Incidents in the Undergraduate Research Experience that Contribute to an Interest in Science, Technology, Engineering, and Math (STEM)

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ABSTRACT

There is national attention and concern from industry leaders, educators and politicians that the United States will not be able to maintain its competitive edge due to the lack of students prepared for careers in science, technology, engineering, and math (STEM) (Hurtado et al., 2008; Kuenzi et al., 2006; Kuenzi, 2008; Laursen et al., 2010). Student-faculty research, such as is done during an undergraduate research experience (URE), has been shown to be a high impact activity leading to greater student interest in STEM careers. A closer look is needed to get an idea of what types of experiences during UREs impact a student's interest in persisting into a STEM field career and to understand what are the key mechanisms of the experience that make it meaningful. The findings in this study add to the literature by exploring participants views of the undergraduate research experience at non-doctoral-granting universities and by supporting the idea that UREs can be effective in these settings as well. Further, this study puts forward a theoretical explanation about how and why UREs promote a student's interest in persisting to a STEM field career.

The purpose of this qualitative study using critical incidents was to identify experiences during a URE that students perceived to encourage or deter their interest in pursuing a STEM field career following graduation and to identify causal mechanisms for why these experiences made a difference in their interest. This study was designed to use

a qualitative approach consisting of individual interviews and a focus group with a total of 31 participants from three institutions to identify and come to a more complex, multi-layered understanding of the undergraduate research experience. A card sorting technique where participants assigned each card to the *encouraged an interest*, *deterred an interest*, *neither encouraged nor deterred an interest*, or *did not experience* category was used initially to generate a conversation about what individual experiences that students perceive encourage or deter them from pursuing a STEM field career following graduation. Follow-up interview questions guided the participant in explaining the incident and how and why it impacted their interest in a STEM field career following graduation.

Findings of the study indicate that all participants began their URE with an interest in science. No one set of critical incidents was identified to encourage or deter an interest as the same incident could have positive and negative outcomes. Because of the initial strong interest in science, incidents identified in the literature as deterring an interest in STEM often served to help participants refine the field or topic in STEM they wanted to pursue rather than causing them to leave STEM altogether. The individual critical incidents during the URE in totality, not individually, had an impact on participants' interest in pursuing a STEM field career. It is a combination of multiple experiences or events that help students gain a greater sense of self and to refine career and research opportunities.

The main contribution of this study is a theoretical model of the mechanisms by which a variety of incidents during a URE can impact an interest in STEM. This model identifies underlying causal mechanisms on how UREs can promote an interest in STEM.

The model is similar to a grounded theory model in that it highlights student characteristics, contextual factors, mechanisms, and outcomes that help to refine STEM field career interest. The URE incidents in totality provide mechanisms resulting in outcomes that refine a career interest in STEM.

As all participants were still involved in their URE, this study is limited in that we do not know with any certainty if the participants will enter a STEM field career. Future research designed with a longitudinal time frame could follow participants throughout the URE then into their career thus allowing greater understanding as to why some students may choose to leave the STEM pipeline. In-depth case studies would allow for testing of the conceptual model to identify turning points in an interest in a STEM field career and how interests in a STEM field career are refined. Further, case studies would allow researchers to compare the conceptual model in different settings.

The goals of UREs can be advanced in settings where there is a central organizing office on campus that makes visible that the institution values research and STEM and creates opportunities where students can to connect to a wider community of researchers. Faculty mentors guiding UREs can advance a commitment to pursue science by continually articulating the importance and wider social significance of the research. Further, faculty mentors play an invaluable role by providing information about the range of opportunities to pursue research, connect students with other research, and encourage URE student attendance at professional conferences in order to begin identification with a wider community of like-minded individuals.

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GENERAL AUDIENCE ABSTRACT

Educators, industry leaders and politicians are concerned about the lack of students prepared for STEM field careers and the United States being able to maintain its competitive edge globally. One opportunity to prepare students for STEM field careers is through student-faculty research, such as is done during an undergraduate research experience (URE). This study was designed to identify and understand critical incidents in undergraduate research experiences that students perceive to encourage or deter their interest in pursuing a STEM field career following graduation and to identify why these experiences made a difference in their interest. An incident sorting process was used to identify individual experiences that students perceive encourage or deter them from pursuing a STEM field career following graduation. Participant interviews and a focus group were conducted to understand how and why the identified experiences had a bearing on the student deciding to pursue a STEM field career following graduation. Findings of the study indicate that incidents during the URE combined, not individually, had an impact on participants' interest in pursuing a STEM field career.

DEDICATION

In loving memory of Walter G. Cox, Sr. and Alma W. Martin

Neither of whom completed formal K-12 education but who were wise beyond their years

In honor of Jonathan, Joshua and Jordan Austin, who I love dearly

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Chapter One

Introduction

We live in a global society. There is national attention and concern from industry leaders, educators and politicians due to the lack of students prepared for science, technology, engineering and mathematics (STEM) field careers and the United States' ability to maintain a competitive edge (Hurtado et al., 2008; Kuenzi et al., 2006; Kuenzi, 2008; Laursen et al., 2010). The United States remains the top investor in science and engineering research and development, including through a commitment of federal resources to support the development of research skills at various levels of the educational pipeline. The United States has the largest population of science and engineering researchers, but the rest of the world is catching up and may soon surpass the United States if changes nationally are not made to remain competitive (National Science Board, 2014). To move the national agenda forward, the United States needs well-prepared graduates who can enter into careers and compete in the global marketplace.

A well-educated, well-prepared national workforce starts at the earliest educational level. Students who show an interest in STEM at the earliest education levels often begin to lose interest in STEM in middle school and may not pursue a career in the field due to poor STEM teaching, a lack of academically rigorous STEM classes and extracurricular opportunities in high school, deciding to pursue another degree option in college, changing their initial STEM major to a non-STEM major while in college, or deciding to pursue a different career path after graduation (Blickenstaff, 2006; Jacobs & Simpkins, 2005; Society of Women Engineers, 2006).

The metaphor of a “leaky pipeline” has been used to describe how students, particularly women and minorities, leave a STEM career trajectory through K-12 and higher education (Blickenstaff, 2006). Generally, students in developing countries leak out in high school with low graduation rates, students in western countries are more likely to leak out in college while students in Asian countries do not have these same types of leaks (Jacobs & Simpkins, 2005). The leaky pipeline metaphor does not, however, account for students who “leak in” or for individuals who may take a leave from STEM for personal or professional reasons but return later (Goulden et al., 2009; Layne, 2011). Nonetheless, understanding the issue of students leaving STEM in terms of a “leaky pipeline” is useful.

Troubling new trends suggest the narrowing of the pipeline to careers in science and engineering at the K-12 level due to failing schools. The Center on Education Policy’s (2012) adequate yearly progress report for academic year 2010-2011 indicates that nearly half (48%) of U.S. schools failed to meet Annual Yearly Progress (AYP) requirements as required by the No Child Left Behind Act (NCLB). This failure percentage is up from a 39% school AYP failure rate in academic year 2009-2010 and represents the highest failure rate since NCLB began in 2002. While the AYP failure rate varies greatly by state, 21 states and the District of Columbia had over half their public schools fail AYP 2010-2011. With schools failing to create an educational environment that promotes educational standards, students start their education at a disadvantage from students at passing schools, in passing states, and other countries with higher achieving schools. These disadvantages limit educational gains and impact college attendance.

The 2014 Condition of Education report confirmed the value of a college degree on economic prosperity. In 2012, one in five school-age students (age 5-17), 11.1 million in total, lived in poverty and this number has increased over the last decade (NCES, 2014). Students who persist and become college graduates will earn twice as much in their job as high school dropouts. Unemployment for college graduates is lower than those with a lower level of education attainment. While 90 percent of the age 25-29 population held a high school diploma or equivalent, only 34 percent of the same population held a bachelor’s or higher degree. Between 1990 and 2013, overall bachelor’s degree educational attainment rates increased for white, black and Hispanic students yet the white-black attainment gap also increased from 13 to 20 percent and the white-Hispanic gap widened 18 to 25 percent. This widening attainment gap means that while all races earned higher numbers of bachelor’s degrees, the difference in the number of bachelor’s degrees earned by white students and minority students continues to grow over previous years. Women have a larger educational attainment rate than men since the year 2000 with women seven percentage points higher than men for a bachelor’s degree earned and three percentage points higher than men for a master’s degree or higher earned in 2013. When compared to other countries that participate in the Organization for Economic Cooperation and Development (OECD), a higher percentage of students earn a bachelor's degree (32 percent) than in other countries where the average is 23 percent. However, since 2001, the bachelor’s degree or higher educational attainment gap between the United States and the other countries decreased by three percent.

A number of national initiatives have underscored the importance of science and technology skills to participation in the U. S. workforce. The *Science for All Americans*

(AAAS, 1989) initiative called for teaching all students to be scientifically and technologically literate. Subsequently, the National Research Council (1996) set forth science education standards that would move schools in a direction where all students were taught science in new ways that would help them become scientifically literate. From the *Science for All Americans* initiative and the National Research Council standards, educators began to evaluate how science was taught and what teaching methods were most effective. What soon became clear is that the standards did not account for the educational inequities among students not only in various regions of the country but also within the same school and same classroom (Calabrese Barton & Yang, 2000). These educational inequities may account for a significant number of students leaking out of the STEM pipeline before or during high school.

High school students interact with science, technology, engineering and mathematics subject matter through their academic coursework as well as clubs and organizations. However, access to these types of courses and extracurricular activities that reinforce in-class concepts varies by the amount of school resources and the student's educational capital such as family financial and educational pursuit support (Aschbacher, Li & Roth, 2010; Parks-Yancy, 2012; Stanton-Salazar, 1997). Students who have an interest in science early in high school yet decide not to pursue a STEM major in college do so for various reasons. These include viewing science as too hard, a lack of science-related extracurricular opportunities, lack of hands-on inquiry activities, limited encouragement from teachers and limited mentors or role models in science while students who persisted in the pipeline after high school had the opposite of these experiences (Aschbacher et al., 2010).

College major selection presents a critical juncture for students in the STEM pipeline. For those students who do select a STEM major, many face introductory courses in their field that serve as “weed out” courses where only the best and brightest persist while others are eliminated from the program (Bystydzienski & Bird, 2006). These courses disproportionally advantage men over women and many high potential students are directed out of STEM by these courses rather than encouraged and cultivated as budding STEM career professionals. “Weed out” courses alone do not explain why students leave STEM field majors during college. Other reasons include a lack of role models both within the institution and the larger body of STEM professionals and not seeing oneself as a scientist (Aschbacher, Li & Roth, 2010; Calabrese-Barton & Yang, 2000; Carlone & Johnson, 2007; Ceglie, 2011; Frazzetto, 2004; Rahm, 2007) as well as lack of family support (Aschbacher, Li & Roth, 2010; Brickhouse & Potter, 2001; Brown, 2002; Chinn, 2002).

Kuh’s (2001) theory of student engagement provides one lens for understanding why students leave STEM. Student engagement is the amount of time and effort a student puts into undergraduate activities (involvement) that result in learning outcomes and the ways in which institutions provide these opportunities to students (Kuh, 2001, 2009). Student engagement has been found to be positively correlated with a student’s grade point average, level of academic challenge, active and collaborative learning, student-faculty interaction, supportive campus climate, reading and writing, quality of relationships, institutional emphases on good practices, and integration of diversity into coursework (Carini et al., 2006).

Collaborative student-faculty research is one of ten high-impact activities of student engagement that enhance development and learning (Kuh, 2009). Results from the most recent administration of the National Survey of Student Engagement (NSSE) indicate that of senior year participants 22 percent of female respondents and 24 percent of male respondents reported participating in out of class research with faculty (NSSE, 2013b). Engagement in research with faculty is positively related to deep approaches to learning that "help students make richer, more lasting connections to material through an emphasis on activities such as integration, synthesis and reflection" (NSSE, 2012, p. 10). NSSE data indicate that the small percentage of students who engage in research with faculty are more likely than their peers who did not engage in research with faculty to gain intellectually and personally, complete their degree and pursue a research related career (NSSE, 2013a).

A Century of Undergraduate Research

In this section, I review the definition of undergraduate research. I also discuss how it is grounded in the apprentice/master model but has now been placed in a more contemporary context.

The Council on Undergraduate Research (2013) defines undergraduate research experiences as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline." These experiences can take several forms: occurring during 10 weeks over the summer or throughout an academic year, be for credit or for pay, be in a lab or in the field, and result in publications or not. Two key features of an undergraduate research experience, according to Lopatto (2009), are collaboration with a faculty mentor and publishing the research either as a presentation or publication.

While the apprentice/master model for enculturating novices into a trade is centuries old, situations where a student conducts research under the close instruction of a faculty member has a long history that traces back to medical schools in the late nineteenth century (Laursen et al., 2010). During the mid-twentieth century, many research universities and liberal arts colleges began to organize undergraduate research opportunities for students (Laursen et al., 2010; Merkel, 2003). Notable institutions such as the Massachusetts Institute of Technology (MIT) and the California Institute of Technology (CalTech) formalized programs designed for undergraduates to engage in research. The MIT Undergraduate Research Opportunities Program began in 1969 with CalTech following later with a Summer Undergraduate Research Fellowships program in the late 1970s (Merkel, 2003).

At this same time, undergraduate research efforts were being formalized across the nation through the founding of The Council on Undergraduate Research (CUR) in 1978 by a group of chemists at private liberal arts colleges, that held its first meeting in 1979 (Merkel, 2003; CUR, 2013). CUR actively supports and promotes undergraduate research and scholarship opportunities as well as provides development opportunities to faculty who mentor undergraduate researchers (CUR, 2013). The organization has grown to now include almost 10,000 individual members and more than 650 institutions.

Between 1987 and 1998, three significant publications called for the reform of undergraduate education, including expansion of opportunities for undergraduates to participate in research. These were: (a) *College: The Undergraduate Experience in*

America by the Carnegie Foundation in 1987, (b) *Scholarship Reconsidered* by Boyer in 1990, and (c) *Reinventing Undergraduate Education: A Blueprint for America's Research Universities* by Boyer in 1998. These reports identified a lack of undergraduate student satisfaction with the college experience, called for a reconsideration of how undergraduate education was delivered and noted a lack of progress by research institutions to revamp undergraduate education (Merkel, 2003). Supporting activities like URE, the Boyer Commission (1998) recommended undergraduate education should focus on research-based learning. In response, institutions across the country have created student research programs to provide students with research-based learning opportunities now commonly known as undergraduate research experiences. These research experiences provide undergraduate students with the opportunity to break away from the traditional didactic teaching pedagogy and engage in hands-on, real world learning.

Resources to support undergraduate research opportunities have come from diverse sources. Undergraduate research is often funded by grants provided to institutions or individual faculty from public and private entities including the National Science Foundation (NSF), the Howard Hughes Medical Institute, the American Chemical Society's Petroleum Research Fund, the Camille and Henry Dreyfus Foundation, the National Aeronautics and Space Administration, the Research Corporation, and the Council on Undergraduate Research among many others (Labov et al., 2009; Laursen et al., 2013). The National Science Foundation's Research Experiences for Undergraduates program funds investigators designing research projects that involve undergraduate students (Laursen e al., 2010; Merkel, 2003). In 2001, the Research Corporation reported $683 million dollars has been granted to fund undergraduate research between 1991 and

2000. In 2014, the NSF alone has granted over half a billion dollars in active awards for Research Experiences for Undergraduate program participants (National Science Foundation, 2014).

With the rapid growth of undergraduate research opportunities and millions of funding dollars invested to support these efforts, the focus on undergraduate research began to shift at the start of the 21st century from creating undergraduate research opportunities to evaluating the programs to determine the benefits and if the research opportunities were worth the effort and financial support (Laursen et al., 2010). This focus on evaluation is part of a larger national focus on accountability, affordability and access in higher education. Within the last ten years, there has been high-volume growth in program evaluation publications, how-to manuals, best-practice statements, and searchable websites and databases on research and funding opportunities. These efforts have built the foundation for an ever expanding, evidence-based understanding of undergraduate research experiences.

Benefits of Undergraduate Research Experiences.

Student benefits from participating in an undergraduate research experience have been studied primarily through program evaluations and research studies (Laursen et al., 2010). Previous research on undergraduate research experiences has examined faculty involvement (Egan et al., 2010), mentoring (Meyers et al., 2010), minority students (Kendricks & Arment, 2011; Strayhorn, 2010; Woodcock et al., 2012), recruitment of students (Wozniak, 2011), and student gains from UREs (Adedokun & Burgess, 2011; Hunter et al., 2006; Lopatto, 2007; Thiry et al., 2011).

The complexity of undergraduate research experiences makes determining the benefits of participation difficult to identify (Lopatto, 2009). During the undergraduate research experience students can learn new skills, grow cognitively and socially, refine their career goals and develop professionally. While four percent of students steer toward science because of participation in an URE and few completely change their science career plans due to the URE, the relationship between undergraduate research experiences to STEM careers remains complex (Lopatto, 2009). There is a wide array of benefits from URE participation including clarifying career goals, strengthening academic credentials for graduate school admission, and helping the student learn more in the classroom after a hands-on research experience.

Laursen et al. (2010) conducted a review of recent literature on undergraduate research experiences. They found that the literature identifies undergraduate research as beneficial to students and increases retention, graduation and advanced study but that there is little knowledge about how or under what circumstances the process is effective. Laursen et al. (2010) identified six categories of student gains from an undergraduate research experience: (a) personal/professional gains, (b) gains in thinking and working like a scientist, (c) gains in becoming a scientist, (d) gains of skills, (e) enhanced preparation for career and graduate school, and (f) clarification, confirmation, and refinement of career and educational goals and interests (p. 45). Laursen et al. state that while much is known about what is working for undergraduate research, there remains a need for research on “how it works and why” (p.40). Additional study is needed to determine the circumstances under which the undergraduate research experience is most likely to be beneficial.

What We Need to Know More About Undergraduate Research Experiences.

Previous research on undergraduate research experiences have used both quantitative or qualitative methods, but no studies have sought to collect data about critical incidents during the undergraduate research experience that have an effect on STEM career interests. Critical incidents are “events, incidents or factors that help promote or detract from the effective performance of some activity or the experience of a specific situation or event” (Butterfield et al., 2005, p. 483). The majority of research studies on undergraduate research experiences rely on quantitative outcomes. Scholars have discussed the need for conducting qualitative research on undergraduate research experiences to provide a deeper understanding of these experiences that is not captured in quantitative studies (Meyers, et. al, 2010; Strayhorn, 2010). Understanding the “how” and “why” of undergraduate research experiences are best addressed through qualitative methods. Focusing on critical incidents during the undergraduate research experience will allow for identification of individual, micro-level experiences over the course of the whole URE.

Previous research studies have been conducted primarily at Research I and Liberal Arts institutions. In fact, the foundational, longitudinal study by Laursen et al. (2010) was conducted at four Liberal Arts institutions. We know that higher education institutions differ by institution type on mission, focus and types of educational experiences offered. Gaining a deeper understanding of undergraduate research experiences at and among various institutions types is needed. Where the previous research is limited is in providing data about undergraduate research experiences completed at Master’s level institutions. These are institutions that award fewer than 50 different doctoral degrees and at least 50 different master's degrees during the year (Carnegie Foundation, 2014). In 2010, the Commonwealth of Virginia had 16 Carnegie classified Master's level (larger, medium and smaller) institutions of which five are currently members of the Council of Undergraduate Research and have active undergraduate research programs (Carnegie Foundation, 2014; Council on Undergraduate Research, 2014). Additional research on undergraduate research experiences needs to expand our understanding of environmental influences by broadening the types of institutions studied. A contribution of this study is to consider how elements of the institutional environment in a more teaching oriented institution may influence the type of experiences students have while engaged in undergraduate research.

Many institutions now have administrative offices responsible for the oversight of undergraduate research experiences that are funded by both institutions and external funds. Findings from this study can potentially be used as a pedagogical tool for administrators working in this area. The exemplar vignettes can be used to identify ways faculty can structure the experience to maximize its potential benefits and to enhance the possibility that students will consider pursuing STEM. The vignettes will identify important incidents that serve to scaffold students' development and interest in STEM. These vignettes can be a way to breech the gap between science practitioners and research in the field. Additionally, the findings of this study can be presented at a conference on best practices in undergraduate research experiences. The vignettes will provide a wide array of student voices in regard to the undergraduate research experience and will highlight what incidents during the URE both promote and inhibit an interest in a STEM field career following graduation.

Purpose of the Study

The intent of this study was to examine STEM undergraduate research experiences (URE). For the purposes of this study, the Council on Undergraduate Research (2013) definition of an undergraduate research will be used. The purpose of this qualitative study using critical incidents was to identify experiences during a URE that students perceived to encourage or deter their interest in pursuing a STEM field career following graduation and to identify causal mechanisms for why these experiences made a difference in their interest. The study focused on identifying individual experiences that undergraduate students perceived encouraged or deterred them from pursuing a STEM field career following graduation and centered on gaining a deeper understanding on how and why the identified experiences had a bearing on the student deciding to pursue a STEM field career following graduation. The findings will add to our understanding about how undergraduate research experiences can contribute to an interest in STEM careers.

Research Questions

The following research questions were explored:

1. What specific incidents during an undergraduate research experience do students perceive to have encouraged their interest in a STEM field career following graduation?
2. What specific incidents during an undergraduate research experience do students perceive to have deterred their interest in a STEM field career following graduation?

3. Why do students perceive that certain incidents had a particularly strong impact on their interest in STEM?

Significance of the Study

This study is significant for several populations including undergraduate STEM students, faculty and staff administrators of undergraduate research experiences, and campus curriculum committees. It also has implications for policymakers developing federal and state programs to support STEM and to guide funders about where resources can be strategically placed to develop evidence based practices.

Undergraduate STEM students may find the findings of this study useful when considering undertaking an undergraduate research experience, selecting a faculty member to work with, and what they can expect from the experience. By understanding the undergraduate research experiences of the participants in this study, students starting a URE may gain insight into some of the issues they could influence the effectiveness of their own research experience.

Faculty and staff administrators and mentors of undergraduate research programs may use the findings of this study to more fully understand the student's perspective of the undergraduate research experience and to better prepare students for what to expect in an undergraduate research experience. Additionally, administrators may find this study useful for making programmatic changes to better facilitate undergraduate research experiences that foster a sense of identity in the field of study. Campus committees assigned to establishing and maintaining the undergraduate academic curriculum may find this study useful in understanding the impact an undergraduate research experience can have on student learning, retention, degree completion and career selection.

Policymakers could be influenced by the findings of this study. The focus on STEM undergraduate retention and matriculation into STEM careers will continue to have prominence in the policy landscape especially as the U.S. continues to compete in the global arena. This study can provide policy makers with information on STEM undergraduate research experiences and how these experiences influence student STEM identity formation. Policymakers may use these findings when making decisions about funding undergraduate research programs. Decisions need to be made on evidence provided by academically rigorous research. The findings from this study can be used to inform these decisions.

This study also has significance for future research. I explored STEM undergraduate research experiences at two Master's level institutions and one baccalaureate institution. Future studies could examine STEM undergraduate research experiences at other institution types or in other disciplines. These possible studies would expand what we know about undergraduate research experiences across all higher education institutions. Other possible studies could examine undergraduate research experiences for a longer length of time or track students from the time they enter the undergraduate research experience through graduation and into their career or graduate study. It would be interesting to have a deeper understanding of the identity development process from undergraduate study to career.

Organization of the Study

This study is organized in five chapters. Chapter One introduced the topic, purpose statement, research questions and significance of the study. Chapter Two presents the literature relevant to this study. Chapter Three describes the methodology including sample selection, data collection and data analysis. Chapter Four presents the study findings. Chapter Five relates the findings from this study to prior research and offers implications for future practice, research and policy.

Chapter Two

Literature Review

Undergraduate research experiences – "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" (Council on Undergraduate Research, 2013) – can occur during a 10-week summer long program, throughout an academic semester or year, or even be multi-year endeavors (Craney et. al, 2011; Laursen, Hunter, Seymour, Thiry & Melton, 2010). Reseachers have documented characteristics of students who benefit from undergraduate research experiences, student gains, and attributed outcomes – what student's learn. Much of this literature offers examples of incidents – specific events – experienced by students during their undergraduate research but no articles specifically address these incidents and the impact the incidents may have on a student's career interests. Finally, two theoretical frameworks have been used to understand undergraduate research experinces. These topics relating to undergraduate research experiences and how an URE may contribute to an interest in STEM are discussed in this chapter.

Characteristics of Students Who Benefit from URE

Laursen et al. (2010) found that faculty mentors of undergraduate research experience students agreed on the characteristics of students who are likely to succeed or not in the URE and are therefore the characteristics they look for in a student to join their research project: tenacity, curiosity, risk taking, ability to handle uncertainty or the unknown, expressive of ideas, willingness to speak for oneself, dependable, independent, high academic grades, hard-working, collaborative, communicative and the ability to work well with others. Conversely, characteristics of students found to be less successful included lack of interest, passive learner, interested only in resume building, interested only to have summer employment, lower academic grades, lack of basic competence, inability to master techniques, and frequent breaking of equipment. In addition, Laursen et al. found that advisors were likely to favorably consider women, male students of color, first-generation students and students from institutions that offered limited research opportunities for their research projects as these students were seen as potentially benefiting most from the undergraduate research experience.

Kinkead (2003) offered three groups of students who may benefit from undergraduate research experiences: honors students, underrepresented students and pre-service K-12 teachers. She explains that honors students are the best and brightest at a university and are prime candidates to enhance their learning by participating in research which can make them competitive for admission into graduate school. Kinkead suggested that underrepresented students benefit from faculty mentoring offered in undergraduate research experiences and the experience itself helps these students gain a deeper understanding of higher education as an enterprise. In addition, she noted that participating in an URE has been linked to retention for minority students. Finally, Kinkead proposed students in education majors who are pre-service K-12 student benefit from undergraduate research experiences as K-12 education becomes ever more focused on discovery learning. Her thought is that if these pre-service teachers are experienced in the scientific method, they will then be able to share this knowledge to other students at an earlier age.

Attributed Gains from Participation in an URE

In response to a growing need to assess undergraduate research experiences, Kardash (2000) began to develop a list of research skills that could be studied to determine outcomes of participating in undergraduate research experiences. A pre- and post-assessment where student rated their research skills was given to students who participated in an undergraduate research experience. Faculty ratings of student's ability to perform the skills were used as an objective measure against the student self-reported measure. Some of the 13 skills rated included: understanding contemporary concepts in your field, making use of primary literature, formulate a research hypothesis, collect and analyze data, orally communicate results, and write for publication. On a scale of one (not at all) to five (a great deal), all skills had a mean rating of 3.2 or higher except for writing for publication which had a mean rating of 2.93. This study resulted in a list that could be used to determine the extent to which students gained in these skill areas from participating in an undergraduate research experience.

Seymour, Hunter, Laursen & DeAntoni (2004) identified five categories of student gains through coding and analyzing interview transcripts from undergraduate research experience students: (a) personal/professional gains, (b) gains in thinking and working like a scientist, (c) specific skills, (d) enhanced career and graduate school preparation, and (e) clarification and confirmation of career plans. Lopatto (2004a), using exploratory factor analysis, found ten factors that were possible benefits of undergraduate research experiences: (a) interaction and communication skills, (b) data collection and interpretation skills, (c) professional development, (d) personal development, (e) design and hypothesis skills, (f) professional advancement, (g) information literacy skills, (h) responsibility, (i) knowledge synthesis, and (j) computer skills. These factors align closely with the categories of gains identified by Seymour et al.

Following up on the findings of Seymour et al. and his work earlier in the year, Lopatto (2004b) surveyed over 1,100 undergraduate students from 41 institutions to confirm earlier findings regarding student gains from undergraduate research and to explore if the gains differed by institution type. Respondents were asked to indicate on a scale of one (no gain) to five (very large gain) the extent to which they had experienced gains on 20 different items. Four items – understanding the research process, readiness for more demanding research, understanding how scientists work on real problems, and learning lab techniques – had overall means of 4.0 and higher. The remaining 16 items – tolerance for obstacles, learning to work independently, skill in the interpretation of results, ability to analyze data, understanding how knowledge is constructed, becoming part of the learning community, ability to integrate theory and practice, understanding primary literature, assertions require supporting evidence, understanding science, understanding how scientists think, self-confidence, clarification of a career path, skills in oral presentation, skills in science writing, and learning ethical conduct – had overall means between 3.15 and 3.99.

Expanding on the earlier work by Seymour et al., Laursen et al. (2010) refined and expanded the grouping of gains to: (1) personal/professional gains, (2) intellectual gains, (3) gains in professional socialization, (4) gains in skills, (5) enhanced preparation for graduate school and work, and (6) career clarification and confirmation. Laursen et al. reviewed 25 well-designed, well-supported research and evaluation studies and identified the commonly reported gains. The three most frequently identified gains were increased confidence, establishing collegial relationships with advisors and understanding research through hands-on experience. Over half of the studies reviewed documented student gains in the ability to work independently; increased knowledge and understanding of concepts, laboratory techniques, instrumentation and how knowledge is constructed; improved communication, critical thinking, problem solving and writing skills; and establishing collegial relationships with peers. A small number of the studies reviewed also identified student gains in the ability to critique literature, understand the nature of research work, think creatively, and how to pose then investigate research questions.

Additionally, gains for students included increases in tolerance and perseverance, an interest in science, understanding collaboration as a professional work norm, and an intrinsic interest in learning.

Sadler and McKinney (2010) reviewed 15 years of scholarly literature on outcomes from undergraduate research and identified six categories of outcomes: career aspirations, confidence, the nature of science, intellectual development, scientific content knowledge, and skills. Career aspiration outcomes related to attending graduate school and general career intentions. Confidence outcomes came from students feeling they were able to do science and establishing science identities. From their participation in an URE, students gained a greater understanding of the nature of science, how science is done, and how doing science is multi-faceted. Intellectual development outcomes related to students improving in critical thinking and scientific reasoning. Scientific content knowledge gains stemmed from self-reported student data that the research experienced improved content knowledge. Finally, students gained various skills from their URE including aspects of the research process, communication, technical and computer skills, working independently, understanding scientific literature, scientific ethics and statistical skills.

Not every student who undertakes an undergraduate research experience benefits and therefore may decide to leave science. Lopatto's (2009) research indicated that students who are put off by undergraduate research leave science because they do not see themselves as researchers. The monotony and tediousness of research, isolation in a lab, and disappointment in mentoring are reasons why students may be discontented with their undergraduate research experience and thus leave the field. Students may enjoy the undergraduate research experience itself but through the process come to realize that a science career is not for them. Those who may have planned for graduate school or other additional education or training in the field appreciate that the undergraduate research experience provided them with a glimpse into the career and allowed them to see it was not for them. Outcomes of the undergraduate research experience are directly related to the individual experiences students have during their URE therefore it is important to consider the individual incidents students encounter to help understand what students gain and if after the URE they wish to pursue a STEM field career or not.

Influential Incidents during URE

In reviewing scholarly literature on undergraduate research experiences, I identified 16 incidents or experiences that are likely to occur during UREs. As defined before, critical incidents are “events, incidents or factors that help promote or detract from the effective performance of some activity or the experience of a specific situation or event” (Butterfield et al., 2005, p. 483). Table 2.1 provides a listing of each identified incident and the scholarly articles where that incident was identified. These incidents were identified through direct quotations from participants used to illustrate findings or were identified through the descriptions and discussion scholars provided in their research articles. While various authors may have used similar, yet varying terminology to describe the same type of incident, I grouped similarly named incidents into my single naming of incidents that occur during undergraduate research experiences. For example, I named one type of incident “performing basic procedures” which other authors called “performing routine procedures,” "monkey work," “menial tasks,” and “no real research.”

The last column of table 2.1 provides the total number of scholarly articles where each incident was identified. One single article did not identify every incident; however, seven of the incidents were identified in over half of the articles.

Two incidents, *collegial relationship with advisor/senior scientist* and *production, analysis and interpretation of data* were each identified in 13 articles and are the two most frequently identified incidents. Incidents during a URE where the undergraduate student developed a collegial relationship with their URE advisor or another senior scientist was discussed at length in many of the articles (Buckley, 2010; Buckley, Korkmaz & Kuh, 2008; Craney et. al, 2011; Harsh, Maltese & Tai, 2011; Hunter, Laursen & Seymour, 2007; Laursen, Hunter, Seymour & DeAntoni, 2006; Laursen et al., 2010; Lopatto, 2003; Lopatto, 2004a; Lopatto, 2007; Seymour et al., 2004; Thiry, Laursen & Hunter, 2011; Thiry, Weston, Laursen & Hunter, 2012) and has been demonstrated to significantly impact the student's experience (Thiry et al., 2011; Lopatto, 2007). Students routinely discussed the importance of the relationship or lack thereof they had with their research advisor or mentor. An example of an identified *collegial relationship with advisor/senior scientist* incident came from a participant in the study by Laursen et al. (2006) who stated,

> As a researcher, [faculty] are your peers; you're working with them. And you ask them questions, and they are just as excited to know what I'm doing as I am to know how they're doing, or what they could help me with … You don't have to be intimidated by them any more. (p. 59)

Table 2.1
URE Incidents Found in Scholarly Literature

Incident	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Total**
Collegial relationship with advisor/senior scientist		x	x	x			x	x		x	x	x	x	x			x	x	x		13
Production, analysis and interpretation of data		x	x		x	x		x	X	x	x		x		x		x	x	x		13
Publish research		x	x	x			x	x	X		x	x				x	x		x	x	12
Work/think independently	x						x	x	X	x	x	x	x	x	x				x		11
Present at/attend a conference			x			x		x	X		x	x			x	x	x		x		10
Use laboratory equipment/techniques		x		x			x	x		x	x	x	x				x	x			10
Review primary scholarly literature		x	x				x	x	X			x	x				x	x			9
Collegial relationship with/mentoring peers			x		x			x		x	x	x				x	x	x			9
Attend project staff meetings		x			x		x										x	x		x	6
One-on-one mentoring	x		x					x							x			x			5
Involved in project design and decisions		x		x		x						x			x						5
Failed experiment		x					x	x		x											4
Perform basic procedures														x	x			x	x		4
Fieldwork		x			x										x						3
Learning new computer software/skills								x					x				x				3
Networking with others in the field								x			x						x				3

Legend
1 Adedokun & Burgess (2011)
2 Buckley (2010)
3 Buckley, Korkmaz & Kuh (2008)
4 Craney, McKay, Mazzeo, Morris, Prigodich & deGroot (2011)
5 Feldman, Divol & Rogan-Klyve (2009)
6 Frantz, DeHann, Demetrikopoulos & Carruth (2006)
7 Harsh, Maltese & Tai (2011)
8 Hunter, Laursen & Seymour (2007)
9 Kardash (2000)
10 Laursen, Hunter, Seymour & DeAntoni (2006)
11 Laursen, Hunter, Seymour, Thiry & Melton (2010)
12 Lopatto (2003)
13 Lopatto (2004a)
14 Lopatto (2007)
15 Russell (2005)
16 Russell, Hancock & McCullough (2007)
17 Seymour, Hunter, Laursen & DeAntoni (2004)
18 Thiry, Laursen & Hunter (2011)
19 Thiry, Weston, Laursen & Hunter (2012)
20 Zydney, Bennett, Shahid & Bauer (2002)

Similarly, *production, analysis and interpretation of data* was another commonly mentioned incident during an undergraduate research experience (Buckley, 2010; Buckley et al., 2008; Craney et. al, 2011; Harsh et al., 2011; Hunter et al., 2007; Laursen et al., 2006; Laursen et al., 2010; Lopatto, 2003; Lopatto, 2004a; Lopatto, 2007; Seymour et al., 2004; Thiry et al., 2011; Thiry et al., 2012). The literature indicates that undergraduate research students find that unlike their classes where the lab experiments produce expected results an earn credit for the lab, experiments in their undergraduate research experience do not have an expected outcome and answer to obtain to earn credit. An identified *production, analysis and interpretation of data* incident came from Stephanie, a participant in the study by Buckley (2010) who stated,

> I would collect data and do graph work and then I would take it to my mentor … We'll interpret on what the data means to use and he'll say, … 'Something's going on here. Something is definitely going on here. I don't know why this is behaving like this.' So it was really nice to just sit there and try to interpret my own data. (p. 153)

Many students who participate in an undergraduate research experience have the opportunity to *publish their research* in scholarly publications within their field (Buckley, 2010; Buckley et al., 2008; Craney et. al, 2011; Harsh et al., 2011; Hunter et al., 2007; Kardash, 2000; Laursen et al., 2010; Lopatto, 2003; Russell, Hancock & McCullough, 2007; Seymour et al., 2004; Thiry et al., 2012; Zydney, Bennett, Shahid & Bauer, 2002). Authoring a scholarly publication positions a student well for competitive job opportunities or enrollment in graduate education (Hunter et al., 2006). This culminating event of the undergraduate research experience is seen by students as a positive experience that inculcates them into the profession.

The undergraduate research experience allows students to w*ork and think independently*, sometimes for the first time in their academic careers (Adedokun & Burgess, 2011; Harsh et al., 2011; Hunter et al., 2007; Kardash, 2000; Laursen et al., 2006; Laursen et al., 2010; Lopatto, 2003; Lopatto, 2004a; Lopatto, 2007; Russell, 2005; Thiry et al., 2012). Students are used to faculty telling them what they need to know through class lectures, are tested on this knowledge and expected to obtain specific, replicable results in laboratory experiments. The undergraduate research experience may offer students the opportunity t0 work independently for the first time. One student in the study by Lopatto (2007) shared, “the most important part of my summer research experience was my amazing mentor. She guided me through the planning, execution, and analysis of my work while allowing me enough space to work independently” (p. 304).

Presenting at or attending a conference was identified as an influential event in ten articles (Buckley et al., 2008; Frantz et al., 2006; Hunter et al., 2007; Kardash, 2000; Laursen et al., 2010; Lopatto, 2003; Russell, 2005; Russell et al., 2007; Seymour, et al., 2004; Thiry et al., 2012). Many undergraduate research students are given opportunities to present their research at their local institutions as well as regional, national and international conference. Presenting their research allows students to interact with scholars in their field and to begin to see themselves as a contributing member of the disciplinary community. A student in the study by Hunter et al. (2006) explained,

> I thought [the conference] was a great experience, seeing other people and then really talking to scientists. And I felt like I was really a part of

> everything because I had my own work that I could share and I understood so much more about what people were doing because I've written my own abstracts, I've written my own sections of papers…It seems like a really big deal, but in the scientific world, it's kind of like you *need* to see these people… (p. 52)

The undergraduate research experience can allow students to learn about and *use laboratory equipment and techniques* not afforded during classes (Buckley, 2010; Craney et. al, 2011; Harsh et al., 2011; Hunter et al., 2007; Laursen et al., 2006; Laursen et al., 2010; Lopatto, 2003; Lopatto, 2004a; Seymour et al., 2004; Thiry et al., 2011). Gaining skills on highly specialized instruments can lead a student to be highly competitive in jobs where this experience is preferred or required. An example of this was found in the study by Hunter et al. (2007) where a student commented,

> I now feel confident that I can walk into any room with any instrument and figure out how to make that instrument work. And that's a very nice confidence to have because it makes me feel a lot more optimistic when I look at somebody's web page and what kind of analytical methods they use in the lab. And I see this laundry list of 10, 15 different methods of analysis they're using, and I can look down that list and say, 'I know how to do half of these, and the other half of them I can figure out pretty easily, based on things I've done.' (p. 54)

An important part of any research project is *reviewing primary scholarly literature* (Buckley, 2010; Buckley et al., 2008; Harsh et al., 2011; Hunter et al., 2007; Kardash, 2000; Lopatto, 2003; Lopatto, 2004a; Seymour et al., 2004; Thiry et al., 2011).

Undergraduate students are expected to read books and journal articles to understand the larger context in which their study is situated. Reviewing the literature is also important for any student who presents or publishes their research. Gaining this skill is important to being successful in graduate school and a research career. Jake, a student in the study by Buckley (2010) explained, “There was a lot of literature that [my mentor] pointed me to. That’s what a lot of the project was doing, a lot of reading to help me with what I was doing” (p. 150).

Similar to building a collegial relationship with a mentor, incidents of c*ollegial relationship with and/or mentoring peers* were identified in nine articles (Buckley et al., 2008; Feldman et al., 2009; Hunter et al., 2007; Laursen et al., 2006; Laursen et al., 2010; Lopatto, 2003; Russell et al., 2007; Seymour et al., 2004; Thiry et al., 2011). While some undergraduate research experiences are individual endeavors, many students complete their research experience with a team that can be comprised of the faculty mentor, post-doctoral associates, graduate students, undergraduate students and staff technicians. The student’s relationship with peers has an impact on their research experience. An example of an identified collegial relationship with peers incident came from a male physics major in the study by Seymour et al. (2004) who stated,

> With my (research partner), we were pretty much working on it together. Especially going in as freshmen and not having any research experience. I think if we were alone, we just couldn’t have mustered the strength to go on with it because it’s so open-ended and so overwhelming – to not have someone else to talk to would have made it very difficult. (p. 511)

Attending project staff meetings is an incident that many undergraduate research students experience (Buckley, 2010; Feldman et al., 2009; Harsh et al., 2011; Seymour et al., 2004; Thiry, et al., 2011; Zydney et al., 2002). As stated previously, many students conduct their research in a team. Team staff meetings are necessary to ensure all members are communicating and sharing information about the research project. Thiry et al. (2011) shared a student's example of attending a meeting by saying, "I attended weekly staff meetings, where everyone would talk about the progress of their work. We would spend most of the time talking about whether their work was going to get funded for the next round" (p. 372).

The traditional apprenticeship model of undergraduate research experiences centers around the idea that a senior scholar mentors a novice apprentice (Wenger, 2006). *One-on-one mentoring* or lack thereof from the faculty mentor is an incident students will experience during their undergraduate research project (Adedokun & Burgess, 2011; Buckley et al., 2008; Hunter, et al., 2007; Russell, 2005; Thiry et al., 2011). Many students are mentored throughout their research study. Mentors may recommend the student for graduate study or employment opportunities and sometimes build lasting relationships with their mentee that last well beyond the undergraduate research project. Conversely, some undergraduate students do not have strong mentoring relationships with their faculty member. A student in the study by Thiry et al. (2011) explained, "I haven't had as much one-on-one time with my academic advisor. So far as a mentor, I would say that I have not had one. I just take care of myself" (p. 367).

Much like being able to work and think independently, undergraduate research students have the opportunity to be i*nvolved in project design and decisions* (Buckley, 2010; Craney et al., 2011; Frantz et al., 2006; Lopatto, 2003; Russell, 2005). Unlike the classroom setting, the undergraduate research project allows a student to present their ideas and design a study of their interest. This incident as identified in the story of a student in the study by Thiry et al. (2012) who described the project design process,

> I had input [into the experimental design]. I looked at a couple of papers that did similar work and then brought my ideas up to [the PI and my research advisor]. And they agreed and disagreed with a few things, and so we changed and found what works best. It was a joint effort. I brought up the ideas and they were just like, 'Oh yeah, that's definitely something that we were hoping to get done.'
>
> (p. 267)

Some undergraduate research students experience a *failed experiment* (Buckley, 2010; Harsh et al., 2011; Hunter et al., 2007; Laursen et al., 2006). This failure helped the student to understand that not every research project provides expected or wanted results. At times, a failed experiment can provide useful information regarding an area of study. A female chemistry student in the study by Harsh et al. (2011) explained this type of incident by stating,

> I'd say [URE] didn't help me with skills, as far as developing skills that I needed in the lab that I work in now, but I would say it did help me to understand a few things about research, which one is failure. A lot of things fail, and it's good to just know that it's not that you're dumb or you can't – you know, it's like that a lot of people fail, and a lot of research is a failure. (p. 87)

Not all undergraduate research students become integrally involved in the mentor's research project. Rather than helping to design a project or analyzing data, some students are relegated to completing smaller tasks such as cleaning lab equipment or p*erforming other basic procedures* (Lopatto, 2007; Russell, 2005; Thiry et al., 2011; Thiry et al., 2012). The undergraduate research experience can certainly be more than just these mundane tasks. A student in the study by Thiry et al. (2011) explained,

> … I found pure research to be pretty mechanical. I felt a lot of times that some sort of well-designed robot could be doing my job. There wasn't a lot of creativity in it at all. And there wasn't a lot of human interaction. I found myself just being in a lab, sort of doing monkey work. Maybe it was an interesting experiment, on the whole, but the day-to-day procedures were pretty isolated interactions.
>
> (p. 378)

Not all undergraduate research experiences take place only in a laboratory. Many students complete *fieldwork* whether it is collecting samples to take back to the lab for analysis (Feldman et al., 2009), social science research with study participants or anthropological studies. Russell (2005) found that 36 percent of undergraduate research students went on a research related field trip of some kind. Julie, a participant in the study by Buckley (2010) described a complication in planning her fieldwork by stating, "I couldn't really set up a specific schedule because of the temperature dependency and I wasn't sure how often I'd be down at the field site versus how often I'd be in town" (p. 144).

Some undergraduate research experiences offer students the opportunity to *learn new computer software and skills*. This is not only an incident experienced during undergraduate research but also a documented student gain from the experience (Hunter et al., 2007; Lopatto, 2004a; Seymour et al., 2004). In addition, the undergraduate research experience offers student the ability to n*etwork with others in the field* and is another documented gain from the experience (Hunter et al., 2007; Laursen et al., 2010). Networking in the field provides student the ability to meet other scholars and see what it may be like to join the profession.

While these 16 incidents were identified through a review of the scholarly literature, it is certainly plausible that other incidents occur during the undergraduate research experience. The incidents I identified represent incidents addressed in the literature, not all incidents provided to the researchers during their interviews, completed surveys or other types of data collection instruments.

Theoretical Frameworks

Three theories, communities of practice, social capital and scientific identity, can be used to understand undergraduate research experiences and its impacts. Communities of practice and social capital theories focus on the broader community and have a strong mentoring component whereas scientific identity theory focuses on the individual. Communities of practice theory looks at how social networks create and disseminate knowledge among the community and newcomers to it. Social capital theory looks at what resources and assets individuals possess that can be used to further their position in society. Communities of practice and scientific identity have been widely used in understanding STEM education, provide a foundational structure in how one can think about and come to understand undergraduate research experiences, and may be drawn upon as I strive to make meaning to understand the experiences of participants in this study.

Communities of Practice. The Boyer Report (1998) called on research institutions to enhance student learning through several means including cultivating a sense of community. Communities of practice are social learning systems comprised of groups of individuals who “engage in a process of collective learning in a shared domain of human endeavor” and “share a concern or passion for something they do and learn how to do it better as they interact regularly” (Wenger, 2006). The term c*ommunities of practice* was introduced by Jean Lave and Etienne Wenger (1991) to describe a community that serves as a “living curriculum” for an apprentice under the guidance of a mentor (Wenger, 2006). Lave and Wenger (1991) emphasize that there is a link between learning and identity development.

To be a part of a community of practice, one must identify with the community (Wenger, 2000). One’s identity is essential in social learning systems. As an individual learns and gains knowledge within the social learning system, they also gain an identity within the system. Each person identifies who they are and are not and consequently what communities of practice they are part of or not. Every person is part of multiple communities of practice be it, for example, their family, job responsibilities, professional organization memberships, life experiences or hobbies. The identity of a community of practice relies on the identity of the people within it. Individuals can interact with their community of practice integrally or marginally (Wenger, 2000). Participation in the community of practice is vital since through participation identity and practice develop (Wenger, 1998; Handley, Sturdy, Fincham & Clark, 2006).

Communities of practice are multilayered from local to global and can contain sub communities (Wenger, 2000). For example, a national professional organization in research methods. Many individuals may identify with this community of practice by sharing knowledge and expertise while also learning from others as the profession grows and expands. Within the larger professional organization community of practice are regional associations and even more local divisions. Individuals may be able to engage more readily with the local or regional layers of the community of practice than the national or global community of practice. Even more layers of the larger community of practice surface when the professional organization divides into areas of interest or specializations which are all still part of the larger community of practice yet have unique identities of their own.

While the concept of communities of practice has its foundation in situated learning in the social sciences whereby a student placed in a real world situation will learn through the co-construction of knowledge, it has been used in a much wider array of disciplines in academe and also reached into industry, government, education, online technologies, and public and private organizations (Wenger, 2006, 2010). Communities of practice in these sectors have provided space for members of a community to interact, expand their knowledge, collaborate on projects and enhance professional development.

Communities of practice works well in business and government because it helps to connect individuals around knowledge areas who all work within a vast and complex organizational structure and may otherwise have no ability to connect or interact

(Wenger, 2006, 2010). Communities of practice have been implemented in several leading corporations including American Management Systems, Buckman Labs, DaimlerChrysler, IBM, Hewlett Packard, Hill's Pet Nutrition, Shell, and the World Bank (Wenger & Snyder, 2000). These communities have improved production systems, increased efficiency, tapped the knowledge and ingenuity of employees and improved service to clients. However these communities were only successful, in part, due to supportive managers and upper management who valued the process and allowed for time and space for the communities of practice to operate.

Similarly communities of practice within education help to foster peer-to-peer learning as well as connecting individuals not only within the same local education system but also with peers state- and nation-wide (Wenger, 2006, 2010). The same knowledge connection fostering peer-to-peer learning is true among professional organizations and other associations. Online technologies such as chat rooms, blogs and social media (Facebook, Twitter) have fostered communities of practice among people with similar interests by breaking down the geographical barriers between individuals and bringing them together online to discuss, learn and inform each other.

A community of practice framework has been used to examine middle school classrooms (Brickhouse & Potter, 2001; Olitsky, 2007; Tan & Calabrese Barton, 2007, 2008). These studies describe the classroom spaces such as large class, small group or individual work, school environments and student interactions which led to the student succeeding or not in the class. Olitsky (2007) argued that for a classroom to be more like a community of practice, traditional methods of teaching and learning must be changed such that the classroom is more like an intellectual discussion session with the teacher as a leader rather than the teacher standing in front of student desks didactically presenting the curriculum. However, it is not enough to rearrange the classroom as interactions that occur in these communities need to be considered to ensure that the interactions do not alienate and discourage participation. Tan and Calabrese Barton (2007, 2008) illustrated how a sixth-grade student evolved from a marginal to an integral participant in her science class as she had science interactions that were not discouraging or alienating. Additionally, classroom communities of practice enhance an interest in science by providing the space for students to share their perspective and voice as they engage in science and become active participants in the community (Furman & Calabrese Barton, 2006).

A recent study by Aschbacher, Li and Roth (2010) on high school students once interested in science, engineering and mathematics indicated that communities of practice in and out of school impact how students developed a scientific identity and if the student pursued science in higher education and as a career. Many of the students' interest in science, engineering and mathematics were not supported by family or teachers. Additionally, the students had few opportunities to work with professionals in these fields. This study demonstrated the importance of communities of practice where student interest in science is supported, role models are available and mentors can be found especially for students who are developing their identity and considering science as a career.

Social Capital. Social capital theory is based on the premise that individuals with the most social network resources are in the highest class while those with the fewest are in the lowest class (Berger, 2000). Bourdieu (1986) defined social capital as,

> the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition – or in other words, to membership in a group – which provides each of its members with the backing of the collectivity-owned capital, a credential which entitles them to credit, in the various senses of the word. (p. 248-249).

The more social capital possessed, the more one is able to leverage for advancement; therefore, those at the top advance more than those at the bottom as they have more resources thus perpetuating a cycle of social inequities (Berger, 2000). In the American education system, social resources that can be leveraged begin in elementary school, through high school and into college, which impacts the extent to which a student will engage in and persist through college. What social capital may look like in a higher education context, for example, is an undergraduate student who has a strong K-12 academic background, won competitive scholarships, comes from an upper-class family and has access to many social resources is more likely to be more engaged in and persist through college than a student who attended an academically weaker high school, must pay for their education through loans and part- or full-time employment, comes from a lower-middle class family and has limited social resources.

One way to advance social capital is to network with an individual with a higher level of social capital such as a mentor (Gaddis, 2012; Moschetti & Hundley, 2008). In the college environment, forming a mentoring relationship with a faculty member can enhance learning and provide an avenue to otherwise unattainable institutional knowledge (Dika, 2012). Dika found that faculty interactions are an important social capital resource for students and are important in predicting student achievement. This is especially true for minority students who have lower social capital (Dika, 2012; Moschetti & Hundley, 2008; Parks-Yancy, 2012). Additionally, faculty mentors can be a resource for internship, research, scholarship and other campus educational opportunities; graduate school and employment recommendations; and advice on a multitude of issues such as college success and career planning (Parks-Yancy, 2012; Stanton-Salazar, 1997). It is important to note, however, that students must be fully engaged in the networking or mentoring opportunity order to gain the most social capital. A student who does not take the relationships seriously most likely will not gain as much as a student who is highly engaged and committed to gaining the most from the opportunities to build their network and thereby their social capital.

The undergraduate research experience is a way for student to gain social capital as they establish a mentoring relationship with a faculty member who serves as a model for professional practice and guides the student into the profession (Hunter et al., 2007; Seymour et al., 2004; Thiry et al., 2011). Effective mentoring of undergraduate research students may improve the overall experience (Russell et al., 2007). Undergraduate students come into their URE expecting a great deal of one-on-one mentoring from their faculty mentor and are often surprised to find that they are mentored by other research team members, such as post-doctoral fellows or graduate students, rather than the faculty leader (Adekokun & Burgess, 2011). Thus, dissatisfaction in gains from the undergraduate experience can occur when undergraduate students are not mentored by the faculty leader (Thiry et al., 2012). But Lopatto (2007) found only a moderate correlation between how student’s evaluated their research mentor and the student’s evaluation of their research experience. Yet while mentoring is a key component to undergraduate research, more work needs to be done to determine what characteristics of mentors support student learning.

Amelink (2010) provided an overview of nine mentoring models: apprenticeship, citizen, cloning, co-mentoring, friendship, hierarchical, nurturing, peer, and relational. The apprentice model centers on the mentor helping the mentee become enculturated into the mentor's profession. Note the apprenticeship model is also the historical foundation for communities of practice. In the citizen model of mentoring the mentor and mentee are equals with shared responsibility in the relationship. The cloning model centers on the mentee becoming a replica of the mentor through the mentor's use of power and control. In the co-mentoring model the mentor and mentee have a cooperative relationship where they share the roles of teacher and student. In the friendship model, the mentor and mentee collaborate as peers. The hierarchical model focuses on the mentor molding the mentee to be like the mentor. The nurturing model positions the mentor in a parent-like role whereby the mentor helps the mentee develop their own abilities. Peer mentoring is a group of individuals who provide support to each other. The relational model values open discussion and sharing of ideas.

Mentoring can be formal or informal and last a short amount of time or over many years (Crisp & Cruz, 2009). High quality mentoring is a key component of the undergraduate research experience and can have a significant impact on whether the student has a positive or negative experience (Buckley, 2010; Buckley et al., 2008; Craney et al., 2011; Hunter et al., 2007; Lopatto, 2004; Russell et al., 2007; Seymour et al., 2004; Thiry et al., 2011; Thiry et al., 2012). Crisp and Cruz (2009) presented findings from a theoretical review of mentoring literature and an empirical review of studies addressing mentoring of college students. They found a lack of a standard but over 50 varying definitions of mentoring, theory to explain a mentoring relationship, and how college students view mentoring. There is agreement within the literature on mentoring, however, that mentoring is focused on individual development, contains various forms of support, are personal in nature and are reciprocal between the mentor and mentee.

The concept of communities of practice is not without its critics (Wenger, 2010). Scholars and practitioners alike have discussed that the concept of communities of practice does not openly address the issue of power although power is inherently part of a community of practice. Others have critiqued the concept as anachronistic; that is, reflective of an earlier era where workers were learning a craft rather than modern day education and networking within a field which is constantly evolving. Additionally, scholars have questioned how the concept of communities of practice was initially an analytical concept and has now spread to being positioned more as a process as more and more entities adopt this framework for understanding learning. Conversely, some practitioners have criticized that the concept is difficult to move from theory into practice particularly in organizations with a strong hierarchical structure. Even with these critiques, communities of practice help guide our understanding of social learning systems and particularly how individuals who want to assume a particular identity do so successfully or not. As Carlone and Johnson (2007, p. 1189) state, “it is essential that we understand how neophytes affiliate with, become alienated from, and/or negotiate the cultural norms within these communities.” Research on how incidents during an undergraduate research experience impact student interest in a STEM field career may add to this needed understanding.

Scientific Identity. The term *scientist* refers to individuals who practice in fields of natural science as well as technology, engineering and mathematics (STEM) (Laursen et al., 2010). *Identity* is defined as recognition "as a certain 'kind of person'" (Gee, 2000-1, p. 99). Scientific identity therefore refers to who one is, who they want to be, and what one thinks they must be to engage in and can accomplish in science (Brickhouse, 2001; Calabrese Barton, 1998). Scientific identity theory is therefore focused qualities of the individual student. Identities are not preset and evolve over time based on life experiences, individual interests and one's potential future (Aschbacher et al., 2010; Brickhouse & Potter, 2001; Brown, Reveles & Kelly, 2005; Gee, 2000–1; Kelly, 2012). As such, researchers are able to study identity in a variety of contexts and points in time. Cognitive development and social identity development, which focuses on various characteristics of a student including their ethnicity, race, gender and sexual orientation, in college students have been studied for decades (Baxter Magolda, 1992, 2008; Chickering & Reisser, 1993; Evans et. at, 2010; Pascarella & Terenzini, 2010).

A large number of the research studies on student identity in science have centered on illustrative case studies (Shanahan, 2009). One of the first studies on student identity in science was conducted by Calabrese Barton (1998) on homeless children. In this study Calabrese Barton examined how the *Science for All Americans* initiative included and affected marginalized students. She posited that educators and researchers must think about not only the curricular aspects of teaching science but also how students perceive science and base their interactions with science upon these perceptions because students have varied ways of learning and one size does not fit all.

Brickhouse and Potter’s (2001) research on two young girls in an urban context, a widely cited student identity formation study, addressed how marginalized students have difficulty entering into the science community at their school while other students who resemble the stereotypical science student have advantages the marginalized students are not afforded. Brickhouse and Potter found that while the girls were considered academically good students, each struggled to fit into science classes where they were part of a small minority. Both young girls experienced difficulties reconciling their identities of female minority students with the identity of being good at science. It also uses community of practice to describe and understand identity.

More recently, other researchers have documented how marginalized students struggle with seeing themselves in relation to the traditionally viewed ideal prototype of a scientist – a white man in a lab coat (Aschbacher et al., 2010; Calabrese-Barton & Yang, 2000; Carlone & Johnson, 2007; Ceglie, 2011; Frazzetto, 2004; Rahm, 2007). It is regrettable that academically qualified students abandon science fields not because of the rigor of the discipline but because they do not feel a sense of belonging or see themselves as part of the science community. Further complicating the issue is the struggle gifted minority students have with finding a balance between their other identities such as race and social class with their identifying as a scientist.

A student’s family unit and culture impact the student identifying as a scientist either positively or negatively (Aschbacher et al., 2010; Brickhouse & Potter, 2001; Brown, 2002). Students with families that encourage science learning are more likely to persist in science than those students whose families encourage other career paths or school activities such as sports. Additionally, students who have immediate and extended family members in science careers are more likely to persist in science than those students with family members in careers unrelated to science. In particular, Brown (2002) identified that Hispanic students with strong family support for science careers had a positive impact on the student. Conversely, Chinn (2002) showed that for Asian American women traditional family expectations negatively influenced the women's persistence in science.

One's ethnicity, race and socioeconomic status have significant impact on a student's ability to identify as a scientist (Aschbacher et al., 2010; Brickhouse & Potter, 2001; Calabrese Barton, Tan & Rivet, 2008; Calabrese Barton & Yang, 2000). With science historically being a white male dominated field, students from other ethnicities and races have struggled to identify with science and move beyond a liking for science-related topics to a serious interest in and continued pursuit for science as a career. Many minority students lack role models from their ethnic and racial backgrounds and may not see their liking of science as a realistic career objective. Further, students from low socioeconomic statuses lack the financial resources to pursue science outside of school and typically attend schools that lack adequate funding for extracurricular activities that support science teaching thereby limiting a student's exposure to science and opportunities to enhance their scientific identity.

The ability to identify as a scientist is also impacted by a student's gender. We know that historically white men pursue and succeed in science at a significantly higher rate than women (Brickhouse, 2001; Brickhouse & Potter, 2001; Carlone, 2003; Hazari, Sadler & Sonnert, 2013). The 2011 National Assessment of Educational Progress (NAEP) report card for achievement in science shows that there was no significant change in the gender gap between male and female students from the previously studied 2009 year with males scoring an average five points higher in science than females (National Center for Education Statistics, 2012). Like other minority students, females have limited role models which can lead to students to struggle in with seeing themselves as a scientist because of their gender. Young women may also have to overcome traditional views of young girls playing with dolls rather than dirt, bugs and building block and a grown woman's role in society pertaining to marrying, starting and raising a family, and caring for elderly family members which is not required of males who are interested in pursuing science.

A person is not just one identity but rather is made up many identities. Each individual identifies with multiple identities in their life such as child, student, friend, co-worker, partner; possible identities are endless. Researchers have studied how identifying as a scientist interplays with other claimed identities, particularly the intersectionality of these identities, such as gender, ethnicity, race, family relationships, school bully, good student, popular student, and others (Aschbacher et al., 2010; Brickhouse, Lowery & Schultz, 2000; Calabrese Barton, 1998; Calabrese Barton et. al, 2012; Carlone, 2003; Carlone, 2004; Hazari, Sonnert, Sadler & Shanahan, 2010; Hazari et a., 2013; Johnson, 2012; Tan & Calabrese Barton, 2008; Tan & Rivet, 2008). While considering how a student develops a scientific identity, findings from these studies suggest the importance of varying identities to how those identities inform, impact and interact with a scientific identity.

Scholars have examined how students navigate and interact in the science classroom. Several scholars have demonstrated the importance of allowing students to have a voice in the classroom with the implications being increased interest in science, taking partial ownership in one's learning and refinement of career aspirations (Basu, 2008; Basu, Calbrese Barton, Clairmont & Locke, 2009; Furman & Calabrese Barton, 2006). However, some students will downplay their interest and aptitude in science in order to maintain social standing with peers. In other words, there are students who will intentionally provide a wrong answer or be disengaged in the classroom to avoid peers socially grouping them as a nerd, acting white or not being cool. Conversely, minority students may have guarded academic interactions in the classroom, such as not raising their hand to answer questions, in order to fit in rather than be seen as an outsider who cannot do science should a wrong answer be given (Olitsky, 2006a; Olitsky, 2006b).

In-class science learning is supplemented by extracurricular science activities. Extracurricular science activities such as science clubs, field trips and science fairs are important to student science identity development (Aschbacher et al., 2010; Calabrese Barton et. al, 2012). An early study by Calabrese Barton (1998) demonstrated an after-school program at a homeless shelter brought learning science into the student's everyday world and engaged them in science learning on topics of their own interest. More recently, Clabrese Barton et. al (2012) asserted that participation in out of school science activities help young girls engage with science and may help minority students identify as future scientists from this engagement.

Scientific identity formation continues from K-12 into higher education. During their college years, students have many opportunities to interact with science and continue to develop their scientific identity (Brown, 2002; Ceglie, 2011; Kozoll & Osborne, 2004; Russell & Atwater, 2005). Much like K-12 education, experiences students have in regard to science impacts how they see themselves in relation to science careers. Students who enter college with preconceived notions about the irrelevance of science in their life and career can struggle in science classes, may never come to see themselves as needing science and ultimately remain distant from it (Kozoll & Osborne, 2004). Conversely, students who are able to see science in everyday life are more likely to connect to science and enhance scientific identity development. A student's intrinsic motivation to succeed in science, K-12 preparation in science curriculum, support from teachers, small class sizes and support from family all impact the transition to studying science in college (Brown, 2002; Ceglie, 2011; Russell & Atwater, 2005).

Carlone and Johnson's (2007) study on college women of color presented an initial, then later refined, grounded model of science identity. The model focuses on the interrelated dimensions of competence, performance and recognition. Carlone and Johnson asserted that an individual cannot identify as a scientist without performing their competence in the discipline and being recognized for it by meaningful others as one with potential in science. The findings of this study focused primarily on the recognition dimension of the model. The participants were grouped into three categories based on how recognition of their potential in science was influenced by meaningful others. The research scientist group had a passion for science and were recognized by meaningful others as science people. The altruistic scientist group found self-created ways of defining who was a meaningful other to be recognized by as a science person. The disrupted scientist group were successful in their science career but struggled to be recognized by meaningful others. It is clear from the findings that positive recognition by meaningful others such as professors or other scientists had a positive influence on a student identifying as a scientist.

The number of students who show an interest in science during their K-12 year funnels down to a smaller number who pursue science in college which is further funneled down to a much smaller number who graduate with a science degree and enter into a professional career related to science. The numbers of minority students who persist into professional science career is even smaller. However, there are many successful minorities in science. An illustrative study by Johnson, Brown, Carlone & Cuevas (2011) presented the stories of three professional female scientists and their journeys that resulted in being successful in their science career. In this study the participants navigated many of the aforementioned influences on scientific identity formation. The three women's stories are vitally important to hear as they provide incredible insights into how along their whole journey from their first interest in science as a young girl through graduate degree completion and into their careers they found ways to persist and overcome many obstacles that have led countless others like them to leave science.

Synopsis

In summary, undergraduate research experiences offer students the opportunity to conduct research and make a contribution to their discipline. This review of the literature provides a context for understanding characteristics of students who benefit from undergraduate research experiences and what these students gain from the opportunity. Of particular interest in this study are the individual incidents or events that occur during the undergraduate research experience that may promote or deter an interest in pursuing a STEM field career post-graduation. A meta-analysis of 20 relavent research articles produced a list of 16 possible critical incidents experienced during an undergraduate research project. The previous research was not focused on individual incidents during the undergradaute reesearch experience but the identified incidets were used to illustrate gains and outcomes. Because this study focuses on critical incidents it will, in part, confirm the list of the identified incidents as exhaustive or show that the list should be expanded with additional incidents. What needs to be explored further is which, if any, of the identified incidents or others that may be offered by participants in this study, do not promote an interest in a STEM field career after graduation. Additionally, how these incidents may help a student refine their post-graduation career plans, even if the student steers away from STEM, needs to be explored more in depth. This information may help undergraduate research experience faculty and administrators tailor individual experiences in order to maximize a student's interest in a STEM field career following graduation.

Three theories can be drawn upon for understanding undergraduate research experiences. Consideration of potential social capital gained through participation in an undergraduate research experience is a unique contribution of this study. While there are studies on models of undergraduate research experiences, student gains and attributed outcomes, a gap exists on critical incidents during the undergraduate research experience that influence a student's interest in a STEM field career following graduation. This study seeks to fill this gap in the literature as findings from this study expand our knowledge of undergraduate research experiences and how these experiences may impact a student persisting in the STEM pipeline.

Chapter Three

Methodology

The intent of this study was to examine STEM undergraduate research experiences (URE). The purpose of this qualitative study using critical incidents was to identify experiences during a URE that students perceived to encourage or deter their interest in pursuing a STEM field career following graduation and to identify student's perceptions of the reasons why they think these experiences influenced their interest. The study focused on identifying individual incidents during the URE that students perceived encouraged or deterred their interest in a STEM field career following graduation and centered on gaining a deeper understanding on how and why the identified incidents had a bearing on the student's interest in a STEM field career following graduation. The findings will add to our understanding about how undergraduate research experiences can contribute to an interest in STEM field careers following graduation. This study was guided by the following research questions:

1. What specific incidents during an undergraduate research experience do students perceive to have encouraged their interest in a STEM field career following graduation?
2. What specific incidents during an undergraduate research experience do students perceive to have deterred their interest in a STEM field career following graduation?
3. Why do students perceive that certain incidents had a particularly strong impact on their interest in STEM?

To answer these research questions, individual semi-structured interviews and one focus group were conducted. Demographic data including gender, race, year in college, and major was obtained from each participant at the beginning of their interview or focus group. During each individual interview and the focus group, each participant was presented with a list of incidents found in scholarly literature that were reported to have an influence on student interest in a STEM field career following graduation and were asked to offer additional incidents they had during their URE that they perceived to influence their interest in a STEM field career following graduation. The participants were then asked to rate each specific incident during their URE that encouraged and each specific experience during the URE that deterred their interest in a STEM field career following graduation. Data analysis occurred by using the constant comparative method to analyze transcripts of the individual interviews and the focus group transcript. The data analysis resulted in vignettes that illustrate a range of different types of URE incidents and how specific incidents had a bearing on the student's interest in a STEM field career following graduation.

In this chapter, I describe the methodology used to conduct this study including the methodological approach, institution and participant selection, data collection and analysis procedures, trustworthiness and authenticity, the role of the researcher and limitations of the study.

Institution Selection

Three institution sites were selected for this study: East Coast University (ECU), Mid-Atlantic University (MAU), and South Eastern College (SEC). The three institutions are geographically located in the mid-Atlantic region and have a Master's L Carnegie or Baccalaureate classification. Institutions with a Master's L Carnegie classification are a subset of all master's colleges and universities which award at least 50 master's degrees and fewer than 20 doctoral degrees (Carnegie Foundation for the Advancement of Teaching, 2014). An L classification indicates a larger program where at least 200 degrees are awarded as opposed to a medium (M, 100-199 degrees awarded) or small (S, 50-99 degrees awarded) sized program. ECU, MAU and SEC were selected for the following reasons: they were not my home institution, I did not have affiliation with either institution in terms of prior academic study or privileged administrative access to student records, the universities were within reasonable travelling distance for on-site data collection, each offered STEM UREs to students on campus during the academic year and throughout the summer, and all three institutions provided detailed information regarding UREs in a prominent location on the university's website.

East Coast University is a public comprehensive institution with more than 4,000 students in over 40 undergraduate and graduate programs (ECU online factsheet, 2013). Majors can be selected from arts and sciences, business and education. ECU has placed undergraduate research as a top priority in the college experience. A Dean's Office coordinates undergraduate research opportunities. Students at ECU are able to apply to an URE that is part of a faculty member's research and earn course credit for the work. Additionally, students can apply for research grants provided by ECU to assist students in conducting research projects. In academic year 2012-2013 over 150 students received a research grant award. URE students have the opportunity to present their research projects in an annual campus symposium. Four outstanding student URE projects are selected each semester for inclusion in a national journal of undergraduate research. Recent student research topics include food security policy, green polymer chemistry, honey bee populations and state welfare spending.

Mid-Atlantic University is a public comprehensive institution with over 8,000 students in more than 150 undergraduate and graduate programs (MAU website, 2014). Majors can be selected from a wide variety of disciplines in business, education, humanities, science and technology. While MAU has a strong teaching and learning focus, research is valued because it is seen to enhance and sustain teaching. MAU maintains an office dedicated to undergraduate research and scholarship which provides assistance to students and faculty engaged in research activities. Recent student research topics include reducing car drag, sparrows in Kenya, mapping ancient rocks, developing vocabulary and studying parasites.

South Eastern College is a private baccalaureate institution with over 1,500 students (SEC website, 2017). Majors can be selected from a wide variety of disciplines in business, science, education, and the humanities. SEC has a strong teaching focus with small class sizes but values undergraduate research through pairing students with faculty through multi-year projects. SEC maintains an office dedicated to undergraduate research and scholarship which provides assistance to students and faculty engaged in research activities. Recent student research topics include bacteria in lobsters, switchgrass growth, storm water drainage into the ocean, and semiconductors.

The selection of ECU, MAU and SEC as study sites offered several benefits. First, each institution has a strong commitment to undergraduate teaching and learning through in and out-of-class opportunities including undergraduate research experiences. Second, while Research I institutions are commonly known for conducting research, research conducted at other institution types is important and may provide a different view of undergraduate research experiences given the emphasis on teaching. Finally, students in undergraduate research experiences at a comprehensive institution had not been widely researched therefore new insights may have been gained by studying this population of students.

Participant Selection

Purposeful, criterion-based sampling was used in order to select participants who would provide meaningful information to answer the study research questions from those who met specified criteria to participate (Creswell, 2003). To obtain my sample, I contacted the administrator of undergraduate research at MAU and SEC to explain my study and request s/he email a call for study participants to undergraduate students who (1) were enrolled at the institution, (2) were currently participating in or had participated in a STEM undergraduate research experience project within the last six months, and (3) had been in their undergraduate research experience for at least two months. This administrator served as a gatekeeper who assisted me in gaining access to the participants. The email (Appendix A) about this study forwarded to students from the campus URE administrator contained information about the study, my role, IRB approval, requirements of participants and a link to an online interest form if the student was interested in participating. Students interested in participating were asked to complete an online interest form (Appendix B). Responses to the online interest form were used to select students meeting the study criteria who were then contacted via email in order to arrange their participation in an individual interview. 22 students total were selected to participate in an interview. Participants at ECU were identified through a faculty gatekeeper who arranged individual interviews with five URE students and a focus group with one undergraduate research class of nine students. The focus group was conducted during a class session for the undergraduate research class at ECU. Students were not required to participate but all chose to do so.

Participant confidentiality was protected in several ways. First, participant names and the names of each institution were altered and referenced throughout the study using pseudonyms.

The participant name and pseudonym key was only accessible to me. Recordings of the individual interviews were only accessible to me and a professional transcriber who signed a confidentiality statement prior to being provided the recordings. Interview data where participants were identified by a pseudonym was only accessible to me, my dissertation chairperson, the professional transcriptionist, and Virginia Tech Institution Review Board personnel if an audit is conducted. Any formats of data were kept in a locked cabinet or on a password protected computer. Results shared with administrators at each institution and in any publications or presentations from this study were done using a summative format where individual participants could not be identified through demographic information or direct quotations.

Approval was obtained from the Virginia Tech Institutional Review Board prior to data collection (Appendix C).

Data collection procedures. Data collection consisted of one 45-60 minute, semi-structured, in-person individual interview with each selected interview participant (Appendix D) and one 45-minute focus group. The individual interviews were scheduled at a mutually conducive time, held at an on-campus location of the participant and researcher's mutual agreement, and were audio recorded. The focus group was held during the scheduled class time at the on-campus location and was audio recorded.

Upon arrival to the individual interview or focus group, the participant was asked to review and sign the Informed Consent form (Appendix D) and fill out a demographic questionnaire (Appendix E). The informed consent form explained the purpose and procedures of the study including assurance of confidentiality, approval by Virginia Tech IRB, the participant's ability to withdraw from the study at any time and how the data obtained will be used. Any individual participant questions regarding the Informed Consent form were answered. Participants were asked to select a pseudonym to use during the interview and provided the pseudonym in the demographic questionnaire. After the informed consent form and demographic questionnaire was collected, the interview or focus group began. The same semi-structured interview protocol (Appendix F) was used for each of the individual interviews and the focus group.

I began each interview by asking the participant to first tell me about the nature their undergraduate research experience, its purpose, the team leader, and the types of roles he/she had played on the project. This question allowed me to gain a holistic understanding of their experience and place the incidents within the larger URE context. Data were then collected during the interview using a variation of the Q sorting process in Q methodology. Q methodology, pioneered by Stephenson (1953), focuses on understanding participant's perceptions and subsequent behaviors thereby providing the ability to study subjectivity and participant point of view (Brown, 1991; van Exel, 2005). The Q sorting process directs participants through forced choice to rank order statements along a Likert scale continuum. In this study participants were asked to sort incidents that occur during UREs into one of four mutually exclusive groups then rate each incident along a Likert scale continuum.

I provided a set of prefilled cards to the interview participant. Each card contained the name of one incident found in the relevant scholarly literature that may encourage or deter a student's interest in a STEM field career following graduation. Each card set also contained several blank cards for the participant to write down any additional incidents that came to mind during the interview. Providing blank cards on which participants would write additional incidents not identified in the scholarly literature but offered during the interview assisted in reducing any unintentional narrowing of possible incidents in a URE introduced through the selection of incidents to include in the card set and allowed space for participant voice to be expressed.

Each set of cards had a unique identification number that was written on every card of that set indicating the institution number and a participant number. For example, the card set from the third interview participant at MAU had an identification number of "I2P3". Having a card set identification number on each card of the set ensured that if an individual card became separated from the card set or a card set was mixed with other sets while making meaning during data analysis I would be able to return each individual card to the original set. Figure 3.1 illustrates a sample incident card.

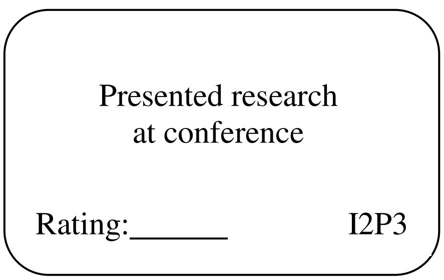

Figure 3.1 Sample incident card. This figure illustrates a sample incident card used in the Q sort exercise.

I instructed the participant to review the set of cards and sort each card into one of four mutually exclusive groups using the Q sort technique. The four groups were: (1) incident that encouraged the student's interest in a STEM field career following graduation, (2) incident that deterred the student's interest in a STEM field career following graduation, (3) incident that neither encouraged or deterred, and (4) incident not experienced.

Once the cards were sorted into the four groups I asked the participant to select one card from those sorted as an incident that encouraged the student's interest in a STEM field career following graduation and describe that critical incident to me. Following the description, I asked the interviewee to explain how that incident encouraged their interest in a STEM field career following graduation. I then asked the participant to explain why the incident encouraged their interest in a STEM field career following graduation. As needed, I asked probing questions – such as other individuals involved in the incident, effects an incident may have had on the student, or consequences from the incident – to gain a deeper understanding of the incident.

Next, I asked the interviewee to select a critical incident they rated as deterred and describe that critical incident to me. Following the description, I asked the interviewee to explain how that incident deterred their interest in a STEM field career following graduation. I then asked the participant to explain why the incident deterred their interest in a STEM field career following graduation. As needed, I asked probing questions to gain a deeper understanding of the incident. This process of selecting a rated incident card and describing the incident to me continued until all cards categorized as encouraged or deterred had been described or no new information was being supplied (e.g. saturation).

The participant had a complete set of cards with the scholarly literature and individually offered incidents written on them. I asked the participant to do a final review of the cards in each of their sorted groups. The participant was allowed to move an incident card from one group to another if they chose to do so based upon the card discussion. The participant was then asked to rate each incident from 0 to 5 in regard to how that incident influenced their interest in a STEM field career following graduation and write the rating for that experience on the card. Table 3.1 lists the card rating scheme.

Table 3.1
Card Rating Scheme

Rating	Description

0	Not experienced during URE
1	Strongly deterred
2	Deterred
3	Neither deterred or encouraged
4	Encouraged
5	Strongly encouraged

I then asked each interviewee to talk about their interest in STEM. This included questions about their original interest and how it had changed over time. Additional probing questions were asked as needed to fully understand the interviewee's perspective. I allowed the interviewee time to share any additional information with me of their choosing related to the study topic. Once all statements had been made I asked if the interviewee had any questions. Once no questions remained, I thanked the interviewee for their time and the interview was concluded.

For accuracy, the interviews were transcribed verbatim by a professional transcriptionist. Once each interview transcript was complete, I compared the audio recording with the transcript to ensure accuracy of the transcript. I wrote field notes which contained such information as nonverbal participant behavior, participant engagement during the interview, items from the interview to follow up on further and other contextual information that provided detail and thoroughness to the interview not recorded in the audio taping.

Data analysis. Data collected during the interview presented in four ways. The first set of data from the interview came from the demographic questionnaire. This data included biographical information as well as each participant's answer to whether they entered the URE with in interest in a STEM field career following graduation or not as well as if after the URE they had an interest in a STEM field career following graduation or not. Participants were given the option to select 'uncertain' for each question. The answers to these two demographic questions were used to group partcipants by interest in a STEM field career and provided understanding as to the student's intents and continuing interests. Table 3.2 shows the grouping scheme.

Table 3.2
Interview Participant Grouping

W Y	W N
O Y	O N
Legend W – student entered URE with interest in a STEM career following graduation O – student entered URE not interested in a STEM career following graduation Y – student in URE has interest in a STEM career following graduation N – student in URE is not interested in a STEM career following graduation	

Second, the interviews were audio taped and transcribed producing a verbatim transcript for each. Using the transcript I compiled a final list of incidents, combined from those in the scholarly literature and those offered by participant in each interview. While the list of the incidents from the scholarly literature was the same for all particpants, the participant offered incidents varied by interview. I used the list of incidents per interview to verify the cards participants ranked. This ensured that incidents not listed during in the interview were not included in the ranked cards.

The third set of data from the interviews came from the individual incident card ratings. I used a rating chart to list each incident, note each participant's rating of that incident and then averaged the rating number per incident across participants. This yielded a final rating per incident which indicated the extent to which each incident was perceived to encourage or deter a student's interest in a STEM feld career following graduation.

The fourth set of data from the interview were the verbatim transcripts and field notes. The transcript and field note data analysis procedures used were generic qualitative research procedures drawn from Glaser and Strauss (1967), Strauss (1987) and later Strauss and Corbin (1990, 1998, 2008). Each interview transcript and field note was read multiple times using reflexivity and acknowledging my own experience as an undergraduate student and my perceptions of undergraduate research experiences. This enabled me to focus on the participants experiences, familiarize myself with all the data, and analyze the data by identifying important statements to gain a deeper understanding of the participants experiences (Creswell, 1998).

Two types of coding were used to analyze each transcript and field note – intial open coding and focused coding (Strauss & Corbin, 2008). First, I completed an initial open, line-by-line coding of each transcript and field note by highlighting important words, phrases and incidents and concisely named them with a suscinct, descriptive code. Predefined codes were not used and assigned to fragments; rather I allowed the codes to emerge from the data. A glossary of codes was developed throughout the coding process to define each code.

Next, I recoded each transcript and field note using focused coding where I selected the most useful and frequent codes from the initial coding and compared them with all the data. Data were compared with other data using constant comparative methods to determine similarities and differences among the data at each stage of analysis (Charmaz, 2006; Glaser & Strauss, 1967). During focused coding groupings of codes emerged and were organized into meaningful categories (Creswell, 1998; Rossman & Rallis, 2003). The elimination of irrelevant, repetitive or overlapping data was then completed.

Finally, the categories were grouped into metacategories (Creswell, 1998) within the data to “[describe] what people experience and how it is that they experience what they experience” (Patton, 2002, p. 107). Examples of possible themes are effective mentoring or enhanced sense of self confidence. Throughout all levels of coding, I maintained analytical memos addressing the data, developing ideas about the data and noting my personal reactions to the participants’ responses to increase reflexivity.

A final analysis of all the interview data focused on the selection of vignettes to illustrate the various incidents that students have during their URE and why these incidents matter in regard to a the student’s interest in pursuing a career in a STEM field following graduation. To select the vignettes, I reviewed the broad themes from the transcript and field note analysis. I then selected one encouraged an interest incident and one deterred an interest incident that best illustrated each theme. A cross-case comparison for each of the themes was written.

Chapter 4

Findings

In this chapter, I present the findings of the study. I begin with a comparison of participant's institutions and demographic characteristics of the participants. Next, findings relating to the first two research questions about incidents during a URE are presented. Findings for the third research question of why incidents are perceived to be impactful to an interest in STEM are offered through a conceptual model for understanding themes from the data and illustrative vignettes. The chapter concludes with a summary of the usefulness of the conceptual model and suggested revisions of it.

Institutional Contexts

I interviewed students from three different institutions. Each of these institutions has unique qualities of the undergraduate research program and student participants, influenced by the institution's distinct mission, yet there are similarities between the three institutions. A strong commitment to providing undergraduate research experiences within the institution and among faculty is important. High quality faculty mentoring of undergraduate research students is vital since undergraduate students look to their mentor for guidance in the research project but also in academics and career goals. The availability of resources for undergraduate research – including but not limited to faculty mentors, purchase of equipment and supplies, travel expenses, and student stipends – does impact the ability for students to engage fully in undergraduate research and is one area where there were institutional differences.

Mid-Atlantic University has an established undergraduate research program. A faculty director coordinates the efforts of the undergraduate research office. Several of the participants from MAU entered their undergraduate research experience through a new student introductory course required of all incoming students, however their section of the course focused on undergraduate research opportunities and making connections with faculty across campus for these opportunities. The other participants entered their undergraduate research experience through making an individual connection with a faculty member. At MAU, there are opportunities for students to apply for university funding for their undergraduate research. A few of the participants from MAU had applied for and successfully received this funding.

East Coast University did not have as established an undergraduate research program as MAU or SEC. Most of the undergraduate research was through a TRIO program or individual faculty member interest in URE rather than a campus-wide focus. The ECU participants were connected to a faculty member who had received a grant for undergraduate research and most entered through an introductory course. Typically, this faculty member is very committed to providing undergraduate research opportunities for students. However, limited funding for undergraduate research did cause several participants to end projects before completion.

South Eastern College also has an established undergraduate research program and integrated undergraduate research throughout a student’s undergraduate studies. Like MAU, a faculty director coordinates the efforts of the undergraduate research office. The college focuses on introducing prospective applicants and their families to the undergraduate research opportunities at SEC as a recruitment tool. Several of the participants from SEC reported that they first became interested in undergraduate research during their prospective student visit and have given back by presenting their research for incoming prospective student visit days. Students at SEC are responsible for making the connection with a faculty mentor, however quite a few participants reported that most faculty are interested in working with students on research. Students at SEC can apply for College funding for their research projects.

At each of the three institutions, undergraduate research was valued. Each campus offered an undergraduate research symposium day where students could showcase their work, answer questions from faculty and student peers, and win awards for their research. Funding for undergraduate research projects and associated activities such as conference travel existed at all three institutions, albeit in differing amounts. Limited funding appears to impact the undergraduate research participants from ECU, that serves a population of first generation college students and students from lower economic statuses, more than participants from MAU or SEC who had greater access to personal or family funds they could use toward their undergraduate research projects for out-of-pocket items such as supplies and conference travel. ECU students tended to present their research locally or regionally whereas several MAU and SEC students travelled nationally in addition to local and regional conferences.

At all three institutions, there were one or more faculty members who championed undergraduate research and ensured students were afforded the opportunity to have the research experience. Most of the participants, regardless of institution, indicated that the faculty support of their undergraduate research was important to them. All participants viewed their faculty mentor as someone who would be able to be a reference for them as the student pursued employment or graduate education after earning their bachelor's degree.

The three institutions differed in what undergraduate students expected to gain from their research experience. Participants at ECU were more likely to view their undergraduate research experience as improving technical skills leading to being more competitive in a limited job market after graduation. Participants at MAU and SEC were more likely to view their undergraduate research experience as improving their resume for getting accepted into graduate school or using their research to have broader community impacts; a “change the world” mindset.

Participants

For this qualitative study, I conducted an individual participant interview with 22 undergraduate students. Additionally, I conducted one focus group with nine additional undergraduate student participants. The individual interviews were conducted with participants in an apprenticeship style URE while the focus group was conducted with participants in a course-embedded URE cohort where it was easier to get access to them all at one time. Participant ages ranged from 18 to 30 years old. Twenty of the participants were female; 11 were male. Twenty-eight participants identified as Caucasian, two Black, and one as bi-racial. More participants were in geosciences than any other major. The non-science major fit with the finding that some of the participants were completing an independent study. Time in the URE varied from one semester to four years. Additionally, several students were funded through grants or a stipend while most were not funded. Table 4.1 shows the demographic characteristics of each participant.

To understand participants’ interest in a STEM field career following graduation before and after the URE, I grouped the participants by their responses to questions asked on the demographic questionnaire about their initial and current interest in a STEM field career following graduation. Seventeen participants entered their URE with an interest in a STEM field career following graduation; 13 did not and one was undecided. After the URE experience, all 17

Table 4.1
Participant Demographics

Pseudonym	Institution	Gender	Age	Race	Major	Time in URE	Funding
Meg	MAU	F	22	White	Psychology	1 year	None
Sarah	MAU	F	22	White	Biology	4 years	Grant
Jenn	MAU	F	22	White	Biology	2 years	Grant
Jordan	MAU	F	19	White	Communication Sciences	1 year	Grant
Alexis	MAU	F	19	White	Psychology	1 semester	None
Nikki	MAU	F	22	White	Art	1 semester	None
Peyton	MAU	F	26	White	Biology	10 weeks	Grant
Luke	ECU	M	30	White	Geoscience	1 year	None
John	ECU	M	21	White	Geoscience	1 year	None
Mark	ECU	M	24	White	Geoscience	1 year	None
Chris	ECU	M	21	White	Geoscience	1 year	None
Ryan	ECU	M	26	White	Geoscience & Chemistry	2 years	None
Caroline	ECU	F	20	White	Geoscience	1 semester	None
Ricky	ECU	M	20	White	Geoscience	1 semester	None
Josh	ECU	U	21	White	Geoscience	1 semester	None
Madison	ECU	F	22	Bi-Racial	Geoscience	1 semester	None
Ann	ECU	F	24	White	Geoscience	1 semester	None
Marie	ECU	F	23	White	Geoscience	1 semester	None
Ola	ECU	F	20	Black	Geoscience	1 semester	None
Zach	ECU	M	26	White	Geoscience	1 semester	None
Shawn	ECU	M	19	White	Geoscience	1 semester	None
Hannah	SEC	F	21	White	Psychology	2 years	None
Leah	SEC	F	21	White	Biology	4 years	None
Erica	SEC	F	23	Black	Environmental Sciences & Biology	4 years	None
Seth	SEC	M	22	White	Physics	10 weeks	Stipend

Kelly	SEC	F	18	White	Sociology	1 semester	None
Lauren	SEC	F	21	White	Psychology	2 years	None
Monica	SEC	F	22	White	Mathematics & Computer Science	2 years	None
Amy	SEC	F	20	White	Chemistry	2 years	None
Brian	SEC	M	20	White	Biology	1 semester	None
Ashley	SEC	F	21	White	Biology	3 years	None

participants who entered the URE with an interest in a STEM field career following graduation were still interested in a STEM field career (Stayers). Of the 13 participants who did not enter the URE with an interest in a STEM field career following graduation, nine were interested in a STEM field career following graduation (Switchers) and four were not (Uninterested). The one participant who entered the URE undecided about an interest in a STEM field career following graduation was interested in a STEM field career after the URE (Switchers). None of the participants entered their undergraduate research experience interested in a STEM field career following graduation and then did not want to pursue a STEM field career after the URE (Leavers).

I coded participants based on type of research project they worked on and determined there were two groups: (1) those who designed and/or conducted unique experiments, and (2) those who ran analyses on already obtained samples. Interestingly, all ECU students and one SEC student were in the analysis of samples group whereas all MAU and all but one SEC student were in the design/conduct experiment group. This may be reflective of the institutional context and field the students are pursuing at ECU that is focused on technical skills that relate to future jobs.

I also coded participants based on the level of responsibility the student was given during their undergraduate research experience. I coded participants' level of responsibility as low, medium, and high. A low level of responsibility was characterized by expectations such as the cleaning of lab equipment, library research for a literature review, or transcribing interviews. A medium level of responsibility was characterized by expectations such as doing a poster presentation, an on-campus student panel, or running research trials. A high level of responsibility was characterized by expectations such as creating and running an individual research project or submitting to and presenting at a peer-reviewed conference. Table 4.2 shows level of responsibly and type of research coding by interest in a STEM field career grouping.

Table 4.2
Types of Research and Level of Responsibility by STEM Field Career Interest Grouping

Pseudonym	Grouping	Major	Research Topic	Level of Responsibility
Kelly	Uninterested	Sociology	Analysis of Samples	Low
Nikki	Uninterested	Art	Conduct a Study	Medium
Hannah	Uninterested	Psychology	Conduct a Study	High
Amy	Uninterested	Chemistry	Conduct a Study	High
Ann	Switcher	Geoscience	Analysis of Samples	Low
Marie	Switcher	Geoscience	Analysis of Samples	Low
Ola	Switcher	Geoscience	Analysis of Samples	Low
Zach	Switcher	Geoscience	Analysis of Samples	Low
Shawn	Switcher	Geoscience	Analysis of Samples	Low
Caroline	Switcher	Geoscience	Analysis of Samples	Low
Josh	Switcher	Geoscience	Analysis of Samples	Low
John	Switcher	Geoscience	Analysis of Samples	Medium
Brian	Switcher	Biology	Conduct a Study	Medium
Leah	Switcher	Biology	Conduct a Study	High
Ricky	Stayer	Geoscience	Analysis of Samples	Low
Madison	Stayer	Geoscience	Analysis of Samples	Low
Meg	Stayer	Psychology	Conduct a Study	Medium
Jordan	Stayer	Communication Sciences	Conduct a Study	Medium
Alexis	Stayer	Psychology	Conduct a Study	Medium
Luke	Stayer	Geoscience	Analysis of Samples	Medium
Mark	Stayer	Geoscience	Analysis of Samples	Medium
Chris	Stayer	Geoscience	Analysis of Samples	Medium
Erica	Stayer	Env. Sciences & Biology	Conduct a Study	Medium
Seth	Stayer	Physics	Conduct a Study	Medium
Sarah	Stayer	Biology	Conduct a Study	High
Jenn	Stayer	Biology	Conduct a Study	High
Peyton	Stayer	Biology	Conduct a Study	High
Ryan	Stayer	Geoscience & Chemistry	Analysis of Samples	High
Ashley	Stayer	Biology	Conduct a Study	High
Lauren	Stayer	Psychology	Conduct a Study	High
Monica	Stayer	Math & Computer Sci.	Conduct a Study	High

In comparing the various ways participants were grouped, I did not find any apparent connection between level of responsibility and an interest in a STEM field career following graduation. This may be due to differences in the length of time in the URE. Of the four participants who were not interested in a STEM field career following graduation, two had a high level of responsibility, one had a medium level of responsibility, and one had a low level of responsibility. Most of the Switchers had a low-level responsibility because it was the first year of the experience. Similarly, there doesn’t appear to be a connection between type of research project and an interest in a STEM field career following graduation. Of the four participants who were not interested in a STEM field career following graduation, three were in the design/conduct experiment group and one was in the analysis of prior samples group.

As may be expected, the type of research project appears connected to the level of responsibility a participant had during the URE. Those students who were in the design/conduct experiment group were in the high (9) or medium (7) level of responsibility group with none in the low group. Those students who were in the analysis of prior samples group were in the low (10), medium (4), and high (1) level of responsibility groups. It is easy to understand that URE students who are designing and conducting unique research experiments are, by nature of the work, generally given a higher level of responsibility versus a student that is tasked with analyses on samples. Most of the Switcher group were given a lower level of responsibility whereas most of the Stayers were given a higher level of responsibility. The level of responsibility appears to be connected to the student’s initial interest in a STEM field career following graduation.

The type of research project and the level of responsibility given to the student directly relates to the incidents a student experienced in their undergraduate research, which is the topic of the next section. Of the 16 incidents identified in prior literature, most were identified as encouraging an interest and no particular incident was identified as being associated with a decision to not pursue a STEM field career following graduation. Several incidents were found to be encouraging for some students but deterring for others. Differences in how an incident impacted a student's interest in a STEM field career following graduation are attributed to contextual factors.

Prior to data collection I had anticipated that I would find differences between participants by Stayers, Switchers, and Leavers. However, after analyzing the data, this did not materialize as expected. In addition, there appears to be no difference between these groups in relation to incidents the encourage or deter an interest in a STEM field career following graduation. A lack of meaningful difference between the groups may be because most of the participants liked science and had some interest in STEM in general prior to beginning their URE, even if they did not see themselves pursuing a STEM field career. Therefore, this group distinction by interest is no longer useful in further understanding the findings of the study.

Research Question 1: Incidents that Encourage

Research question one asked what specific incidents during a URE do students perceive encouraged their interest in a STEM field career following graduation. During each interview and the focus group, participants were asked to rate each of the 16 incidents identified during a review of the literature. Table 4.3 indicates the number and percentage of participants who indicated each incident *encouraged* or *strongly encouraged* their interest in a STEM field career following graduation.

Table 4.3
Incidents that Encourage an Interest in a STEM Field Career Following Graduation

Incident	Total Encouraged	Percent
Collegial relationship w/ advisor/senior scientist	29	94%
One-on-one mentoring	26	84%
Work/think independently	26	84%
Collegial relationship with/mentoring peers	24	77%
Fieldwork	22	71%
Involved in project design and decisions	22	71%
Networking with others in the field	22	71%
Use laboratory equipment/techniques	21	68%
Learning new computer software/skills	17	55%
Perform basic procedures	16	52%
Present at/attend a conference	16	52%
Production, analysis and interpretation of data	16	52%
Publish research	13	42%
Review primary scholarly literature	9	29%
Attend project staff meetings	8	26%
Failed experiment	6	19%

Table 4.3 shows that each of the 16 incidents had at least six participants indicate that incident encouraged or strongly encouraged their interest. Over half of the participants identified 12 of the incidents as encouraging an interest in a STEM field career following graduation. The top four incidents – collegial relationship with advisor/senior scientist, one-on-one mentoring, work/think independently, and collegial relationship with/mentoring peers – were identified by over three quarters of the participants. The top incident, collegial relationship with advisor/senior scientist, was identified as encourage or strongly encouraged by 29 of the 31 participants. As will be discussed more in depth in Chapter 5, this finding is congruent with the literature.

Research Question 2: Incidents that Deter

Research question two asked what specific incidents during a URE do students perceive deterred their interest in a STEM field career following graduation. Table 4.4 indicates the number and percentage of participants indicating each incident *deterred* or *strongly deterred* their interest in a STEM field career following graduation.

Table 4.4
Incidents that Deter an Interest in a STEM Field Career Following Graduation

Incident	Total Deterred	Percent
Production, analysis and interpretation of data	5	16%
Review primary scholarly literature	5	16%
Failed experiment	3	10%
Learning new computer software/skills	3	10%
Present at/attend a conference	2	7%
Attend project staff meetings	1	3%
Collegial relationship w/ advisor/senior scientist	1	3%
Collegial relationship with/mentoring peers	1	3%
Use laboratory equipment/techniques	1	3%
Fieldwork	0	0%
Involved in project design and decisions	0	0%
Networking with others in the field	0	0%
One-on-one mentoring	0	0%
Perform basic procedures	0	0%
Publish research	0	0%
Work/think independently	0	0%

As you can see in Table 4.4, fewer incidents were identified as deterring or strongly deterring an interest in a STEM field career following graduation than those identified as encouraging or strongly encouraging an interest. The top four deter or strongly deter incidents were production, analysis and interpretation of data; review primary scholarly literature; failed experiment; and learning new computer software/skills. Of all incidents identified as deterring an interest, fewer participants identified the incident as a deterrent when compared to the incidents identified as encouraging an interest. Seven incidents from the literature were not identified by any participant as deterring their interest in a STEM field career following graduation (use laboratory equipment/techniques, fieldwork, involved in project design and decisions, networking with others in the field, one-on-one mentoring, perform basic procedures, publish research, work/think independently). When comparing Table 4.3 and Table 4.4, the percentage of students identifying the top deterred incidents (16%) is less than the percentage of students identifying the lowest encouraged incident (19%).

It is important to note that several of the same incidents are in each table. This is because each of the 31 participants rated each incident individually. The same incident could, for example, be rated as strongly encouraged by one participant and another participant may rate the same incident as deterred. For example, Monica from SEC, demonstrates how an incident could be encouraging and deterring in her relationship with two advisors, one for each of her two UREs. While she ultimately rated this incident as strongly encouraged based on her relationship with one advisor, Monica did struggle with having meaningful interactions with and getting project guidance from the other advisor. Specifically, Monica discussed how she did not feel she could go to her first URE advisor with issues she was experiencing in the project but learned how to rely on herself more because of it; something she viewed as a gain from that URE. Conversely, Monica described how she was able to work daily with her second URE advisor, openly asking questions and moving forward on the project in a “very fun environment”. The positive relationship with the second URE advisor and successful results in the URE project ultimately led to Monica expand upon the URE project for her senior honors project.

Additional Incidents Identified

Throughout the interview and focus group protocols, each participant could add additional incidents that they felt encouraged or deterred their interest in a STEM field career following graduation. The option to add additional incidents helped to minimize bias as to critical incidents that occurred during the participant's URE and allowed an opportunity to expand the literature. Several of the participants added additional incidents to the card sets that were used during the interview. These were: engagement with public/translation to real world, imposter syndrome, interpersonal relationships, obtaining funding/getting paid, travel, and working with lab animals. A couple of the additional incidents were perceived as encouraging an interest in a STEM field career following graduation (obtaining funding/getting paid, travel). A couple incidents were perceived as deterring an interest in a STEM field career following graduation (imposter syndrome, working with lab animals). Engagement with the public/translation to the real world as well as interpersonal relationships were rated as both deterred and encouraged by different participants. The additional incidents added by participants are listed in Table 4.5 along with the rating(s) given by a participant for that incident.

Table 4.5
Additional Incidents that Impact an Interest in a STEM Field Career Following Graduation

Additional Incident	**Rating**
Engagement with public/translation to real world	Strongly deterred, Encouraged (2), Strongly encouraged (2)
Imposter syndrome	Strongly deterred
Interpersonal relationships	Strongly deterred, Deterred (2), Strongly encouraged
Obtaining funding/getting paid	Encouraged (3), Strongly encouraged
Travel	Strongly encouraged
Working with lab animals	Deterred

Summary of Incidents

Sixteen incidents were identified in the literature as likely to occur during an undergraduate research experience. The top *encourage an interest* incidents related to relationships with a faculty mentor and peers as well as being involved in the research design and implementation. Nine incidents, all relating to aspects of conducting research and relationships with advisor/peers, were identified as encouraging an interest for some participants while the same incident deterred an interest for others. The top *deter an interest* incidents related to aspects of conducting research such as creating and interpreting data, conducting a literature review, having a failed experiment, and learning new computer software. The findings on individual incidents show that undergraduate students are looking for strong, positive relationships with their faculty mentor who will guide them through a research project they have an involvement in designing and implementing. However, incidents during the URE that are central to conducting research such as interpreting data or conducting a literature review tend to be deterrents for student indicating that students may not yet fully understand critical components of conducting scientific research or that they have yet to develop an appreciation for research that is so central to a scientific career.

Research Question 3: Why Incidents Encourage and/or Deter

Research question three asked why students perceive that certain incidents had a particularly strong impact on their interest in STEM. To answer this research question, all transcripts were coded, categories created, and themes identified. A conceptual model was developed to explain the data. Each participant's unique undergraduate research experience fits this conceptual model although in different ways. I will use a cross-case comparison of illustrative vignettes to answer this research question.

Conceptual model. Figure 4.1 displays the conceptual model I developed inductively to explain the data and answer why students perceive that certain incidents had a particularly strong impact on their interest in STEM. The model is linear beginning with how a student initially becomes involved with their undergraduate research experience and the student's academic major or discipline. These two areas lead to what a student's undergraduate research topic will be and the incidents s/he will experience during the URE. The research topic and incidents inform an interactive process of being provided opportunities, developing a professional identity, determining the value of research, and developing marketable or transferrable skills. From this iterative process, career interest is refined and a passion for STEM is fueled all leading to an interest in a STEM field career after graduation. Overarching through the entire process are the institutional context and impactful interpersonal relationships.

The next section is organized by the components of the model.

Reasons for getting involved in URE and undergraduate major. At the beginning of each interview, participants were asked to describe how they became involved in their undergraduate research project. Responses varied from the student intentionally seeking out the experience, a faculty member approaching the student about a research opportunity, or a class introducing undergraduate research as a topic. Not all students were in a STEM field major but became involved in a STEM field undergraduate research experience.

Research topic selection and incidents experienced. How the undergraduate research topic was selected also varied among participants. Some students worked on projects given to them by the faculty mentor whereas others were given the autonomy to select and design their research project with guidance from the faculty mentor. Several students worked on multiple research projects. The research project topic directly related to the incidents a student experienced in their undergraduate research. For instance, field work was a major component of the undergraduate research experience for students in

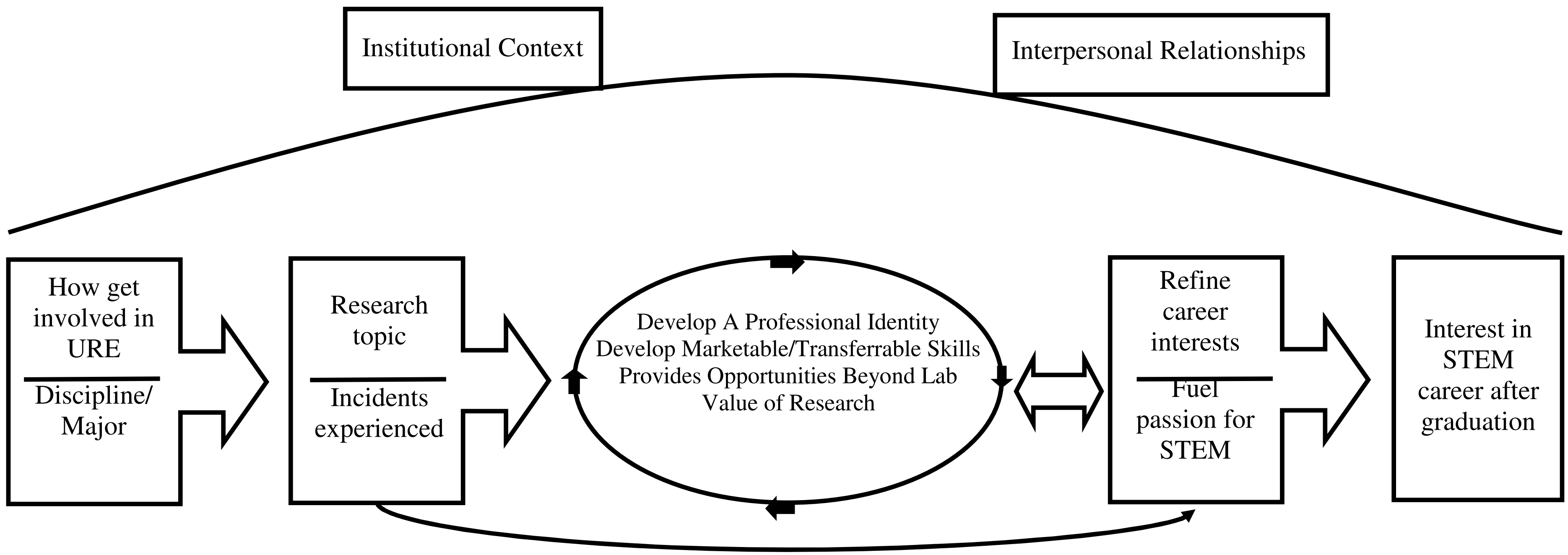

Figure 4.1 Conceptual model.

geoscience and biology whereas it was not experienced by students in psychology or computer science, which were lab based experiences. Incidents experienced also directly relate to fueling of a passion for STEM, either positive or negative. For example, lab work resulting in meaningful results positively fueled a passion for STEM whereas doing animal dissections did not. The research topic and incidents experienced throughout the undergraduate research experience lead to the interplay among five themes of why students perceive that certain incidents had a particularly strong impact on their interest in STEM.

Provides opportunities beyond the research lab. Participants indicated that incidents during their undergraduate research experience had a particularly strong impact on an interest in a STEM field career following graduation because these incidents provided opportunities beyond the research lab. These include attending or presenting at a conference, earning a stipend, and opportunities to do fieldwork. Many of the participants discussed being able to attend or present at a conference whether a local campus research symposium or a national conference. These types of experiences were important when participants felt that they were recognized for becoming an expert on their research topic and because it helped them to more fully imagine what a career in research may look like for them. Several of the participants were paid a stipend for their undergraduate research experience which was used for travel to field sites or conferences, purchase of research supplies, and personal living expenses. Stipend funding came from external grants the student applied for and received, faculty grant funding for student research or institutional funds. Fieldwork provided the opportunity for URE student to get out of the classroom and lab settings and into the outdoors – a key interest for many of the participants. Additionally, the field work sites provided domestic and international travel opportunities.

> *"The adventure of it."* It was just a total adventure, from the beginning until the end. It was my first time on a plane, it was my first time out of the country, and it's my first time

> under 24-hour daylight. Every day it was a different adventure. Sleeping out, camping out for 3 weeks. There were some rough times; that comes along with camping out in the middle of nowhere but overall it was amazing. …Just the adventure of it; being able to get out and be somewhere not in the United States was fantastic. – Chris

Chris is a geoscience major at ECU. For his URE, Chris travelled to two field sites with his faculty mentor to collect data. In this vignette, Chris describes the opportunities he had through his fieldwork for international travel and experiencing another part of the world. Along with getting practical research experience through collecting data in the field, these experiences have may have helped him develop some confidence in stretching his boundaries beyond those that were familiar to him. Chris indicated in his interview that he would not have had the ability for international travel had it not been for the URE and did not foresee that he would have that opportunity any other way due to limited personal financial resources. For Chris, the international travel for his fieldwork strongly encouraged an interest in a STEM field career because it provided an opportunity and experiences he would not have had otherwise. A future career in STEM may also afford Chris these types of opportunities to travel for work.

Ryan, a double major in geoscience and chemistry at ECU had a very different experience while presenting a poster at a conference.

> *"It's very boring."* Some of the conferences that I have been to are just boring. You just sit at a poster for six hours and talk to the person beside you because they're bored too; it's just very boring. I put this as a deterrent for following a STEM field career. I went to a geoscience conference and sat in a chemistry section for the entire time because everything else I didn't really care about. I think this was a major deterrent with me. – Ryan

For his geoscience URE, Ryan travelled to a regional conference to do a poster presentation. In this vignette, Ryan describes how the opportunity to present at a conference deterred his interest in a STEM field career because he struggled to find value in presenting during a poster session and felt bored with and by the experience. He did not receive validation during the experience that reinforced a sense that he was developing a specialized expertise or that the work he was doing was interesting or important. While Ryan had multiple opportunities to attend professional conferences through his URE, the time he spent at the conferences did not help encourage his interest in the geoscience field. This is a missed opportunity to make meaningful connections to and increasing an interest in STEM. For Ryan, the opportunity of presenting at and attending conferences deterred an interest in a STEM field career because he was unable to find value in presenting research and did not use the opportunity to its fullest potential and connect with the STEM field.

Chris and Ryan experienced incidents that provided opportunities they may not have had otherwise. Chris' URE required him to travel internationally, an opportunity he would not have had outside the URE. Ryan was selected for a poster presentation at a regional conference but failed to find an interest in the poster presentation or other sessions at the conference. Taking advantage of the opportunities afforded by a URE to personally grow, have unique experiences and connect with the field is impactful and contributes to an interest in STEM.

Develop marketable/transferrable skills. The participants indicated that incidents during their undergraduate research experience had a particularly strong impact on an interest in a STEM field career following graduation because these incidents allowed the student to build the confidence that they had the skills to be competitive in graduate school or in a science career. Learning to think critically, problem solve, manage one's time, and demonstrate knowledge of concepts were transferable skills gained during the URE. Grant writing, learning new computer software, and using specialized equipment were perceived to be marketable skills enhanced during the URE. Participants also viewed designing research projects and being able to produce, analyze and interpret data as key skills gained from the URE.

> *"A leg up."* I definitely had to learn how to use a couple new computer programs. I learned a lot of MatLab and computer software associated with the instruments we were using. I learned how to integrate the software, move data and actually make some preliminary models. While it was challenging, and could be difficult and frustrating at times, it was definitely overall a very positive experience. I felt really good about it when I was done. At the end of 10 weeks I really made a lot of strides and I knew that it would give me a leg up going to graduate school. That was really good to do that. I had fun doing it as well. – Seth

Seth is a physics major at SEC who entered his summer URE based on a suggestion from his faculty mentor. Seth's URE focused on storm water drainage in a coastal area. In this vignette, Seth describes his experience learning and using new software, transforming data for analysis, and generating models for the data. He views these skills learned during the URE as beneficial to his graduate school application. For Seth, learning new skills and analyzing data helped him to gain the confidence that he had the skills that could be used to set him apart from other graduate school applicants or job candidates that did not have this type of experience. The experiences resulting in gained skills may positively influence Seth's career plans in STEM as he feels that he has a realistic chance of success.

It was not until she was able to take on some more intellectually demanding tasks that Jordan, a communication science major at MAU, began to find satisfaction in a science project.

> *"Do I want to clean beakers?"* I got one of the research projects that was highly coveted; people wanted to be working with our team. Some of the other URE project possibilities

> were a little dry. I originally thought I wanted to be on the behavioral and neurocognitive team working in the rat lab. When I think about doing undergraduate research, do I want to be sitting cleaning beakers or having to change the rat food every five minutes? Not ideally. Now that I have done a fun research project that gave me an understanding of the positive outcomes of doing undergraduate research, I would be willing to do that now. I will be willing to spend hours at a lab seeing how many times a mouse flinches their whiskers. But I think it's certainly something that you should ease into so that you are not turned off by the idea of undergraduate research because you got stuck doing something that you didn't think you were going to be doing. – Jordan

Jordan entered her URE after an introductory course focused on undergraduate research. Jordan's URE project on non-verbal communication included identifying potential participants, collecting data and presenting results. In this vignette, Jordan compares her URE where she gained skills in recruiting study participants, running experiment trials, and producing graphs for data representation to a URE where she could be tasked with cleaning lab equipment or counting actions of interest such as rat whisker flicks. Jordan alludes to the idea that performing basic or routine tasks could deter an interest in conducting research and I posit also in a STEM field career. Her statement also indicates that she believes little is gained from getting "stuck" cleaning and counting. For Jordan, not being relegated to only performing basic procedures during her URE encouraged an interest in a STEM field career once she was able to see the positive outcomes of the research.

Seth and Jordan experienced incidents that expanded and strengthened their skill set such as running specialized computer software and producing data visualizations. Through Seth we can see that undergraduate students are wanting to gain advanced skills to give them an advantage over other candidates in graduate school or employment applications. The URE provides an opportunity to learn and enhance these desired skills. Jordan demonstrates how a URE where she can see the positive outcomes of undergraduate research is preferable to one a where a student only performs basic tasks. Therefore, incidents in the URE are impactful and contribute to an interest in STEM when they provide students with marketable and transferrable skills whose value are understandable to them.

Develop a professional identity. The participants indicated that the incidents during their undergraduate research experience had a particularly strong impact on an interest in a STEM field career following graduation because these incidents helped the participant to develop a professional identity. While a few of the participants indicated that they struggled with imposter syndrome at the beginning of the URE, many of the participants indicated that their confidence in their abilities increased during the URE. Several participants indicated they began to learn and use terminology and language in their field, gained greater understanding of class concepts through applying them in the research, had their opinion valued by faculty and peers, and had success as a STEM major. Additionally, a few participants shared how the URE afforded them leadership opportunities among their peers.

Luke is a geoscience major at ECU who entered the major based on his interest in a career that would allow him to work outdoors. It wasn't until Luke participated in an intensive field project where he worked closely with a mentor that his passion for the work itself increased and he begin to identify as a geologist.

> *"Matched with my soul."* Fieldwork, that's what I love to do. Sitting in a classroom and reading a PowerPoint I can do. But it's a whole other thing if you're outside in the mountains in the snow in July and you're eating lunch on the mountain top, looking at this and thinking "man how did I get here?" Being out there [at the mountainous region site] and walking and trekking through or being in [the glacial region], the whole experience of being in that environment and thinking that you're looking at something

> and thinking about something that nobody else probably has before. It's a cool precipice to be on. You're outside trying to figure it out and the whole environment, that's what I'm passionate about and love. When I went with [faculty mentor] and saw that this is what a field geologist does, I knew that this was for me. … It really matched up with my soul. – Luke

Luke entered his URE interested in a STEM field career but sought out the experience for employment reasons. Luke's URE began the summer before his senior year where he travelled to two field sites to collect data then the URE continued into the academic year where the data samples were analyzed. In this vignette, Luke describes his experience conducing fieldwork, an incident he rated as strongly encourage. Luke explains the connection he made between the work of a geologist and his personal interest in working outdoors. In this, Luke began to see himself as a novice geologist. For Luke, his fieldwork strongly encouraged an interest in a STEM field career because it helped him develop a professional identity; specifically, a geologist.

Jenn is a biology major at MAU who changed to the major from nursing after joining a physiology lab as she wanted to further explore biology. She struggled mightily to overcome a lack of confidence in her ability to be a scientist. A turning point came when her professor validated her expertise when she was making her first presentation at a conference.

> *"I'm not a scientist."* One thing I really struggled with, and still somewhat struggle with, is impostor syndrome. It very much deterred me. You start out with applying for funding and I remember I waited until the very last day for my first one. My mentor called me thirty minutes before it was due saying "You need to do this!" and I just kept thinking I'm not going to do this. I don't know how to do any of this stuff. I'm not a scientist or a researcher. I cannot imagine getting from writing the grant to carrying the research out. I

don't know what it means to be a scientist. I wonder what actual scientists do. I also struggled with thinking why am I wasting my time because [getting the grant] is never actually going to happen. I felt I was tricking everyone into thinking that I was smart and that I could do this. It is a huge thing that keeps you from making progress. It really gets you down. It makes you feel like you're lying to everybody. I know I got in my own way a lot of times and didn't get as much done because I was thinking I'm not really supposed to be here. I probably could've stepped forward a little bit more and would have applied for more opportunities if I hadn't felt like I was wasting everybody's time.

That feeling continued all the way until I was presenting at my first conference and my professor said I was probably the expert on [chemical] at the conference. Part of me thought What? No way!; the other part of me thought Well maybe, because it's not very widely studied. Most people haven't even heard of it. That was really cool, to be an expert in something. During my presentation, I could answer almost every single question and that was a really good and fulfilling feeling to feel like I knew my stuff. I did all of [my research project]; I picked, designed, worked and finished it. Sometimes I still start to feel [like an imposter] and have to say No, I just have to be confident about it and not let it get in my way and consciously move past it. I've never been a quitter so not letting myself quit. – Jenn

Jenn entered her URE interested in a STEM field career. Jenn's URE occurred during the academic year where she was one of several students conducting undergraduate research with the same faculty mentor in a lab setting. In this vignette, Jenn shares her ongoing struggle with imposter syndrome, an incident she added to the card set and rated as strongly deterred. Jenn recalled her thoughts about not being a scientist and how this negatively impacted her ability to conduct her research project.

Even after Jenn began to see herself as an expert on her research project, she still had moments of self-doubt and disconnection with being a scientist. For her, imposter syndrome strongly deterred an interest in a STEM field career because it hampered Jenn's STEM professional identity development.

Luke and Jenn experienced incidents that impacted their identity as a scientist. During the fieldwork incident, Luke identified as a geologist and this strongly encouraged his interest in STEM. For Jenn, the imposter syndrome stifled her ability to see herself as a scientist and the incident strongly deterred her interest in STEM. As discussed in Chapter 2, we know from prior research that identifying as a scientist plays a significant role for an interest in and persisting to STEM. Incidents in the URE are impactful and contribute to an interest in STEM when they assist students in developing a professional identity.

Value of doing research. The participants indicated that the incidents during their undergraduate research experience had a particularly strong impact on an interest in a STEM field career following graduation because these incidents helped the participant find value in conducting research. Students gained practical applications of their coursework through hands-on learning, made new discoveries, communicated their research, and saw how research can be used for a greater common good. By participating in their URE, students took the concepts they were learning in the classroom and applied them to a research problem. This hands-on learning provided though the URE was important for applying classroom concepts.

Several participants described how they felt their undergraduate research would allow them to make new discoveries and research cutting edge ideas. After conducting research and making new discoveries, many participants shared their undergraduate research in several ways. One key skill gained during the research presentations was to share the research in a way that was understandable to those outside of the field and with the general public. Several participants also discussed how they wanted to conduct research to impact the greater good. The students could see how they, through conducting research, could identify a problem, research solutions and then present the results to stakeholders who had decision making authority.

Peyton, a biology major at MAU, is one of those students who grew convinced that the research she was doing about insect feeding preferences had many important practical implications.

> *"Make a difference."* What can I study that's going to actually make a difference? Part of it for me is actually being able to make a difference. The reason that I want to study bugs is because I feel they are understudied. I feel like people see a bug and they say "Oooh! I'm going to kill it!" And for me there could be different ecosystem services that they provide that we don't know about; they could be a huge part of the food web. There's all kind of things that we don't know about. Being able to read papers that talk about that kind of thing encourages me and gives me hope that I'll be able to do the same thing and find something, maybe critically important, to share. It definitely encourages my work because I want to be able to do that too. – Peyton

In this vignette, Peyton describes wanting to make a difference through her research and finds that desire as an encouragement to pursuing STEM. She explains that to her the value of doing research is obtaining a greater understanding of things we do not currently know about. For Peyton, it's insects; for others, it is countless other topics for discovery. The URE provided Peyton with confidence in her ability to make a difference in her area of research.

Monica is a double major in mathematics and computer at SEC who completed more than one undergraduate research experience. In this vignette Monica compares her two research experiences and the value the research had for her. In the first URE, the research had no practical application which led to her disinterest whereas the second URE had many practical applications and lead to her increased interest in STEM because it increased her confidence that she could make a difference and a contribution.

> *"No practical application at all."* The most important thing that affects my decision on what I want to do and where I want to go is will I be doing something that impacts others. My research on Ramsey numbers had no practical applications at all. That made it very frustrating and hard to get motivated. Sometimes in the morning I would play Free Cell while I waited for myself to wake up because I was not motivated to work on the research. Whereas for my recognition software, there are so many applications that I was totally interested. I knew I was making a difference and a contribution. – Monica

In the first URE, the research had no practical application which led to Monica's disinterest whereas the second URE had many practical applications and lead to her increased interest in STEM. Had Monica not experienced her second URE she may have continued to have a disinterest because she was not making a contribution to the greater good through her research.

Peyton and Monica experienced incidents that contributed to their appreciation of the value of research. Through both students we see how they each understood the value of, and themselves valued, doing research. Monica's experiences show how conducting research with seemingly no practical applications does in fact contribute to a disinterest in a STEM field career. Incidents in the URE are impactful and contribute to an interest in STEM when they assist students in understanding the value of doing research. Thus, working with students in developing their understanding of the value of doing research in general and the application of the individual research project specifically can contribute to an interest in STEM.

Refine career interests. The participants indicated that the incidents during their undergraduate research experience had a particularly strong impact on an interest in a STEM field career following graduation because these incidents helped refine their career interests. Students found an interest in the field during the URE. Many shared that they saw the URE as an investment for greater opportunities in their future such as graduate school or available jobs. Students were offered career advice from their faculty mentors and built their resume through research publications and presentations. Several participants indicated they found a passion for research and their STEM field during the URE.

Leah is a biology major at SEC who worked with crustaceans in the same wet lab for four years. It wasn't until had to the opportunity to network with some professors at a conference that she began to see what the next steps for her career might be.

> *"Do you really want to do plan A?"* I came in wanting to go to medical school and part of me wants to, whether or not I get in is the question. When I attended the national conference, I realized I had always been doing research for the credit. Yes, I enjoy my research, but it wasn't something that I could see myself doing because I never really got to see outside of undergraduate research. At the conference, I had the chance to talk to some graduate professors about their research and openings in their labs. It was a fun experience. It really made me question what I really wanted to do; to take a step back and be like do you really want to do plan A? Why don't you look into plan B because maybe this is better for you? Attending that conference specifically made me realize I could go to Hawaii and work in the coral reef there. I could go to UC Berkley and they have all these fantastic marine biology programs. I got to network with the professors there and learn more about their research. Now I'm questioning if I don't get into medical school perhaps I'll take a year off, take the GRE, peruse around, see what's going on grad-school wise, and apply there and go for my PhD. Now I'm definitely more interested in

> the actual research parts; this is something I want to do. I attached to myself so much to this plan B, I don't know if I like plan A, which is going to medical school. – Leah

Leah is a biology major at SEC who worked in the same URE since her freshman year. Leah's responsibilities in the wet lab increased over four years. Her first year she was responsible for maintaining equipment and the crustacean tanks as well as shadowing an upperclass lab partner on her research project. At the end of Leah's sophomore year, she took over the research project from the student she was shadowing and modified it to make it her own. While Leah entered her URE anticipating going to medical school and not into a STEM career, experiences she had during the URE including presenting at a national conference and advising sessions with her URE mentor lead Leah to begin considering STEM research as a career. Leah's experience demonstrates how powerful early undergraduate research experiences can be in directing students into STEM during the first two years of undergraduate coursework when many students are exploring majors and deciding on a career path. She now has a plan B – a STEM career – to her original plan A, going to medical school.

Alexis is a psychology major at MAU who, like others, entered the undergraduate research experience with an interest in science. Her early experiences convinced her that she did not want to work with live animals.

> *"I don't necessarily have to work with rats."* I learned how to work with the Morris water maze which was cool but I don't see myself using that in future experiments. And it was cool to understand it but as far as neuropsychology, if I do research, I would do it with humans not rats. I didn't like the rats thing. I hated picking them up. I'm against doing injections, so anytime my mentor asked me to do one I said no because I don't like the idea of harming them or making them feel pain; I didn't like that. It definitely had an impact. In a way, it deterred me from that STEM field but at the same time it made me

> rethink well, I don't necessarily have to work with rats. I can work with maybe monkeys or anything else really, as long as I'm not hurting them in any way. In the lab we got to see a brain perfusion of a rat, which was cool. It was just like preserving the brain before you actually do the slicing and looking for neurogenesis. That's when I got interested in the brain; just cut it open and look at that instead of having to work with the live rats. Working with rats pushed me away from the behavioral aspect of psychology. It made me want to do neuropsychology. I want to focus on the neuro part and hopefully get my neuropsychology degree, get my PhD, and work in a hospital somewhere working with brain damage victims. I like the idea of asking the patients to do tests to see how it affects the brain; maybe do brain scans. I love people, I do not love rats. That's why I chose the brain area. – Alexis

Working with lab rats deterred Alexis' interest in a STEM field career. While this incident deterred her interest, Alexis did not give up her STEM career interest completely. Rather, she used the incident of working with the lab rats to clarify and refine her possible career options. She remained interested in neuropsychology but through the URE determined that she would need to focus in an area of the field that did not require using lab animals. The URE presented Alexis the opportunity to explore other areas of neuropsychology that she may have not been aware of as a career option without seeing it, specifically the brain profusion procedure, during her URE. Alexis presents an interesting finding in that rather than turning away from STEM completely as may have been expected, she used the URE to hone in on an area that fit with her personal beliefs and comforts. In this we see Alexis using the deterred incident to her advantage in that she refined her career path.

Leah and Alexis experienced incidents that refined their career interests albeit in different ways. Leah had her career options expanded to include a STEM field career. Alexis used her experience to hone in on an area of her field to focus on. No participants in this study were deterred significantly enough during their URE to change their career interest away from STEM. For some the URE solidified their interest in their desired field. For others, possible STEM career opportunities were shown to them through the URE. The URE is a mechanism to "try on" STEM research and determine where one's interests lay and where to focus one's attention. Therefore, incidents in the URE are impactful and contribute to an interest in STEM when they provide students with opportunities to refine their career paths.

Impactful interpersonal relationships. The participants indicated that the incidents during their undergraduate research experience had a particularly strong impact on an interest in a STEM field career following graduation because these incidents centered on impactful interpersonal relationships with a faculty mentor, research peers, family members and/or friends. Impactful interpersonal relationships interact among and influences the student's experience throughout the model. For participants in this study, positive interpersonal relationships encouraged an interest while challenging interpersonal relationships were likely to deter an interest in a STEM field career following graduation.

> *"Teach rather than punish."* I think Dr. Cook is an excellent advisor. He's really helped me with my research. He's very friendly, very open. There's always a sense of respect and decorum with him. There's obviously separation - he's a "Dr." and I'm a college student – but he doesn't use that to separate himself; he just uses that to teach you more. He wants to teach rather than to just punish you for your lack of knowledge. Whenever you don't know something he just teaches it. – John

> I feel like all the professors in geoscience are really down to earth. In other majors, it was like, "oh! I'm the professor and I know more than you do, you'll never be on my level",

> but with Dr. Cook and Dr. Anderson, they're just cool guys and they don't make you feel stupid about anything. If you have questions you can go ask them. – Josh

John and Josh, geoscience majors at ECU, are reflecting on the relationship they have with their faculty mentors. Both note the positive interactions they have had with the faculty mentors and the benevolent character of the faculty. Josh compares the geoscience faculty to other faculty at the same institution and notes that these two faculty members focus on teaching and guiding rather than lording their knowledge and expertise over the students. John and Josh allude to the fact that this approach from the faculty really helps the student be open with questions and willing to conduct the research without reservation rather than being timid about asking questions for fear of being thought less of or holding back in the research for fear of failure. The image John and Josh provide is one of mentoring colleagues who guide and share knowledge rather than a more traditional approach of master vs. apprentice. This mentoring colleague approach from the geoscience faculty at ECU was noted by all of the ECU participants as encouraging their interest in a STEM field career following graduation. While considerable time and effort is required on the faculty member's part to support this mentoring colleague approach, clearly it has positive impacts on students and encourages an interest in STEM.

> *"There's fierce competition."* I think sometimes advisors compete for students. I mentioned having a fall out with my academic advisor. He doesn't get along with my research advisor. When [the academic advisor] found out that I joined [the research advisor's] lab he was "disappointed" because he was going to ask me to join his. [The research advisor's] research was about plants and that's just not something I'm interested in. I think the competition – it's happened to a few students before, mainly with those two advisors – they don't try to make it awkward for you. As a freshman I had no idea [about the competition between the advisors] but now as a senior I understand why I don't get

> that 'hi' in the hallway or get that side look or I'm told that he's [academic advisor] disappointed in me. Now I understand the reason behind it. There's fierce competition to get into the labs and to stay in the labs actually. The competition between advisors, picking students to stay in the lab, and I guess between students. I think there's always that 'oh, well I'm published' kind of thing going around. For the most part I would say in the biology department it's not that competitive, which is really nice. I have friends in the math department and the chemistry department where [the students are] competitive to find that discovery first or synthesize the product first. I luckily haven't had that experience. Competition is something you should know about. – Leah

At the end of each interview I asked participants if there was anything about undergraduate research experiences that they thought I should know about but had not been asked during the interview. Leah took this opportunity to describe difficult interpersonal relationships between faculty members, faculty and students, and among students due to what she perceived was competition among individuals. She personally experienced her faculty academic advisor giving her a cold shoulder after she chose to work in her URE mentor's lab. Through her years of undergraduate study, she came to learn this was not an isolated incident and competition between the two faculty members over students was felt by several students. Elsewhere in her interview Leah described how important the relationship with her research advisor was to her both for the research experience and in academic advising and that this relationship strongly encouraged her interest in STEM. Leah also described competition between undergraduate research students in other disciplines to be the first to make discoveries or complete steps in their research process. Leah's description of competition that causes difficult interpersonal relationships between student and faculty or among student researchers brings to light the importance of positive relationships as the negative relationships can deter an interest in STEM. This is particularly true for women and minorities as we know that competition tends to steer them out of STEM fields (Burke & Mattis, 2007; Espinosa, 2011; Hurtado et al., 2007; Seymour & Hewitt, 1997). The competition felt by Leah during her URE and that she witnessed with other students could easily have deterred her interest in STEM had it not been for the positive relationship with her research advisor and other impactful incidents during the URE that encouraged her.

John, Josh and Leah all experienced incidents concerning impactful interpersonal relationships. They each talk about the positive role their research mentor played in the undergraduate research experience and demonstrate how critical the mentoring relationship is to learning and a willingness to ask questions. Leah's experiences show how strained interpersonal relationships can impact the research experience as thereby can negatively influence an interest in STEM. Therefore, incidents in the URE are impactful and contribute to an interest in STEM when they provide students with positive, supportive interpersonal relationships with and among faculty and other students.

Summary of Usefulness of Conceptual Model

The preliminary conceptual model was inductively developed from an initial round of open and focused coding of the data to conceptualize the potential impact of URE on student's long-term career interests. The linear model worked to explain the unique URE for some students but does not always fit precisely when looking at the participants as a whole. A revised model is presented at the beginning of the next chapter.

Parts of the model that fit. Several parts of the conceptual model – the interactive process of being provided opportunities, developing a professional identity, determining the value of research, and developing marketable or transferrable skills; impactful interpersonal relationships; and institutional context – continue to fit well for understanding how UREs contribute to an interest in a STEM field career interest following graduation.

The interactive process of being provided opportunities, developing a professional identity, determining the value of research, and developing marketable or transferrable skills, what I will now refer to as a collection of high impact outcomes, is the strongest part of this conceptual model and the crux of why UREs impact an interest in a STEM field career following graduation. When taken as a whole, a combination of URE critical incidents provide the mechanisms for these outcomes to occur. For instance, presenting at a conference (critical incident) where the faculty advisor validates that the student is the expert in their research topic (mechanism) allows the student to recognize their growing expertise (outcome). When these outcomes occur, students are more likely to be interested in a STEM field career following graduation.

Interpersonal relationships impact a student's interest in a STEM field career particularly when it is with a mentoring faculty member. Collegial relationship with a faculty mentor was rated by 29 of the 31 participants as encourage or strongly encourage an interest in a STEM field career following graduation. Many participants discussed in detail the important role their faculty mentor played in the research experience. Positive, meaningful interactions with the faculty mentor during the URE often helps students with an interest in STEM to refine their career interests in ways that match their skills.

Institutional context must be considered when understanding UREs and how the URE may contribute to an interest in STEM. Undergraduate research experiences were valued at MAU, SEC and ECU. This is seen through each institution having an office that coordinates undergraduate research experiences, institutional funding for research that students can apply to receive, and faculty willingness to offer these research experiences to students. The three institutions each had a different way of providing UREs to students, but a critical component is that all committed funding and other resources in support of undergraduate research. The potential to present research at conferences was particularly instrumental to a student's ability to see the significance of their research and to gain a sense of being part of a community. Faculty support for providing undergraduate research opportunities is vital to the URE program and strong support from faculty was found at each of the three institutions.

Parts of the model to be further conceptualized. The conceptual model was a good place to start to begin to conceptualize how UREs contribute to an interest in a STEM field career interest following graduation but some parts need further conceptualization. In particular, little difference was found between disciplines, research topics, and how the student first became involved in the URE. Further, I found that no single incident encouraged or deterred students from an interest in a future in STEM. Additionally, interpersonal relationships with peers, while mentioned by some participants, did not play as strong of a role as expected.

The initial model indicates that there are differences between disciplines, research topics, and how the student first became involved in the URE. This did not materialize as anticipated. There certainly were differences among the participants in discipline, research topic, and how they became involved in the URE, but it did not seem to play a role in an interest in a STEM field career following graduation. All participants in this study liked STEM even if they did not have an initial interest in pursuing it as a career option. This initial liking led to the participants becoming involved in their URE. Through the URE, students began making connections between their interests in STEM and future career options. Therefore, the model should be re-conceptualized to focus on an initial interest in STEM. Further, having the URE experience produce outcomes rather than giving much consideration to discipline, topic and how a student became involved as is delineated out in the current model.

The findings of this study indicate that it is these incidents in totality, not individually, that lead to an interest in a STEM field career following graduation. While some participants had individual incidents that deterred their interest, they had more encouraged incidents that mitigated the impact of the deterred incidents. Each URE encompassed a combination of individual critical incidents. Even incidents participants identified as a deterrent sometimes contributed to a clarification of interests and a re-direction to another path. Therefore, the model should be re-conceptualized to consider incidents in totality, not individually as in the current model.

I expected to find that interpersonal relationships with peers would impact a student's interest in STEM, especially when working in teams. This did not materialize in the findings, most likely because none of my participants were on research teams but rather worked on individual projects, albeit sometimes in the same faculty member's lab. Participants did not see their research project as linked to or collaborative with other student's research projects. Lab meetings, if held, were structured as a debrief on the progress each student had made on their individual research project where the faculty mentor and lab peers could offer feedback and support. When working in a lab setting, participants did indicate that, for the most part, they got along with their lab mates and were able to work through any areas of interpersonal conflict. Therefore, to reflect participants' perceptions, the model should be re-conceptualized to focus on the interpersonal relationship with the faculty mentor that did impact an interest rather than all interpersonal relationships experienced during the URE as is in the current model.

As there are several portions of the conceptual model that fit well and other portions that did not, a revised conceptual model for understanding how UREs contributed to an interest in a

STEM field career following graduation is needed and will be presented, then discussed, in the next chapter.

Chapter Five

Discussion

In this chapter I provide a discussion of the research findings. I begin with proposing a revised conceptual model for understanding why UREs influence an interest in STEM. Discussion of key findings and connections to prior research will be guided by the model. A discussion on the contributions of this study is offered. Finally, what implications the findings have for practice and future research will be discussed.

Revised Conceptual Model

Figure 5.1 shows a revised conceptual model of why students perceived that certain incidents had a particularly strong impact on their interest in STEM. This model acknowledges the critical incidents in totality rather than individually. It also highlights the mechanisms of and outcomes from the URE for refining a career interest in STEM following graduation. The model is intended to guide future research experiences. It can be used by URE program directors to tailor research experiences offered to undergraduate students in ways that maximize outcomes and an interest in a STEM field career following graduation.

In the model, students begin with an initial interest in STEM before entering the URE. The URE incidents provide mechanisms resulting in outcomes that refine a career interest in STEM. The mechanisms explain why or how an experience influences an outcome. All of this occurs within an overarching institutional context that differs between institutions. An interest in STEM is promoted by a URE when students have increased confidence when their expertise and skills in STEM are affirmed; gain experience in the field outside of the lab; the significance or practical implications of research become evident; experience what conducting research looks like as a career option; make connections with other researchers in the discipline and feel part of

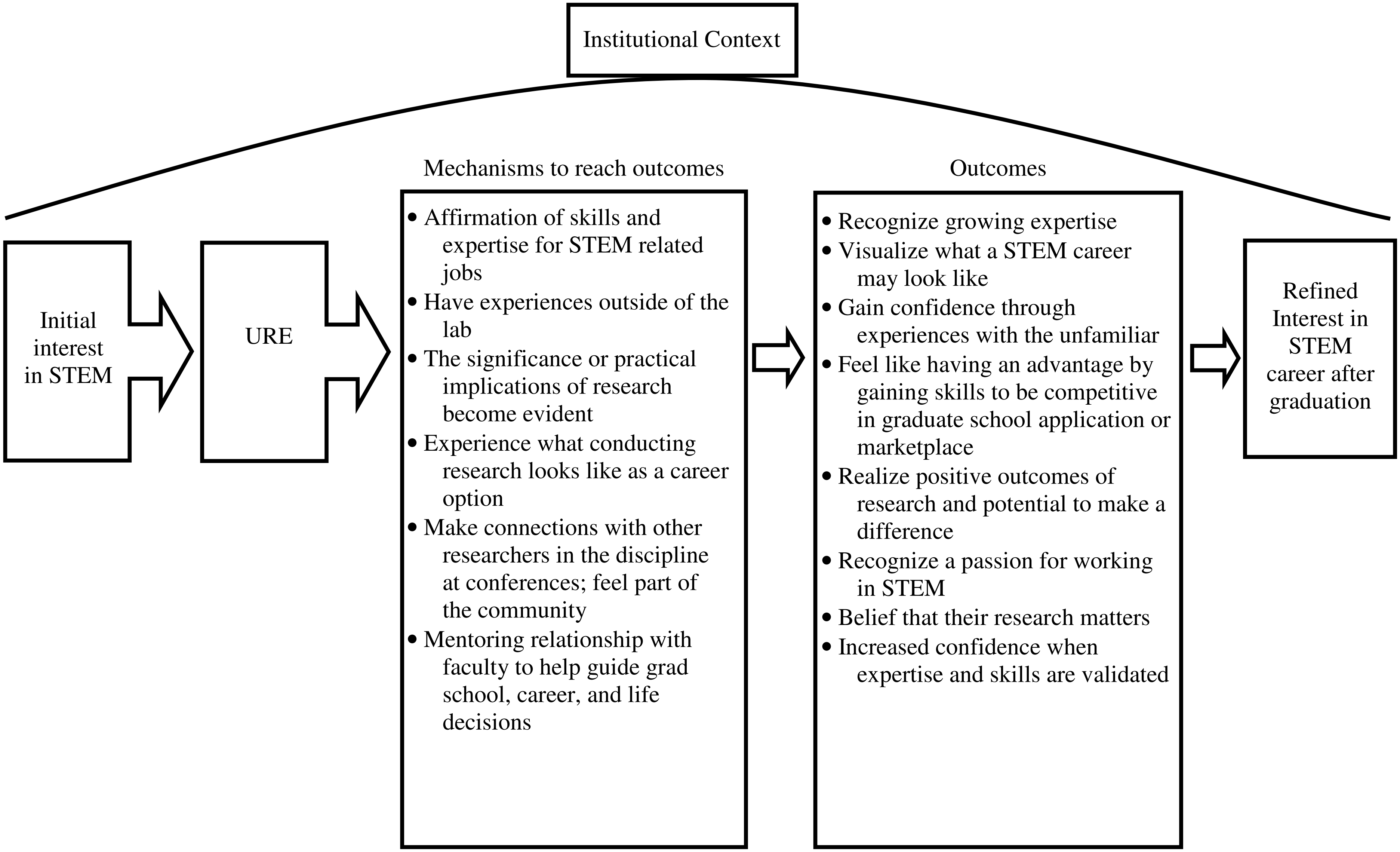

Figure 5.1 Revised conceptual model showing influence of URE on STEM careers.

the community; and have mentoring relationships with faculty who help guide graduate school, career, and life decisions. These mechanisms allow students to recognize their growing expertise, visualize what a career in STEM may look like, gain confidence through experiences with the unfamiliar, feel like they have an advantage by gaining skills to be competitive in graduate school applications or the marketplace, realize positive outcomes of research and potential to make a difference, recognize a passion they have for working in STEM, and believe that their research matters. Students are encouraged to pursue and able to refine their STEM career interest when these outcomes are present.

Summary of the Revised Conceptual Model and Its Connection to Prior Research

As is seen in Figure 5.1, there are six parts to the revised conceptual model. I will now discuss key findings in each part of the model and how they connect to prior research.

Initial interest. Participants in this study all had an initial interest in STEM even if they were not majoring in a STEM discipline. This liking of science is what propelled the student to become involved in the URE. Having an initial interest in science, not the process of how a student became involved in the URE, is the starting point for the revised model. This revision to the model illustrates that UREs are more likely to influence an interest in a STEM field career when the student begins the URE with an initial interest in science.

Results from this analysis are similar to that of Lopatto (2009) who also found that the majority of participants began their URE with an interest in science. The majority of Lopatto's participants were juniors or seniors. Only four percent of his participants discovered an interest in STEM from their URE. The URE is one mechanism for encouraging students to consider STEM field careers and timing of the experience is critical. Providing an early introduction to undergraduate research in the freshman and sophomore years opens opportunities to explore STEM and possible STEM field careers during the pivotal college years when students are deciding their disciplinary and career interests.

The URE. A major change from the initial conceptual model (Figure 4.1) to the revised conceptual model (Figure 5.1) is in how the individual critical incidents impact an interest in a STEM field career following graduation. As stated before, the incidents in totality, not individually had an impact on participants in this study. No single incident was likely to encourage or deter a partipicant from pursuing a STEM field career. In fact, most incidents students identified as deter an interest actually played a positive role as they helped the student in refining their STEM career interest. This strongly connects with the student having an initial interest in science. For students with an initial interest in science, it seems to take more than one or two deter incidents to impact STEM career interest. Furthermore, many participants indicated that they anticipated some of the deter incidents could occur when entering the URE. For example, a failed experiment was expected as it is part of science. Thus, students who have an initial interest in science who understand what doing science may entail are more likely to not be discouraged by the incident occurring during the URE and able use these deter incidents to their advantage to refine career interests.

Conclusions are not entirely consistent with the research by Lopatto. Lopatto (2009) reported that about four percent of his study participants were discouraged and left science after the URE. This departure is most likely due to being put off by the URE or the student gaining insight into themselves during the URE that scientific research is not a career option that meets their interests. Lopatto's results help explain why my findings do not include any Leavers since they make up a small portion of the students who participate in UREs. Additionally, some of my participants may eventually be Leavers as most were still engaged in their URE at the time of this study.

Mechanisms and outcomes. In the revised model, mechanisms are what happens because of the URE incidents that contribute to the outcomes and lead to a refined interest in a STEM field career after graduation. Multiple incidents can lead to the same mechanism. For example, fieldwork, learning new software, and presenting at a conference can provide the opportunity for affirmation of skills and expertise for STEM related jobs. There is not a one-for-one association between a single mechanism and an outcome as multiple mechanisms can influence an outcome. For example, the significance or practical implications of research become evident (mechanism) can result in a student's belief that their research matters (outcome). Likewise, making connections with other researchers in the discipline at conferences; feel part of the community (mechanism) can result in a student's belief that their research matters (outcome). Additionally, a single mechanism can influence multiple outcomes. For example, affirmation of skills and expertise for STEM related jobs (mechanism) can result in increased confidence when expertise and skills are valued (outcome) as well as recognition of growing expertise (outcome). Because mechanisms and outcomes are so intertwined, I will discuss them in tandem.

Many of the participants described directly or indirectly how their confidence grew during the experience conducting research. Confidence is important because students began to see themselves as legitimate researchers and to identify as a scientist (Carpi, Ronan, Falconer & Lents, 2017; Stanford, Rocheleau, Smith & Mohan, 2017; Thirty et al., 2011; Thiry et al., 2012). Participants discussed how taking the knowledge, skills and techniques learned in class and applying them to an actual research project made them more confident of their abilities. Several discussed how they began to realize they were becoming an expert in their research project and the unique aspects of the project that set it apart from other research in the field. Confidence increased as students received validation for this expertise and learned that their skills were valued, especially by faculty members. Validation of skills and expertise in research encourages an interest in a STEM field career. This outcome shows how vital faculty encouragement can be to student confidence and belief in their abilities.

The findings reported in this section are consistent with those reported by Laursen et al. (2010). These authors identified student gains from an undergraduate research experience: (a) personal/professional gains, (b) thinking and working like a scientist, (c) becoming a scientist, (d) skills, (e) enhanced preparation for career and graduate school, and (f) clarification, confirmation, and refinement of career and educational goals and interests (p. 45). The outcomes identified through this study resonate with Laursen et al.'s gains, specifically increased confidence, skills, enhanced preparation for career and graduate school, and refinement of career and educational goals and interests.

Findings from this research are consistent with prior research that underscores the value of an opportunity to publish and present the results from undergraduate research

(Buckley, 2010; Buckley et al., 2008; Craney et. al, 2011; Harsh et al., 2011; Hunter et al., 2007; Laursen et al., 2010; Russell, Hancock & McCullough, 2007; Thiry et al., 2012). Presenting their research results allowed the students to contribute knowledge in the field, gain practical skills in sharing research finding with others, and build confidence in and garner recognition for their identity as a researcher. Knowing you are making a contribution to the field though your research that you publish either through presentations or publications connects with the student's desire to have purposeful research. Further, many of the participants in this study discussed how their presentations or publications were important for their resume and graduate school applications as this demonstrated skills and abilities, initiative, and commitment to the field. Being able to make a contribution through presenting research encourages students to pursue STEM careers.

This study confirms the literature that communities of practice matter (Carpi et al., 2017; Graham et al., 2013; Kobulnicky & Dale, 2016). Communities of practice are multilayered social networks that create and disseminate knowledge among the community (Wenger, 2000, 2006). As students conducted fieldwork, presented at conference, or had a faculty mentor recommend others in the field to meet, they were able to make connections with other researchers in the discipline and begin to feel part of the larger disciplinary community. The undergraduate research symposia held at each campus offered participants an opportunity to interact with a community encompasing individuals across all disciplines who valued and were engaged in undergraduate research. From these interactions with others in the field and larger research community, students recognized their growing expertise, received affirmation of their skills and abilities, and formed networks with others who can be research collaborators, provide job opportunities, or give feedback on research endeavors. All of these contribute to an interest in a STEM career.

The importance and value of the mentoring relationship with the URE faculty member cannot be underscored enough (Adedokun & Burgess, 2011; Buckley, 2010; Buckley, Korkmaz & Kuh, 2008; Craney et. al, 2011; Egan et al., 2013; Harsh, Maltese & Tai, 2011; Hernandez et al., 2016; Hunter, Laursen & Seymour, 2007; Laursen, Hunter, Seymour & DeAntoni, 2006; Laursen et al., 2010; Lopatto, 2003; Lopatto, 2004a; Lopatto, 2007; Thiry, Laursen & Hunter, 2011; Thiry, Weston, Laursen & Hunter, 2012). Findings in this study are consistent with these prior studies that highlight the importance of faculty involvement and mentoring. Over and over the particpiants indicated how critical this relationship was to their experience and encouraging their interest in a STEM field career. The faculty mentor was more than a supervisor of the research project. In most cases, the faculty mentor also helped guide graduate school, career, and life decisions.

As was concluded by the National Academy of Sciences (2017), the quality of mentoring a student receives can make a substantial difference with their research experience. Participants in this study looked to their faculty mentor for guidance and direction not only with the research project but with their undergraduate academic career path and graduate school or career options. This is consistent with the findings of Thiry and Laursen (2011) that indicated students value the individual support provided by their faculty mentor. While all participants in this study reported a good relationship with their primary undergraduate research advisor, several discussed the negative impact poor relationships with other faculty members had on their interest to pursue STEM. Specifically, several students demonstrated resourcefulness as the noted how they turned to their URE mentor for undergraduate academic path advice as the relationship with their assigned major advisor was unproductive or contentious

Institutional context. Undergraduate research was valued at each of the three institutions in this study. Each institution demonstrated support for undergraduate research through having an office on campus that encourages undergraduate research, actively recruiting students to participate in URE, and by organizing an annual undergraduate research on-campus symposia. MAU and SEC had a dedicated office for undergraduate research and ECU has a TRIO program office that helped coordinate undergraduate research. Additionally, each institution had faculty who actively recruited students to participate in a URE. Finally, each institution offered an on-campus undergraduate research symposia day where URE students could present their research, faculty and students could interact across disciplines, and the campus community could see the research being conducted on campus.

ECU and MAU are comprehensive universities and SEC is a baccalaureate institution. None of the institutions had the type of large labs or externally funded research grants that are more characteristic of doctoral-granting institutions. All served a smaller number of students when compared to doctoral-granting institutions studied in prior research on UREs. The UREs at the three institutions in this study were typically unfunded individual projects or part of a cohort model of instruction. These institutional characteristics probably explains the absence of discussion about research teams and the importance of peer relationships among my participants that is evident in the wider body of research about UREs.

While there were similiarities between the three institutions, one striking difference that seems to impact the URE for my participants was access to resources. Resources can be a limiting factor to who and how many can participate in undergraduate research experiences (Auchincloss et al., 2014; Desai et al., 2008). Financial concerns impact URE students, especially those who are underrepresented minorities (Hurtado et al., 2007). Resource allocation and connecting with someone who has more social capital (i.e., a faculty member) is critical to undergraduate researchers. Social capital, what resources and assets an individual may possess to further their position in society, was seen within the UREs in this study (Berger, 2000; Bourdieu, 1986).

Individual resources, or the lack thereof, impacted several participant's URE. Most of the students at MAU and SEC had families with financial resources that were able to help their student with travel expenses to attend conferences. This generally was not the case for students at ECU. Some participants at ECU had to end their research earlier than desired due to limited institutional funding and no personal financial resources. The real impact from limited resources is students having fewer opportunities to refine an interest in a STEM field career following graduation. Students who, for example, are not able to finish their research project or who are unable to present at a conference could miss opportunities to have their expertise affirmed, connect with others in the field, or to see the purpose of their research thereby not seeing their growing expertise, realize positie outcomes of the research, or gain confidence in their abilities. This can directly impact an interest in a STEM field career after graduation.

Departures from the Literature

Based on my understanding of prior research on undergraduate research experiences, in my initial framing of the research I anticipated I would find participants who were Switchers, Stayers, and Leavers; that incidents in and of themselves could deter an interest in a STEM field career following graduation and that this would make the student leave the field; and that teams would matter. None of these materialized in my findings.

From prior research by Lopatto (2007), I expected there would be students who were Stayers, Switchers, and Leavers. This did not materalize as expected. I suspect this has to do more with who self-selected to participate in the study. All my participants had overall positive experiences and were willing to share information about these with me. It may be that Leavers were no longer on contact rosters or, if they were still on contact rosters, were not interested in recounting their experience to me. It is probable that larger differences between incidents would be seen if Leavers were part of the study and would provide greater understanding of the threshold that must be met before encouraged turns to deter an interest in a STEM field career overall.

Further, I expected that there would be differences in incidents that encourage and deter an interest in a STEM field career by these groups (Hunter, Laursen & Seymour, 2006; Lopatto, 2003, 2007). This was unfounded because, as is discussed above, the incidents in totality, not individually, contribute to an interest in a STEM field career following graduation. No one incident was so much of a deterrant that the student left the STEM field. I also anticipated differences in incidents that encourage an interest, incidents that deter an interest and overall interest in a STEM field career following graduation between male and female students. There were no observable differences seen between male and female students in regard to incidents that encourage and incidents that deter or with the URE overall encouraging or deterring and interest. This too may be because all participants had overall positive experiences. Another possible explanation is that UREs may be less likely to "weed out" students like introductory classes that disproportionately affect women and minorities.

Finally, prior literature discusses the impact of of working on research teams on the URE experience (Adedokun & Burgess, 2011; Buckley, 2010; Frantz et al., 2006; Russell, 2004; Zydney et al., 2002). None of the participants in my study reported that they worked in a research team although a few did work in a lab with other students who worked on similar, yet separate projects. Therefore, collegial relationships with peers did not emerge as a prominent part of the URE experience within the findings of this study. The lack of discussion about research teams could be because students working in UREs at non-Research-Intensive institutions were often working on independent, non-funded projects. Another possibility is that the faculty members at ECU, MAU and SEC intentionally structure the UREs to be individualized, even if complimentary between the interests of students and the faculty mentors. Another possiblity for the lack of discussion about research team may be that students may actually be working on a larger team research project but are unable to see the larger research agenda because they are narrowly focused solely on their individual piece of the research. Finally, particularly for the students in the cohort model URE, they may not see their cohort as a team but rather as only classmates since students received an individual grade and much of the research work occurred as assignments within the context of the semester-long class.

Contributions of the Study

This study provides several contributions to the existing literature on undergraduate research experiences. The first contribution is the proposed theoretical framework for why incidents during a URE influence an interest in a STEM field career following graduation. The heart of the conceptual model is the explanation of why or how critical incidents lead to the outcomes. The conceptual model identifies causal mechanisms that have not been offered in prior literature which has focused on critical incidents and a list of gains from the URE. The conceptual model also contributes toward the need for research on how and why a URE is working. While the findings of this study cannot be generalized to all undergraduate research experiences, the conceptual model provides a new way of thinking about the undergraduate research experience to understand how and why it works. This study also helps to fill a gap identified by the National Academies of Science (2017) for more research to address how UREs can function to support a student's initial interest in STEM.

Second, findings in this study expands Laursen et al.'s (2010) gains from undergraduate research. Recognition of growing expertise, visualization of what a STEM field career would be like, and recognizing the societal impact of research are additional gains students in this study indicated encouraged their interest in a STEM field career following graduation. This notion of research for the greater good fueled an interest in conducting research and gave meaning to and motivation for the students to persist even when faced with failed experiments or other setbacks in the research process.

Next, this qualitative study contributes to a deeper understanding of undergraduate research experiences that is not known through prior quantitative studies

(Meyers et al., 2010; Strayhorn, 2010). Semi-structured individual interviews and a focus group allowed participants to discuss the various incidents they experienced conducting undergraduate research as well as describe why those incidents were impactful. The use of a Q-sort helped guide the participants to discuss their experience without limiting the participant's ability to add to the list of incidents experienced. The Q-sort method proved to be very useful in guiding the interview with undergraduate students as it focused their attention on completing an action before talking directly to me thereby slowly easing into the interview. The critical incidents prompted the participants in discussing their URE. Participants were also able to add critical incidents in the Q sort which resulted in six additional critical incidents being identified through the interviews that were not found in prior literature. The Q sorting process assisted participants in being more reflexive about their URE, which could help clarify their STEM field career interests.

Fourth, the two models of URE represented in this study, while not part of the initial sampling plan, provide further understanding on how UREs can be structured. The UREs at MAU and SEC were apprentice style whereas the UREs at ECU were primarily course-embedded. The traditional apprenticeship model URE is one where a faculty mentor works directly with a student on a project related to the faculty member's research agenda (National Academy of Science, 2017). The course-based URE engages a cohort of students in a research project through a series of sequential academic courses. With a cohort model, I anticipated that collegial relationship with/mentoring peers would be prominent when compared to apprenticeship style UREs. This however did not emerge, possibly because the cohort students did not see themselves as team-based. They saw their work as part of the course assignments.

Finally, this study included two institutions with a Carnegie Classifications of Master's Colleges and Universities and one institution with a Baccalaureate College classification. Master's Colleges and Universities and Baccalaureate Colleges are not traditionally viewed as having the same research focus as institutions with a Doctoral-granting University classification. These findings help fill the gap on non-Doctoral-granting University undergraduate research experiences by supporting the idea that UREs can be effective in these settings as well in promoting an interest in science and research.

Limitations

As with all research, there were limitations to this study. The first is related to securing participants. It took far more time to recruit an adequate number of participants than I anticipated. As an outside researcher, having good institutional liaisons is key to recruiting participants. While I initially encountered willing gatekeepers who were committed to UREs, were enthusiastic about my research topic and willing to help me with the data collection process, on more than one occasion this initial enthusiasm did not translate into access to a pool of participants. In one case, a gate keeper never followed up. In other settings, I found that the influence of gate keepers in recruiting interview participants was not as strong as I anticipated. I anticipated that once the gatekeeper encouraged participation in the study, URE students would want to participate, but this did not happen. Recruiting students from the institution employing the cohort model was much easier because the faculty coordinator was willing to allocate class time for data collection, which alleviated the need to find a common time to conduct a group interview.

Because of the issues I encountered with obtaining participants, I had to significantly modify the initial data collection plan. Initially, I had planned to conduct an on-campus focus group with 8 to 10 participants at two institutions. After the focus groups, I would then select 8 to 12 participants from all focus group participants to conduct individual in-depth interviews. This plan proved unrealistic given college student time constraints, inability to coordinate one focus group time at each institution, and the need to schedule multiple interviews with participants selected for both rounds of data collection. One interview time resulted in more students willing to participate and provided more data on individual incidents than originally planned. Further, because of the issues with obtaining participants even after several months of attempts, the intended purposeful sample changed into a convenience sample of any student who agreed to participate from now three institutions. Using a convenience sample limits the representative nature of the results, could have introduced unintended bias, and may have impacted the data, particularly the experience of Leavers.

I conducted an individual interview with 22 participants and one focus group with 9 additional participants. The same data collection procedure (i.e., the Q-Sort) was used during the interviews and the focus group. The interviews allowed for in-depth discussion with each participant and were expedient to arrange based on just two people's schedules. The focus group allowed for open discussion among the nine participants on the critical incidents and many times participants would play off each other thereby providing a fuller description of how the incidents occurred and influenced their interest in STEM. While the focus group allowed for open discussion of incidents, it did limit the ability to delve deeper on the individual experiences of each participant like the interview afforded. Therefore, the nine participants in the focus group were limited in the richness and volume of individual experience data unlike the interview participants had.

Participants from ECU were all in the same field-based major; a reflection of the contact with the faculty gatekeeper. Participants from MAU and SEC were in multiple majors, most of which were primarily lab-based. The idiosyncrasies of the institutions in this particular study are not reflective of all institutions that offer UREs. Furthermore, participants in this study attended an institution with a Master's L or Baccalaureate Carnegie classification and located on the East Coast. We cannot assume that the findings in this study are applicable to students at other institution types or geographic regions. Finally, the qualitative nature of the study and the relatively small sample size of 31 participants limits the transferability of the findings.

Implications for Future Practice

The study findings have several implications for future practice. Higher education administrators who oversee undergraduate research offices and faculty guiding UREs can benefit from this research. Future practice should be concentrated on providing opportunties for the mechanisims identified in Figure 5.1 to be achieved.

Offer affirmation of skills and expertise for STEM related jobs. Gaining confidence in one's skills and expertise was an outcome from the URE. Faculty should identify ways for a student to become aware of their skills and expertise. These ways could include faculty affirmation through verbal or written commendation, assigning the student to train others on equipment or processes, or acknowledging contributions through conference presentations or publications. Once the student has become aware of their skills and expertise, faculty can then work with the student to identify STEM related jobs needing these skills. These type of conversations will allow the student to see how they are positioned well to be successful in meeting job requirements.

Provide experiences outside of the lab. UREs often allow students to see that while part of the research process may occur in the lab, one can also do research outside the lab through fieldwork or present the research at conferences. Opportunities outside the lab can also provide students with the opportunity to gain skills or experiences that make them more competitive in graduate school or job applications since they would have more than just science lab experience. These opportunities broaden the student's perception of what a scientist does and allows them to visualize what a STEM career or conducting research looks like as a career option. This can fuel a passion for working in STEM, increase one's interest in becoming a scientist and encourage pursuing a STEM field career.

Participants understood that undergraduate research can have a large laboratory component. However, many discussed how they also liked getting outside of the lab either in field work or at conferences and that this contributed to their interest in STEM. Faculty can identify opportunities for students to conduct fieldwork whether that be collecting data for their project or shadowing another researcher who is working out in the field. This allows the student to see another venue for conducting research and in particular can be encouraging to those students who want to have careers with a large outdoor component. Attending conferences was encouraging to some students as they were able to move beyond the lab setting and share their research with others. Faculty should encourage students to attend a professional conference and play a meaningful, affirming role in student conference presentations.

Make evident the significance or practical implications of the research. Participants were clear that their interest in a STEM field career was encouraged when they saw their research had practical implications or when others affirmed the significance of the research. When working with URE students, faculty should be explicit about what practical implications the research could have, ways the research can be used for the common good, and how the research is significant. Through intentional conversations, faculty can guide student to make connections between their research results and procedures, products, policies and the like. Further, faculty can discuss with students the ways in which the research is significant and not just busy work to fulfill the URE requirements.

Experience what conducting research looks like as a career path. Undergraduate students may enter the URE interested in science but without knowing research can be a career option and what that career could look like. The hands on learning a URE provides allows students to “try out” research and begin to envision what being a STEM research could entail. Faculty, to the greatest extent possible, should help students identify processes, procedures, and applications within the URE that connect with and may be used in a future career. For instance, students at ECU learned to use specialized equipment and to do field site mapping. Each of these hands-on experiences can be part of a career in geology. Faculty can also help URE student understand the multiple career options available to them in research and in STEM. An impactful best practice from faculty mentors in this study was to share job postings, funding opportunities, and graduate program information with students through email or a common space bulletin board. While the students may not act on each opportunity that was shared, the student could start to see the range of possibilities there are for a STEM field career, including those that involve research.

Provide opportunities for students to connect with other researchers in the discipline at conferences. This study demontrates that attending conference where the URE student can make connection between their research and the field, network with others, and receive affirmation of their skills and knowledge from faculty encourages an interest in a STEM field career following graduation. Higher education adminitrators should intentionally allocate funding opportunities specifically for students to attend conferences. These opportunities are pivotal to an interest in a STEM field career and can provide immeasurable return on investment. Resources were a limiting factor for several participants in this study. Student access to institutional funding for conference attendance can help ensure no student loses out on having this experience during their URE simply due to lack of financial resources.

Networking opportunities where students can build professional connections and begin to feel part of the disciplinary and greater research communities encourage an interest in a STEM field career following graduation. Administators of URE programs should seek ways to encourage student networking across projects, between institutions, or in collaboration with industry professionals. Networking across projects could occur through small scale social or professional development events held bring students and faculty involved with UREs on campus together. An annual undergraduate research symposia day on campus can provide an opportunity for students to share their research, learn about the research of others, and interact with faculty. Collaborations between institutions can be encouraged through faculty colleague connections, as was seen through the URE experience of Seth, or partnering with URE administrators at other institutions to share URE opportunites between schools. Finally, partnerships with professionals in industry can provide real-world, hands-on career experience and contacts for future employment.

Mentoring relationship with faculty to help guide graduate school and career decisions. The relationship with the faculy mentor plays a key role in the URE, including through a one-on-one relationship and the cohort model. Having a faculty mentor who affirms the student's skills and abilities, supports the student throughout the research process, and shows an interest in the student as a person beyond the research project encourages a student's interest in a STEM field career. Intentional mentoring is needed to maximize this relationship. Not all faculty researchers make good research mentors and it cannot be assumed that all faculty know how to be good mentors. URE faculty mentors should be carefully selected and given resources by the institution, including training and time allowances, for mentoring undergraduate research students. Higher education adminitrators should offer thorough, intentional training opportunities so faculty can learn how to be good mentors to URE students, including for those with special needs.

Institutional administrator support of faculty to provide UREs is also important. Institutional policies and work load requirements must take into account faculty mentoring of URE students. Quality mentoring requires adequate time commitment that should not be limited because of teaching, service, and faculty research requirements. Additionally, administrators should highlight campus best practices and provide ways to recognize mentoring successes. This can be done through an awards program or through social media.

Additional implications. The participants in this study all liked science. The revised conceptual model is based on students having an initial interest in science. Since the goal is to encourage an interest in a STEM field career following graduation, there does not appear to be much gained by trying to recruit those without an initial interest in science. Therefore, faculty offering URE opportunities should recruit students who have an initial interest in science and build upon this interest rather than finding students who want have little to no interest in science and hoping that the URE will change their interest thereby leading to a career in science.

Many participants in this study indicated they wished they would have known about undergraduate research experiences before their junior or senior year. If undergraduate research administrators and faculty primarily offer STEM UREs to juniors and seniors, they are not capitalizing on a prime opportunity for students who have some interest in STEM to further explore this interest early in the college major selection process. Offering STEM UREs in the freshman or sophomore years will require faculty to identify students with high potential and administrators who commit resources to promising students rather than focusing on recruiting only declared STEM majors into undergraduate research. Future practice can focus on identifying students who have an interest in science but may not know that UREs are available. Higher education administrators can use many ways to help identify these students such as summer bridge programs, high SAT Analysis in Science cross-test or Math test scores, new student orientation, students in an undeclared, general studies major, and first or second year students in STEM majors and minors. Additionally, curricular partnerships through a college 101 courses or first year seminar courses can identify students with an interest in science. Campus partnerships with general education academic advisors and career center staff can also help identify students. Regardless of how the student with an interest in science is identified, notifying the student of undergraduate research opportunities is important but encouraging the student to pursue the experience is vital. This is one possible solution, for a problem that will require many, to help close the leaky STEM pipeline and retain outstanding students in STEM.

Resources is the key variable that distinguished the participating institutions and is part of the final model. Access to financial resources was an issue for several participants in this study. There is a potential for inequity among students with an interest in science who could benefit from a URE. Few participants in this study were receiving funding; one from a stipend and three others from small research grants from their institution. The lack of funding creates two issues. First, students may opt out from participating in a URE due to time commitments. It is likely that students with limited financial resources may not have the time necessary for the URE as they may be working outside of school to pay for their education and living expenses. Second, for those with limited financial resources who do participate in a URE, it may limit their ability to complete research projects or to participate in conferences if these activities, for example, require personal funds to buy equipment or to pay for travel expenses. In these cases, students would not have the same opportunities to reach the outcomes that encourage an interest in a STEM field career following graduation as other URE students who do not experience the same financial limitations. These issues raise a concern for the potential to limit access to UREs for students with limited resources. This highlights the need for institutions to be intentional about targeting resources so a diverse group of students can benefit from the URE experience.

Future Research

This study suggests future research opportunities. The primary contribution of the findings is the revised conceptual model. Future research can test this revised conceptual model to determine if it continues to work for additional student in undergraduate research experiences, particularly those in other disciplines, such as engineering or chemistry, and at other institution types, such as community colleges or doctoral-granting institutions. One way to conduct this research could be through in-depth case studies of individuals to confirm the mechanisms that lead to URE outcomes that encourage an interest in a STEM field career.

There were no participants in the "Leavers" group; those who were interested in a STEM field career entering the URE but were no longer interested after. Because of this, it is unclear of the revised conceptual model holds true for Leavers. It is important for future studies to consider the Leavers group to identify the mechanisms that deter an interest in a STEM field career and identify any common themes for why the student's career interest changed. Focusing on Leavers and using the data collection methods of this study, a future study could determine if individual incidents play a role for Leavers, if it is groups or clusters of incidents, or if it is the incidents in totality for Leavers too that deter an interest. If the incidents in totality do deter an interest, a conceptual model focused on the mechanisms that lead to unreached outcomes could be derived from the experiences of Leavers. Once a model for Leavers is developed, the mechanisms between the two models could be compared.

Because there were no participants in this study that began the URE without an interest in science, it is unclear if the revised conceptual model would fit for students who began the URE with little or no interest in science. A longitudinal research design would make it possible to explore the experiences of student who enter UREs with an interest in STEM but chose at some later date to pursue another route. This might be the case, for example, for students who find they do not enjoy research or think they are suited for it. This type of design would also make it possible to explore the experiences of students who begin the experience without an interest in science to identify the mechanisms that changed the student's interest in STEM. It might be possible to create a theoretical model that incorporates the experiences of Leavers, Switchers, and Stayers.

This study contributed to the list of gains offered by Laursen et al. (2010). Specifically, gains identified in this study include increased confidence, skills, enhanced preparation for career and graduate school, and refinement of career and educational goals and interests. Of these, increased confidence in one's skills and abilities as a researcher was a prominent, recurring gain among participants. Future research could consider how confidence in one's skills and abilities as a researcher, or lack thereof, impacts an interest in STEM. Further, future research could explore what activities during a student's undergraduate career, including but not limited to UREs, contribute to increased or diminished confidence. Knowing how confidence impacts an interest in STEM and what undergraduate experiences are more likely to lead to increased confidence in one's ability to do research can be used to improve future practice.

Qualitative resarchers are keenly aware of the benefits of thoughtful, articulate, and forthcoming participants when conducting interviews. Through prior research experience, I was mindful that undergraduate students may not always deliver a thoughtful or articulate interview. I found the Q-sort technique to be very useful in interviewing undergraduate students (Brown, 1991; Stephenson, 1953; van Exel, 2005). The sorting activity allowed the students to focus on an action before talking about their experiences. This seemed to calm nerves and allowed for a few extra moments to get comfortable in the setting. Using the incident cards from the Q-sort helped guide the students in discussing their experiences. The Q-sort technique was effective and provided rich interview data. Future research can benefit by incorporating this data collection technique when interviews are to be conducted.

Conclusion

Based on the findings of this study, I believe it is realistic to think that UREs are instrumental in promoting an interest in a STEM field career following graduation for students who enter the experience with an initial interest in a STEM field career. I also believe that UREs can be instrumental in promoting an interest in a STEM field career for students who like science but who have yet to determine if they wish to pursue a career in a STEM field career *if* the URE occurs early in their undergraduate career while the student is exploring multiple disciplinary and career options. It is perhaps less likely that students who like science but are not interested in a STEM field career will enter a STEM URE or switch their career interest to STEM later in their undergraduate career. I do not believe it is realistic to think that UREs are instrumental in promoting an interest in a STEM field career for those students who are not interested in STEM or engage in a STEM URE opportunity for employment reasons. Fundamentally their objectives for the URE are different from those who like or already interested in STEM. It is my hope that the understanding gained from this study will be used to engage and further encourage undergraduate students to enter STEM field careers and successfully compete in the global marketplace.

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Appendix A

Participant Recruitment Email

Subject: Research Participation Invitation: Student Perceptions of Undergraduate Research Experiences

This email message is a request for participation in research that has been approved by Virginia Tech's Institutional Review Board (IRB). The purpose of this research is to examine incidents during the Undergraduate Research Experience that students perceive to encourage or deter their interest in a STEM field career following graduation. Results from this study can potentially be used by universities to improve undergraduate research experiences.

You were selected to receive this email because you have been identified as an undergraduate student who has participated or is currently participating in an Undergraduate Research Experience at [E.C.U./M.A.U] University. Participation in this research is strictly voluntary. The researcher will make every effort to protect participant confidentiality. Participant names, the name of your institution, and any other identifier will be altered to further this goal. No information that can be used to specifically identify you will be divulged from this study.

Participants are requested to participate in one 45 to 60 minute interview. Participants will be compensated $10/hour of their time as well as being entered in a drawing among all participants for one iPad mini for participation.

If you are interested in participating in this research, please complete a short online interest form at [website] by [date].

Questions about this research should be addressed to Janice Austin, doctoral student in the Educational Research and Evaluation program at Virginia Tech, at jema@vt.edu.

Appendix B

Online Interest Form

The purpose of this study is to examine incidents during the Undergraduate Research Experience that students perceive to encourage or deter their interest in a STEM field career following graduation. Participants are being sought from currently an undergraduate student at a master's level institution who have participated in or are currently participating in an Undergraduate Research Experience. It is the goal of the investigators to identify experiences during the URE and common themes among participants involving their experiences. This information can potentially be used by universities to improve the experiences of undergraduate students during undergraduate research experiences. If you are interested in participating in this study please complete the following interest form. Thank you.

Name: _________________________ Email Address:_________________________

Current Institution Name:____

Year in School:__________________ Major: _________________________

Phone Number:__________________ Age:___________________________

Gender:_________________________ Race:__________________________

The Council on Undergraduate Research (2013) defines an Undergraduate Research Experience as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline."

STEM is an acronym for Science, Technology, Engineering and Mathematics

Are you currently participating in a STEM undergraduate research experience? Yes No

Have you completed a STEM undergraduate research experience? Yes No

How long have you been in/was your undergraduate research experience? ___________________

Describe your undergraduate research experience including when you started and finished the URE, what project you worked on, anyone who was part of your URE and any final product produced from the URE.

Are you willing to participate in a 45-60 minute on-campus interview? Yes No

Appendix C

IRB Approval Letter

VirginiaTech

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

MEMORANDUM

DATE:	November 21, 2014
TO:	Elizabeth Creamer, Janice E Austin
FROM:	Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)
PROTOCOL TITLE:	Incidents in the Undergraduate Research Experience that Contribute to an Interest in STEM
IRB NUMBER:	**14-670**

Effective November 20, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

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

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

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

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

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

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 6,7**
Protocol Approval Date:	**November 20, 2014**
Protocol Expiration Date:	**November 19, 2015**
Continuing Review Due Date*:	**November 5, 2015**

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

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

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

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

Invent the Future

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Appendix D

Informed Consent Form

Virginia Polytechnic Institute and State University

Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project: Incidents During an Undergraduate Research Experience that are Perceived to Encourage or Deter a Student's Interest in a STEM Field Career Following Graduation

Investigator: Janice Austin

I. Purpose of the Research.

The purpose of this study is to examine incidents during the Undergraduate Research Experience that students perceive to encourage or deter their interest in a STEM field career following graduation. The participants of this study are different age, genders, and ethnicities. Each participant is currently an undergraduate student at a baccalaureate or master's level institution and has participated in or is currently participating in an Undergraduate Research Experience. It is the goal of the investigators to identify experiences during the URE and common themes among participants involving their experiences. This information can potentially be used by universities to improve the experiences of undergraduate students during undergraduate research experiences.

II. Procedures

Participants will be asked to participate in one, 45 minute to one hour individual interview with me. In total, the time commitment is not expected to be longer than the interview. The interview will be audio-recorded. The interview will be conducted on the [E.C.U./M.A.U.] campus in [Southeastern United States].

III. Risks

I understand that this study may potentially evoke emotions related to my experiences as an undergraduate student participating in an undergraduate research experience. If the emotional toll is too great, I can choose not to answer certain questions or describe certain events. If I need professional services as a result of the questions asked, I acknowledge that the researcher(s) and university do not have the funds to provide me with these services.

IV. Benefits

I understand that this study may potentially benefit universities seeking to improve their undergraduate research experience program. I understand that my answers and descriptions may potentially help improve the experiences of undergraduate students in the future.

V. Extent of Anonymity and Confidentiality

I understand that the investigators in this study will make every effort to protect my confidentiality as a participant. My name, the name of the institution I attend, and any other identifier will be altered to further this goal. No information that can be used to specifically identify you will be divulged from this study. Only the researchers listed at the bottom of this study and an audio recording transcriptionist will have access to any data collected in this study. After all reports regarding the study are completed, all audio-recordings and data records will be destroyed.

It is possible that the Institutional Review Board (IRB) at Virginia Tech may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

Participants will be compensated $10/hour of their time and entered in a drawing among all participants for one iPad mini.

VII. Freedom to Withdraw

I am free to withdraw from this study at any time. I may answer or choose not to answer any of the questions in this study.

VIII. Participant's Responsibilities

I voluntarily agree to participate in this study. I have the responsibility of answering questions truthfully and to the best of my knowledge.

IX. Participant's Permission

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ ____________________

Subject Signature Date

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

Investigators:

Janice Austin	Dr. Elizabeth Creamer	Dr. David M. Moore
Graduate Student	Faculty Member, EDRE	Chair, IRB
Virginia Tech	Virginia Tech	Virginia Tech
jema@vt.edu	creamere@vt.edu	moored@vt.edu

Appendix E

Demographic Questionnaire

Name: ______________________________ Pseudonym: __________________________

Institution Name: (prefilled)______________

The Council on Undergraduate Research (2013) defines an Undergraduate Research Experience as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline."

STEM is an acronym for Science, Technology, Engineering and Mathematics

Did you begin your URE interested in a STEM field career following graduation?

Yes No Uncertain

Are you currently interested in a STEM field career following graduation?

Yes No Uncertain

Did you begin your URE intending to attend graduate school in a STEM field major?

Yes No Uncertain

Do you currently intend to attend graduate school in a STEM field major?

Yes No Uncertain

Appendix F

Interview Protocol

Complete informed consent and demographic questionnaire

As the participant arrives ask him/her to take a seat. Instruct them review and sign the informed consent form and complete the demographic questionnaire. Allow time for these to be completed.

If it is ok with you, I will turn on the recording equipment now and start the interview. (get verbal consent); *Start audio and video recording*

This interview with *(Pseudonym)* is being conducted by Janice Austin on (DATE) at (TIME). Thank you for taking the time to participate in an individual interview about your undergraduate research experience. The purpose of this interview is to discuss individual incidents during your undergraduate research experience in depth. In this interview I will guide you through a card sorting exercise in order to talk about your undergraduate research experience.

In front of you, you have an envelope. Please write your pseudonym name on the envelope. *[pause]*

You may now open it. In the envelope you will find a set of cards and a pen. On each card is an incident found in scholarly literature to occur during an undergraduate research experience. Some or many of the incidents may not apply to you and there may be incidents that you think of that are not listed on the cards. The purpose of these cards is to have you start to think about the individual incidents that you experienced during your undergraduate research experience.

Please take a few minutes to review the set of cards and sort each card into one of four mutually exclusive groups: (1) incident that encouraged your interest in a STEM field career following graduation, (2) incident that deterred your interest in a STEM field career following graduation, (3) incident that neither encouraged or deterred, and (4) incident not experienced. There are no right or wrong answers to this sorting exercise. *[pause – a list of the four categories will be provided on a piece of paper to the interviewee]*

You see there are blank cards in your set. These are for you to add any incidents experienced during your undergraduate research experience that were not on the previous cards. Please take a few minutes to add any additional incidents that encouraged or deterred your interest in a STEM field career following graduation and add them to the appropriate pile of sorted cards. If during our discussion of the incident cards additional incidents come to mind, please let me know and we will add it to a new card.

Let's start our discussion with a card you placed in the "encouraged your interest in a STEM field career following graduation."

Please describe this incident to me.

How did this incident impact you?

Why was this incident influential in encouraging your interest in a STEM field career following graduation?

Now please select an incident from the deterred your interest group.

Please describe this incident to me.

How did this incident impact you?

Why was this incident influential in deterring your interest in a STEM field career following graduation?

[Repeat previous two question groupings until all incidents are discussed or allotted interview time remaining is 15 minutes]

Please describe to me your current interest in pursuing a STEM career following graduation. [*How has your interest changed over time? What has influenced the change?]*

Ranking cards (10 minutes)

Now I would like you to rate all the cards. You will see a blank line in the bottom right of the card. On this line, please rate each card on the following scale *[scale will be displayed for the participant to reference]*:

0	Not experienced during URE
1	Strongly deterred
2	Deterred
3	Neither deterred or encouraged
4	Encouraged
5	Strongly encouraged

Now that you have completing your ratings for each card, please use the rubber band in the envelope to bind the cards together then place them in the envelope

Summary and Closure (5 minutes prior to end time)

It is getting close to the end of our allotted time and before we end the interview I would like to offer a brief time for any final information regarding your undergraduate research experience that you would like to share. *[pause for responses]*

May I contact you after this interview if I have additional questions regarding the information you provided today?

Thank you for your time and participationg in this study!

Appendix G

Administrator Email

Dear [Administrator],

My name is Janice Austin and I am a doctoral candidate in the Educational Research and Evaluation program at Virginia Tech. For my doctoral dissertation, I will be studying the experiences students have during their undergraduate research experience at a Master's level or Baccalaureate level institution. The purpose of this research is to examine incidents during the Undergraduate Research Experience that students perceive to encourage or deter their interest in a STEM field career following graduation. This research study has been reviewed and approved by the Virginia Tech Institutional Review Board (IRB).

I am contacting you to request that you forward the study call for participation email (text below) to your undergraduate students. I would appreciate if you will let me know if you are able to forward this call to your students. If you able to forward, please also provide me with the date and time the email call was sent as well as the number of students the call was sent to. This will help me in keeping accurate study procedure notes.

Thank you in advance for your willingness to assist me in my research study. If you are interested in a summative report of my findings I am happy to provide this to you at the conclusion of the study.

Sincerely,

Janice Austin

Subject: Research Participation Invitation: Student Perceptions of Undergraduate Research Experiences

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You were selected to receive this email because you have been identified as an undergraduate student who has participated or is currently participating in an Undergraduate Research Experience at [E.C.U./M.A.U/S.E.C.] University. Participation in this research is strictly voluntary. The researcher will make every effort to protect participant confidentiality. Participant names, the name of your institution, and any other identifier will be altered to further this goal. No information that can be used to specifically identify you will be divulged from this study.

Participants are requested to participate in one 45 to 60 minute individual interview. Participants will be compensated $10/hour for their time as well as being entered in a drawing among all participants for one iPad mini for participation.

If you are interested in participating in this research, please complete a short online interest form at [website] by [date].

Questions about this research should be addressed to Janice Austin, doctoral student in the Educational Research and Evaluation program at Virginia Tech, at jema@vt.edu.

Appendix H

Interview Participant Email

Dear [Participant],

You have been selected to participate in one 45 to 60 minute individual interview. The interview will be conducted on the [E.C.U./M.A.U./S.E.C.] campus in [Southeastern United States] and will be audio-recorded for data accuracy purposes. Individual interview participants will be compensated $10/hour for their time and entered in a drawing among all participants for one iPad mini.

Please reply to this email message indicating all dates/times listed below that you are available to attend the interview with me. Once a final date/time is selected, you will be notified by email confirming your participation and indicating the interview location on campus.

Date/Time

Date/Time

Date/Time

Etc.

Thank you again for your willingness to assist me in my research study. If you have any questions regarding the study please feel free to contact me at jema@vt.edu or 540-XXX-XXXX.

Sincerely,

Janice Austin