Nagda, B., Gregerman, S., Lerner, J., von Hippel, W., & Jonides, J. (1998). Undergraduate student-faculty research partnerships affect student retention. *The Review of Higher Education*, *22*(1), 55–72.

National Center for Science and Engineering Statistics. (2013). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013*. Retrieved from www.nsf.gov/statistics/wmpd/

National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital* (pp. 1–62). National Science Foundation. Retrieved from http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf

National Science Foundation. (2016). Robert Noyce Teacher Scholarship Program. Retrieved from http://www.nsfnoyce.org/meetings/

National Science Foundation National Science Board. (2015). Revisiting the STEM workforce: A companion to science and engineering indicators 2014.

Onwuegbuzie, A., & Collins, K. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report*, *12*(2), 281–316.

Onwuegbuzie, A., Dickinson, W., Leech, N., & Zoran, A. (2009). A qualitative framework for collecting and analyzing data in focus group research. *International Journal of Qualitative Methods*, *8*(3), 1–21.

Onwuegbuzie, A., & Leech, N. (2006). Linking research questions to mixed methods data analysis procedures. *The Qualitative Report*, *11*(3), 474–498.

Packard, B. (2016). *Successful STEM mentoring initiatives for Underrepresented Students: A research-based guide for faculty and administrators*. Stylus Publishing, LLC.

Packard, B., & Nguyen, D. (2003). Science career-related possible selves of adolescent girls: A longitudinal study. *Journal of Career Development*, *29*(4), 251–263.

Plano Clark, V., & Creswell, J. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications.

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future* (pp. 1–142). Executive Office of the President, President's Council of Advisors on Science and Technology. Retrieved from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CCcQFjAA&url=http%3A%2F%2Fwww.whitehouse.gov%2Fsites%2Fdefault%2Ffiles%2Fmicrosites%2Fostp%2Fpcast-stemed-report.pdf&ei=gTj9UpTxFu_hsATdqoCQAQ&usg=AFQjCNFA_2H4xEWVmTlQC2K4N97mCthrKA&sig2=7xTflcCN64-yCaZglFmEgw&bvm=bv.61190604,d.cWc

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review*, *29*(6), 892–900.

Roe, A. (1952). A psychologist examines 64 eminent scientists. *Scientific American*, *187*(5), 21–25.

Russell, S., Hancock, M., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*(5824), 548–549.

Seymour, E., Hunter, A., Laursen, S., & Deantoni, T. (2004). Establishing the benefits of Research Experiences for Undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493–534. https://doi.org/10.1002/sce.10131

Small, M. L. (2011). How to conduct a mixed methods study: Recent trends in a rapidly growing literature. *Sociology*, *37*(1), 57.

Stake, R. (2005). Qualitative Case Studies. In N. Denzin & Y. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 443–466). Thousand Oaks, CA: SAGE Publications.

Strayhorn, T. (2010). Undergraduate research participation and STEM graduate degree aspirations among students of color. *New Directions for Institutional Research*, *2010*(148), 85–93.

Summers, M. F., & Hrabowski III, F. A. (2006). Preparing minority scientists and engineers. *Science*, *311*(5769), 1870–1871. https://doi.org/10.1126/science.1125257

Taraban, R., & Blanton, R. (2008). *Creating effective undergraduate research programs in science: The transformation from student to scientist*. Teachers College Press.

Tashakkori, A., & Teddlie, C. (2003). *Handbook of mixed methods in social & behavioral research*. Sage.

Terenzini, P. T., Yaeger, P. M., Bohr, L., Pascarella, E. T., & Amaury, N. (1997). African American college students' experiences in HBCUs and PWIs and learning outcomes.

Thiry, H., Laursen, S., & Hunter, A. (2011). What experiences help students become scientists?: A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *The Journal of Higher Education*, *82*(4), 357–388.

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. ERIC.

Tyack, D., & Cuban, L. (2009). *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

University of Maryland Baltimore County. (2016). Meyerhoff Scholars Program - UMBC. Retrieved August 26, 2016, from http://meyerhoff.umbc.edu/

University of Vermont. (2016). University of Vermont Rubenstein Ecosystem Science Laboratory NSF Research Experiences for Undergraduates. Retrieved from http://www.uvm.edu/~ecolab/?Page=REU.html

Villarejo, M., & Barlow, A. (2007). Evolution and evaluation of a biology enrichment program for minorities. *Journal of Women and Minorities in Science and Engineering*, *13*(2).

Villarejo, M., Barlow, A., Kogan, D., Veazey, B., & Sweeney, J. (2008). Encouraging minority undergraduates to choose science careers: Career paths survey results. *CBE-Life Sciences Education*, *7*(4), 394–409.

Weston, T. J., & Laursen, S. L. (2015). The Undergraduate Research Student Self-Assessment (URSSA): Validation for use in program evaluation. *CBE-Life Sciences Education*, *14*(3), 10.

CHAPTER 6 IMPLICATIONS

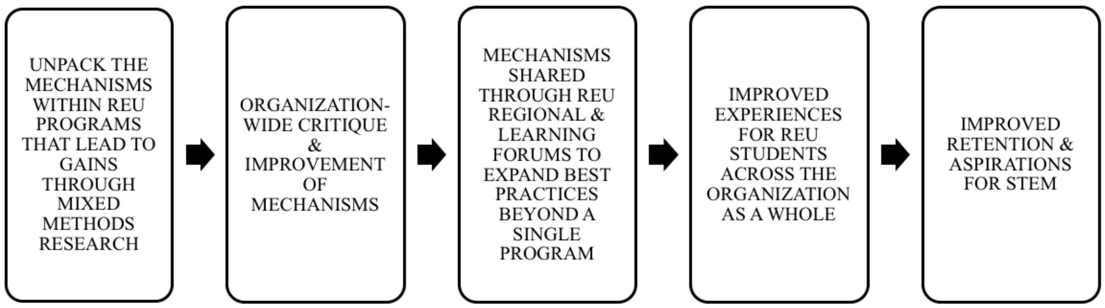
The purpose of this research was to expand upon the body of research that links students' experiences with conducting research and their gains in research skills, confidence and self-efficacy for research, and STEM aspirations. By identifying and illuminating the nature of the mechanisms within Research Experiences for Undergraduates (REU) programs that support these important gains, the findings from these studies have implications for scholarship about REUs as well as REU organizational leadership.

Implications for Scholarship and Research Experiences for Undergraduates Organizational Leadership

Despite the demand for a diverse STEM-educated population and workforce, college students have consistently turned away from these disciplines in large numbers, especially individuals from underrepresented groups in STEM (e.g. Carnevale, Smith, & Strohl, 2010; Chen, 2013; National Science Board, 2016). REU programs are designed to inspire, attract, and retain STEM majors and that is why it is important to incentivize scholarship that focuses on the pragmatic elements of what works within these programs (Plano Clark & Creswell, 2011; Small, 2011).

This research provides a fresh framework for approaching this research agenda (Figure 7). The overarching vision is to encourage those studying REUs to utilize a mixture of quantitative and qualitative data to identify the mechanisms that give rise to the gains we see in the extant literature that focuses either on quantitative statistics that are mostly outcome-based in nature, or qualitative studies that focus on themes generated from individual experiences. Once the mechanistic archetypes that support students are identified in individual settings, they can be expanded, replicated, and applied more broadly, such that this model of learning becomes the norm.

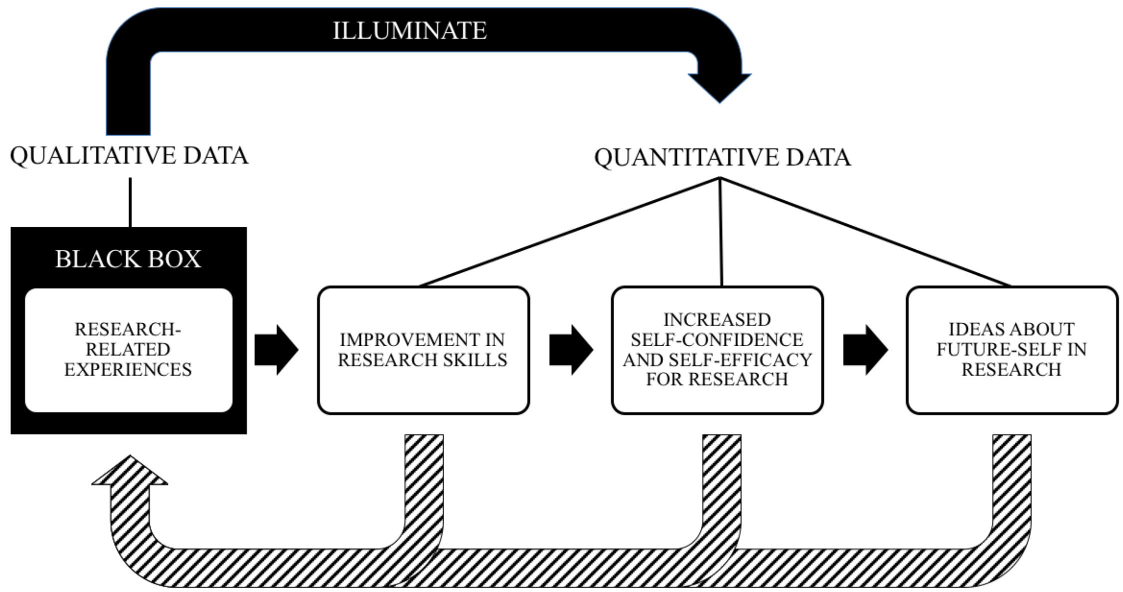
Figure 7: Proposed approach to future research agenda for REU programs.



With an eye towards programmatic sustainability and the desire to see best practices expanded beyond a single program, I propose that REU programs organize to come together annually as regional cohorts to share information and strengthen the organization. Other NSF-funded programs, like the Robert Noyce Studentship program, use this cohort model by gathering Noyce program principal investigators and students from specific regions together on an annual basis to share work (National Science Foundation, 2016). REU program administrators and students alike could participate in roundtables, poster sessions, and even panel discussions and explore important topics and meet colleagues from similar fields. For example, it would be interesting to have a roundtable discussion on types of data REUs collect (e.g. surveys, focus groups) and the quality of information that is gleaned from those instruments. For example, in my studies, data from the blog was surprisingly rich—students opened up and described their experiences, which provided valuable insight into the inner workings of the program and of their thinking about themselves and their futures.

My study offered an important conceptual contribution to extant literature, a new way of thinking about approaching REU research study designs. By using backwards design, I unpacked the mechanisms that exist within the black box of the Lake Champlain REU program (Figure 8). I analyzed the quantitative data, which was grouped into three categories, identified in the extant literature, of important gains. Other items may fall into the realm of important gains as REUs are more understood and as national priorities evolve. Once the survey data were grouped into the three outcome areas of improvements in research skills, gains in confidence and self-efficacy for research, and changes in aspirations for future self in STEM, I read, coded, and sorted the qualitative data into categories. The combination of the three frameworks, the theory of possible selves (Markus & Nurius, 1986), theory of self-efficacy for research (Caprara et al., 2008), and social cognitive career theory (Lent et al., 2002), were important for creating codes, because these theorists' research revealed the key elements that go into one's conceptualization of one's abilities, self-efficacy, and what one may consider a viable pathway for one's future. Once side by side, the qualitative data served to illuminate the means and frequency results from the quantitative data. The personal experiences of individuals illuminated the trends within the whole group. For example, an extensive description of a student's circumstance with his or her mentor brought awareness and understanding around a low mean for a survey item like "number of hours spent with my mentor."

Figure 8: The conceptual framework with three output areas (research skill improvement, self-confidence and self-efficacy for research, and conceptualizations of future-self) were analyzed using quantitative data from the exit survey. These areas were then traced back to the research-related experiences identified in the qualitative data (short answer sections of the survey, focus group interview, blog, and student reflection) that gave rise to these outputs. Qualitative data analysis illuminated the findings from the quantitative data analysis.



The four key mechanisms for the program that surfaced using this research approach were: (1) experiential education through interdisciplinary research experiences, (2) student independence and ownership balanced with expert researcher guidance and support, (3) formal and informal mentoring networks where students were mentored and where they mentored others, and (4) the establishment of an intentional learning community that advanced leadership, research skill building, perseverance, and reflection.

Results from this mixed methods research cannot be generalized beyond the context of the Lake Champlain REU, however, findings are in alignment with extant literature. The results from this research may prove to be an important starting point for future research on REUs. It would be interesting to examine the extent to which other

REU programs foster student capacity building within a safe, inclusive, and positive setting and to identify mechanisms that foster (or not) students feeling like they are an active participant in the world of research. By zeroing in on the within-program mechanisms that support these important gains, this methodological approach and theoretical framework offer a new direction for the research field, one that focuses on identifying, understanding, and replicating best practices.

COMPREHENSIVE BIBLIOGRAPHY

Abraham, L. (2002). What do high school science students gain from field-based research apprenticeship programs? *Clearing House*, *75*(5), 229–232.

Adedokun, O. A., Bessenbacher, A. B., Parker, L. C., Kirkham, L. L., & Burgess, W. D. (2013). Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *Journal of Research in Science Teaching*, *50*(8), 940–951.

Adedokun, O. A., & Burgess, W. D. (2011). Uncovering students' preconceptions of undergraduate research experiences. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 12.

Adedokun, O. A., Dyehouse, M., Bessenbacher, A., & Burgess, W. D. (2010). Exploring faculty perceptions of the benefits and challenges of mentoring undergraduate research. *Online Submission*.

Adedokun, O. A., Zhang, D., Parker, L. C., Bessenbacher, A., Childress, A., Burgess, W. D., & Adedokun, B. O. A. (2012). Understanding how undergraduate research experiences influence student aspirations for research careers and graduate education. *Journal of College Science Teaching*, *42*(1), 82–90.

Alexander, B. B., Foertsch, J., & Daffinrud, S. (1998). The spend a summer with a scientist program: An evaluation of program outcomes and the essential elements for success. *Madison, WI: University of Madison-Wisconsin, LEAD Center*.

Alfred, L. J., Atkins, C., Lopez, M., Chavez, T., Avila, V., & Paolini, P. (2005). A science pipeline pathway for training underrepresented students in the biomedical sciences. *Journal of Women and Minorities in Science and Engineering*, *11*(1).

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

Bauer, K., & Bennett, J. (2003). Alumni perceptions used to assess undergraduate research experience. *The Journal of Higher Education*, *74*(2), 210–230.

Bauer, K., & Bennett, J. (2008). Evaluation of the undergraduate research program at the University of Delaware: A multifaceted design. *Creating Effective Undergraduate Research Programs in Science: The Transformation from Student to Scientist*, 81–111.

Beninson, L. A., Koski, J., Villa, E., Faram, R., & O'Connor, S. E. (2011). Evaluation of the Research Experiences for Undergraduates (REU) sites program. *CUR Quarterly*, *32*(1), 43–48.

Berkes, E. (2007). *Practicing biology: Undergraduate laboratory research, persistence in science, and the impact of self-efficacy beliefs*.

Boyer, E. (1998). The Boyer commission on educating undergraduates in the research university, reinventing undergraduate education: A blueprint for America's research universities. *Stony Brook, NY*, *46*.

Brooks, L., Cornelius, A., Greenfield, E., & Joseph, R. (1995). The relation of career-related work or internship experiences to the career development of college seniors. *Journal of Vocational Behavior*, *46*(3), 332–349.

Brown, D. (2002). *Career choice and development*. John Wiley & Sons.

Business Roundtable. (2005). *Tapping America's potential: The education for innovation initiative* (pp. 1–21). Washington, D.C.: The Business Roundtable. Retrieved from http://www.uschamber.com/sites/default/files/reports/050727_tapstatement.pdf

Campbell, A., Skoog, G. D., Taraban, R., & Blanton, R. (2008). Transcending deficits and differences through undergraduate research. *Creating Effective Undergraduate Research Programs in Science: The Transformation of Student to Scientist*, 206–214.

Caprara, G. V., Fida, R., Vecchione, M., Del Bove, G., Vecchio, G. M., Barbaranelli, C., & Bandura, A. (2008). Longitudinal analysis of the role of perceived self-efficacy for self-regulated learning in academic continuance and achievement. *Journal of Educational Psychology*, *100*(3), 525.

Carnevale, A. P., Smith, N., & Strohl, J. (2010). *Help wanted: Projections of job and education requirements through 2018*. Lumina Foundation.

Carter, F. D., Mandell, M., & Maton, K. I. (2009). The influence of on-campus, academic year undergraduate research on STEM Ph.D. outcomes: Evidence from the Meyerhoff Scholarship Program. *Educational Evaluation and Policy Analysis*, *31*(4), 441–462.

Chen, X. (2013). *STEM Attrition: College Students' Paths into and out of STEM Fields* (No. 2014–1). National Center for Education Statistics.

Committee on Science, Engineering, and Public Policy. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future* (pp. 1–591). Washington, D.C.: National Academy of Sciences. Retrieved from www.nap.edu/catalog/11463.html

Committee on Science, Engineering, and Public Policy. (2012). *Coordinating Federal science, technology, engineering, and mathematics (STEM) education investments: Progress report*. The Office of Science and Technology Policy: National Science and Technology Council Committee on STEM Education, Federal Coordination in STEM Education Task Force.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: SAGE.

Critcher, C. R., & Dunning, D. (2009). How chronic self-views influence (and mislead) self-assessments of task performance: self-views shape bottom-up experiences with the task. *Journal of Personality and Social Psychology*, *97*(6), 931.

Dahlberg, S. (2001). Using climate change as a teaching tool. *Canadian Journal of Environmental Education*, *6*, 9–17.

Dewey, J. (1916). Democracy and Education: An Introduction to Philosophy of Education.

Dolan, E., & Johnson, D. (2009). Toward a holistic view of Undergraduate Research Experiences: An exploratory study of impact on graduate/postdoctoral mentors. *Journal of Science Education and Technology*, *18*(6), 487–500.

Doney, S. (2010). The growing human footprint on coastal and open-ocean biogeochemistry. *Science*, *328*(5985), 1512–1516.

Duncan, A., & Martin, C. (2010). *A blueprint for Reform: The reauthorization of the Elementary and Secondary Education Act*. Washington, D.C.: US Department of Education Office of Planning.

Fortenberry, N. (2016). Forward. In *Successful STEM mentoring initiatives for underrepresented students: A research-based guide for faculty and administrators* (pp. xiii–xiv). Sterling, Virginia: Stylus Publishing, LLC.

Gandara, P., & Maxwell-Jolly, J. (1999). Priming the pump: A review of programs that aim to increase the achievement of underrepresented minority undergraduates. *College Board, New York*.

Grubb, W. (2009). *The money myth: School resources, outcomes, and equity*. Russell Sage Foundation.

Hackett, E. J., Croissant, J., & Schneider, B. (1992). Industry, academe, and the values of undergraduate engineers. *Research in Higher Education*, *33*(3), 275–295.

Haen, K. M., Raman, D. R., Polush, E., & Kemis, M. (2012). Training the next generation of creative, innovative and adaptive scientists and engineers: The NSF Engineering Research Center for Biorenewable Chemicals (CBiRC) Research Experience for Undergraduates. *Education for Chemical Engineers*, *7*(4), e230–e240.

Hakim, T. (1998). Soft assessment of undergraduate research: Reactions and student perspectives. *Council on Undergraduate Research Quarterly*, *18*(4), 189–192.

Halstead, J. (1997). What is undergraduate research? *Journal of Chemical Education*, *74*(12), 1390.

Hathaway, R., Nagda, B., & Gregerman, S. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study. *Journal of College Student Development*, *43*(5), 614–631.

Henne, R., Henne, W., McMahon, W., Yee, S., Brasel, T., & Mehdiabadi, N. (2008). Alumni perspectives on undergraduate research. In *Creating effective undergraduate research programs in science: The transformation from student to scientist* (pp. 215–232). Colombia University: Teachers College Press.

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277–1288.

Hu, S., Scheuch, K., Schwartz, R., Gayles, J. G., & Li, S. (2008). Reinventing undergraduate education: Engaging college students in research and creative activities, *33*(4), 1–103.

Hunter, A., Laursen, S., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36–74.

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2008). Diversifying science: Underrepresented student experiences in structured research programs. *Research in Higher Education*, *50*(2), 189–214.

Hurtado, S., Eagan, K., & Chang, M. (2010). Degrees of success: Bachelor's degree completion rates among initial STEM majors. *Higher Education Research Institute at UCLA, January*.

Jacobi, M. (1991). Mentoring and undergraduate academic success: A literature review. *Review of Educational Research*, *61*(4), 505–532.

James, P. (1998). Progressive development of deep learning skills through undergraduate and postgraduate dissertations. *Educational Studies*, *24*(1), 95–105.

Johnson, R. B. (1997). Examining the validity structure of qualitative research. *Education*, *118*(2), 282.

Jones, M. T., Barlow, A. E., & Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in biology. *The Journal of Higher Education*, *81*(1), 82–115.

Kardash, C. (2000). Evaluation of undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology*, *92*(1), 191.

Kardash, C., Wallace, M., & Blockus, L. (2008). Undergraduate Research Experiences: Male and female interns' perceptions of gains, disappointments, and self-efficacy. *Creating Effective Undergraduate Research Programs in Science: The Transformation from Student to Scientist*, 191–205.

Ladd, H., Chalk, R., & Hansen, J. (1999). *Equity and adequacy in education finance: Issues and perspectives*. National Academies Press.

Lam, P. C., Ugweje, O., Mawasha, P. R., & Srivatsan, T. S. (2003). An assessment of the effectiveness of the McNair Program at the University of Akron. *Journal of Women and Minorities in Science and Engineering*, *9*(1).

Laursen, S., Seymour, E., & Hunter, A.-B. (2012). Learning, teaching and scholarship: Fundamental tensions of undergraduate research. *Change: The Magazine of Higher Learning*, *44*(2), 30–37. https://doi.org/10.1080/00091383.2012.655217

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*(1), 79–122.

Lent, R. W., Brown, S. D., & Hackett, G. (2000). Contextual supports and barriers to career choice: A social cognitive analysis. *Journal of Counseling Psychology*, *47*(1), 36.

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. *Career Choice and Development*, *4*, 255–311.

Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., … Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically Black universities. *Journal of Counseling Psychology*, *52*(1), 84.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate Research Experiences: Impacts and opportunities. *Science*, *347*(6222), 1261757.

Locks, A. M., & Gregerman, S. R. (2008). Undergraduate research as an institutional retention strategy: The University of Michigan model. *Creating Effective Undergraduate Research Programs in Science: The Transformation from Student to Scientist*, 11–32.

Lopatto, D. (2003). The essential features of undergraduate research. *Council on Undergraduate Research Quarterly*, *24*(139–142).

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, *3*(4), 270–277.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE-Life Sciences Education*, *6*(4), 297–306.

Lopatto, D. (2008). Exploring the benefits of undergraduate research: The SURE survey. *Creating Effective Undergraduate Research Programs in Science*, 112–132.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877–907.

Markus, H., & Nurius, P. (1986). Possible selves. *American Psychologist*, *41*(9), 1–954.

Maton, K. I., Hrabowski, F. A., & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff Scholars Program. *Journal of Research in Science Teaching*, *37*(7), 629–654.

Mau, W.-C. (2003). Factors that influence persistence in science and engineering career aspirations. *The Career Development Quarterly*, *51*(3), 234–243.

Maxwell, J. (1992). Understanding and validity in qualitative research. *Harvard Educational Review*, *62*(3), 279–301.

McIntosh, P. (1988). White privilege: Unpacking the invisible knapsack. *Race, Class, and Gender in the United States: An Integrated Study*, *4*, 165–169.

Mervis, J. (2015, February 5). NSF's new budget reflects White House priorities on climate and environment. *ScienceInsider*. News. https://doi.org/10.1126/science.aaa7810

Miles, M., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: biodiversity synthesis*. Island Press.

Nagda, B., Gregerman, S., Lerner, J., von Hippel, W., & Jonides, J. (1998). Undergraduate student-faculty research partnerships affect student retention. *The Review of Higher Education*, *22*(1), 55–72.

National Center for Science and Engineering Statistics. (2013). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013*. Retrieved from www.nsf.gov/statistics/wmpd/

National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital* (pp. 1–62). National Science Foundation. Retrieved from http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf

National Science Board. (2016). *Science & engineering indicators 2016*. Arlington, VA: National Science Foundation.

National Science Foundation. (2016). Robert Noyce Teacher Scholarship Program. Retrieved from http://www.nsfnoyce.org/meetings/

National Science Foundation. (2016, June). National Science Foundation: About Funding. Retrieved from https://www.nsf.gov/funding/aboutfunding.jsp

NSF National Science Board. (2015). Revisiting the STEM workforce: a companion to Science and Engineering Indicators 2014.

Ong, M., Wright, C., Espinosa, L., & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard Educational Review*, *81*(2), 172–209.

Onwuegbuzie, A., & Collins, K. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report*, *12*(2), 281–316.

Onwuegbuzie, A., Dickinson, W., Leech, N., & Zoran, A. (2009). A qualitative framework for collecting and analyzing data in focus group research. *International Journal of Qualitative Methods*, *8*(3), 1–21.

Onwuegbuzie, A., & Leech, N. (2005). On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies. *International Journal of Social Research Methodology*, *8*(5), 375–387.

Onwuegbuzie, A., & Leech, N. (2006). Linking research questions to mixed methods data analysis procedures. *The Qualitative Report*, *11*(3), 474–498.

Packard, B. (2016). *Successful STEM mentoring initiatives for underrepresented students: A research-based guide for faculty and administrators*. Stylus Publishing, LLC.

Packard, B., & Nguyen, D. (2003). Science career-related possible selves of adolescent girls: A longitudinal study. *Journal of Career Development*, *29*(4), 251–263.

Page, M. C., Abramson, C. I., & Jacobs-Lawson, J. M. (2004). The National Science Foundation Research Experiences for Undergraduates program: Experiences and recommendations. *Teaching of Psychology*, *31*(4), 241–247.

Parsons, F. (1909). *Choosing a vocation*. Houghton Mifflin.

Pelling, M. (2011). *Adapting to climate change, from resilience to adaptation*. Routledge, New York, NY, USA.

Plano Clark, V., & Creswell, J. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications.

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future* (pp. 1–142). Executive Office of the President, President's Council of Advisors on Science and Technology. Retrieved from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CCcQFjAA&url=http%3A%2F%2Fwww.whitehouse.gov%2Fsites%2Fdefault%2Ffiles%2Fmicrosites%2Fostp%2Fpcast-stemed-report.pdf&ei=gTj9UpTxFu_hsATdqoCQAQ&usg=AFQjCNFA_2H4xEWVmTlQC2K4N97mCthrKA&sig2=7xTflcCN64-yCaZglFmEgw&bvm=bv.61190604,d.cWc

Princen, T., Manno, J. P., & Martin, P. L. (2015). *Ending the fossil fuel era*. MIT Press.

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review*, *29*(6), 892–900.

Roe, A. (1952). A psychologist examines 64 eminent scientists. *Scientific American*, *187*(5), 21–25.

Russell, S., Hancock, M., & McCullough, J. (2006). *Evaluation of NSF support for undergraduate research opportunities: Follow-up survey of undergraduate NSF program participants*. Arlington, VA: SRI International.

Russell, S., Hancock, M., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*(5824), 548–549.

Sadler, T. D., Burgin, S., McKinney, L., & Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, *47*(3), 235–256.

Sadler, T. D., & McKinney, L. (2010). Scientific research for undergraduate students: A review of the literature. *J Coll Sci Teach*, *39*(5), 43–49.

Sala, O., Chapin, F., Armesto, J., Berlow, E., Bloomfield, J., Dirzo, R., … Kinzig, A. (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*(5459), 1770–1774.

Seymour, E., Hunter, A., Laursen, S., & Deantoni, T. (2004). Establishing the benefits of Research Experiences for Undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493–534. https://doi.org/10.1002/sce.10131

Small, M. L. (2011). How to conduct a mixed methods study: Recent trends in a rapidly growing literature. *Sociology*, *37*(1), 57–86.

Stake, R. (2005). Qualitative Case Studies. In N. Denzin & Y. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 443–466). Thousand Oaks, CA: SAGE Publications.

Strayhorn, T. (2010). Undergraduate research participation and STEM graduate degree aspirations among students of color. *New Directions for Institutional Research*, *2010*(148), 85–93.

Summers, M. F., & Hrabowski III, F. A. (2006). Preparing minority scientists and engineers. *Science*, *311*(5769), 1870–1871. https://doi.org/10.1126/science.1125257

Taraban, R., & Blanton, R. (2008). *Creating effective undergraduate research programs in science: The transformation from student to scientist*. Teachers College Press.

Tashakkori, A., & Teddlie, C. (2003). *Handbook of mixed methods in social & behavioral research*. Sage.

Terenzini, P. T., Yaeger, P. M., Bohr, L., Pascarella, E. T., & Amaury, N. (1997). African American college students' experiences in HBCUs and PWIs and learning outcomes.

Thiry, H., Laursen, S., & Hunter, A. (2011). What experiences help students become scientists?: A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *The Journal of Higher Education*, *82*(4), 357–388.

Thiry, H., Weston, T., Laursen, S., & Hunter, A. (2012). The benefits of multi-year research experiences: Differences in novice and experienced students' reported gains from undergraduate research. *CBE-Life Sciences Education*, *11*, 260–272.

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. ERIC.

Trosset, C., Lopatto, D., & Elgin, S. (2008). Implementation and assessment of course-embedded Undergraduate Research Experiences: Some explorations. *Creating Effective Undergraduate Research Programs in Science*, 33–49.

Tyack, D., & Cuban, L. (2009). *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

University of Maryland Baltimore County. (2016). Meyerhoff Scholars Program - UMBC. Retrieved August 26, 2016, from http://meyerhoff.umbc.edu/

University of Vermont. (2016). University of Vermont Rubenstein Ecosystem Science Laboratory NSF Research Experiences for Undergraduates. Retrieved from http://www.uvm.edu/~ecolab/?Page=REU.html

Villarejo, M., & Barlow, A. (2007). Evolution and evaluation of a biology enrichment program for minorities. *Journal of Women and Minorities in Science and Engineering*, *13*(2).

Villarejo, M., Barlow, A., Kogan, D., Veazey, B., & Sweeney, J. (2008). Encouraging minority undergraduates to choose science careers: career paths survey results. *CBE-Life Sciences Education*, *7*(4), 394–409.

Ward, C., Bennett, J., & Bauer, K. (2002). Content analysis of undergraduate research student evaluations. *Retrieved January*, *2*, 2008.

Weston, T. J., & Laursen, S. L. (2015). The Undergraduate Research Student Self-Assessment (URSSA): validation for use in program evaluation. *CBE-Life Sciences Education*, *14*(3), 10.

Wilson, Z. S., Holmes, L., Sylvain, M. R., Batiste, L., Johnson, M., McGuire, S. Y., … Warner, I. M. (2012). Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate STEM disciplines. *Journal of Science Education and Technology*, *21*(1), 148–156.