THE EFFECT OF UNDERGRADUATE BIOLOGY RESEARCH EXPERIENCES AND MENTORING STRUCTURES ON STUDENT SELF-EFFICACY

by

Kyle James Harris

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

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APPROVED BY:

Scott Watson, Ph.D., Committee Chair

Norman Reichenbach, Ph.D., Committee Member

Timothy Brophy, Ph.D., Committee Member

Abstract

Collaborative inquiry within undergraduate research experiences (UREs) is an effective curriculum tool to support student growth. This study seeks to understand how collaborative inquiry within undergraduate biology student experiences are affected within faculty mentored experiences and non-mentored experiences at a large private southeastern university. Undergraduate biology students engaged in UREs (faculty as mentor and non-mentor experiences) were examined for statistically significant differences in student self-efficacy. Self-efficacy was measured in three subcomponents (thinking and working like a scientist, scientific self-efficacy, and scientific identity) from student responses obtained in an online survey. Responses were analyzed using a nonparametric equivalent of a *t* test (Mann Whitney *U* test) to make comparisons between faculty mentored and non-mentored student groups. The conclusions of this study highlight the statistically significant effect of faculty mentoring in all three subcomponents. Faculty and university policy makers can apply these findings to develop further support for effective faculty mentoring practices in UREs.

Keywords: collaborative inquiry, self-efficacy, undergraduate research experiences, mentoring

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Dedication

I dedicate this work to my family. To my beloved wife, Toni, thank you for your unwavering support and listening ear along the way. To my children, Josiah, Emma, Cyrus, Lydia, and William, you are the ones I am committed to mentor.

Acknowledgments

First, I would like to recognize my chair, Dr. Scott Watson, for his enthusiastic support of this topic and for his guidance throughout the dissertation. I would also like to acknowledge my committee members, Dr. Norm Reichenbach and Dr. Tim Brophy, for many hours of advice, insight, and encouragement through this process. In addition, I would like to thank my colleagues within the Department of Biology and Chemistry for their support of this dissertation. It is your mentoring of undergraduates that has born meaningful and lasting fruit in the lives of students.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

American Association for the Advancement of Science (AAAS)

Council on Undergraduate Research (CUR)

Course Based Undergraduate Research Experiences (CURES)

Institutional Review Board (IRB)

Scientific Research Society (SRS)

Science, Technology, Engineering, and Math (STEM)

Undergraduate Research Experiences (UREs)

Undergraduate Research Student Self-Assessment (URSSA)

CHAPTER ONE: INTRODUCTION

Overview

Collaborative inquiry within an undergraduate setting takes many forms. Within the biological sciences, collaborative inquiry is an integral method to stimulate and assess the growth of young biologists (Lankford & Saal, 2012). The continual development of undergraduate research experiences (UREs) provides a platform to not only stimulate the growth of individual learners, but also to assess the effect of unique faculty mentored research experiences within individual student populations (Aikens et al., 2016; Lankford & Saal, 2012). The uniqueness of research experiences can be achieved in different ways, stemming from various mentoring structures to the types of opportunities needed to develop professional scientific skills (Aikens et al., 2016). Such skills might include designing, developing, and communicating research findings.

Background

UREs are shown to stimulate and improve student understanding and skill acquisition in relation to empirical processes (Aikens et al., 2016; Auchincloss et al., 2015; Myatt & Jones, 2015). The various forms of collaborative inquiry within a URE provide a framework for the integration of knowledge, student motivation, and the development of leaders in science (Lankford & Saal, 2012). However, comparative studies on the effectiveness of such use on student learning outcomes and self-efficacy with varied mentoring frameworks are less understood (Aikens et al., 2016). For example, UREs have previously been identified to reveal a contrast between student perceptions and faculty/academic perceptions (Aikens et al., 2015). This contrast has been noted to require further examination with additional acquisition of student self-efficacy survey data that exhibit diverse mentoring frameworks (Aikens et al., 2016).

Furthermore, an examination of the intentions of instructors in relation to student perceptions of how directed research is engaged is identified as a gap in research (Auchincloss et al., 2015). Ongoing self-efficacy data collections could be used to examine URE learning outcomes (Auchincloss et al., 2015). Instructors could apply this data to align their expectations with student perceptions (Auchincloss et al., 2015). Additional outcomes from UREs that can be utilized by university policy makers include: a more diverse way to assess student learning, strong rationales to increase undergraduate research funding, and improved scientific literacy (Aikens et al., 2016; Myatt & Jones, 2015).

A recent emphasis on improving undergraduate research opportunities at the selected study site is underway through the design, development, and dissemination of undergraduate and graduate research. A causal-comparative analysis of student perceptions would be an invaluable source of information for university policy makers to improve UREs (Aikens et al., 2016). An emphasis to increase UREs would benefit from an evaluation of perceived student gains within the current faculty mentor/mentee framework (Aikens et al., 2016). Researchers have noted the need to compare the effects of different mentoring structures at different institution types (Aikens et al., 2016). Recent studies on the faculty mentor relationships involved in UREs have primarily obtained data from large public universities (Aikens et al., 2016). Gathering and reporting data from a large private university would provide invaluable insight into distinct pedagogical practices related to UREs found in private universities (Aikens et al., 2016; Myatt et al., 2014).

Historical Context

Science, technology, engineering, and mathematics (STEM) fields have a rich pedagogical history of learning by doing (Milner, Horan, & Tracey, 2014). However, a traditional lecture and laboratory setting can come across to the learner as anticlimactic when the content is not put into practice as part of skill acquisition (Houseal et al., 2014). Such necessary skills can be applied in the process of inquiry so that a student moves from more basic levels of Bloom's Taxonomy to the analysis and development of their own research projects through directed research (Stern, Powell, & Hill, 2014). Having students create their own experiments within a science classroom is not a novel idea. The last two hundred years of scientific advancement have refined the process of inquiry and packaged its history into textbooks for the consumption of students at all grade levels (Harper & Quaye, 2009). However, the ability to make one's own discoveries with the same empirical practice is often left out of the learning process in order to have a more intentional focus upon objective exams for summative assessment (Trauth-Nare, 2015).

Collaborative opportunities can be used to support a student's application of empirical discovery (Trauth-Nare, 2015). The role of collaborative inquiry and peer mentoring has been shown to be an effective curriculum framework for the integration of content knowledge in the sciences (Trauth-Nare, 2015). As students become more fluent with the content through direct application in empirical discovery this experience can affect positive gains in the overall student self-efficacy (Lewis, 2015; Trauth-Nare, 2015). In regard to an undergraduate biology student, self-efficacy can be understood as an individual learner's conception of content mastery along with the ability to apply the content to empirical studies. Within the sciences, the process of collaborative inquiry can be identified as one or more faculty members committed to the oversight and mentoring of one or more students in the design, development, and dissemination of research (Lankford & Saal, 2012).

Social Context

Finding ways to improve UREs may better equip students as professional scientists (Robnett et al., 2015). These improvements could include addressing student strengths and weaknesses and understanding student perceptions found within UREs (Kessler & Alverson, 2014). Involvement in directed undergraduate research can have a profound impact on student self-efficacy and student scientific identity (Milner et al., 2014; Robnett, Chemers, & Zurbriggen, 2015). Such self-efficacy can be strengthened and shaped with increased involvement in the process of scientific investigation from the initial formation of an empirical design to the presentation of the findings among professional scientists (Robnett et al., 2015).

One of the noted keys to a successful undergraduate research program involves mentorship (Kessler & Alverson, 2014). However, there is a lack of quantitative studies that focus upon mentoring efforts within undergraduate biology and chemistry programs (Kessler & Alverson, 2014; Miller, 2014; Lin, Liang, & Tsai, 2015). This research plan focuses upon a quantitative approach to the topic of self-efficacy and mentoring structures among UREs and highlights how quantitative data analysis is needed to more fully understand UREs. Such analysis will consider the conceptions of how a group of students are shaped as scientists and the effectiveness of mentoring through collaborative inquiry (Kessler & Alverson, 2014; Lin et al., 2015).

Theoretical Context

In relation to social learning theory, Bandura (1977) established empirical foundations to connect behaviorist learning theories with the concepts of self-efficacy. Social learning theory suggests that the experience of undergraduate research does not stand alone as a unique experience, but is connected to a series of interrelated experiences that begin with each student’s childhood, familial, peer, and broader societal interactions (Bandura, 1997). As a researcher examines the data from a self-efficacy study, there are considerations that could be necessary as to the type of major being pursued (e.g. biomedical, zoo and wildlife, etc.…) and how these vocational aspirations are intertwined with the perceived self-efficacy that will be unique to each student (Bandura et al., 2001). However, within the uniqueness of each student, a quantitative study can establish patterns of self-efficacy that may be the result of the directed research learning environment and the interaction(s) with faculty and student mentors (Aikens et al., 2016).

Another theoretical framework to guide a study of UREs is Vygotsky's Sociocultural Theory. Vygotsky's Sociocultural Theory provides a context for the interactions between student development and student learning. Vygotsky's scaffolding framework assists in evaluating how active student participation with undergraduate research can significantly engage cognitive activities (Miller, 2001). As applied to this proposed study, there is an expectation that the mentoring frameworks of UREs will influence and help explain effects on student self-efficacy because of the enhanced and creative interaction within the experiences of undergraduate research.

In relation to the sciences and the discipline of this researcher in the biological sciences, the *Biophilia hypothesis* as first described by Davis, Kellert, & Wilson (1996) provides an added framework for recognizing the motivational gains within scientific research. Both naturalistic and Creator-centered worldviews approach the living world with a desire to understand life (Wise, 2015). Great gains in student learning can take place when the innate love for the living world is engaged within the learning process (France & Bay, 2010; Johnston, 2010; Sammet, Kutta, & Dreesmann, 2015; Hummel & Randler, 2012). Educators have a unique platform to engage the living world with hands-on experiences to support higher level learning (Zhai, Jocz, & Tan, 2014). Such connections should ideally begin in childhood and should not end when students begin more formal training within the sciences at the undergraduate level (Benbow & Camphire, 2008; Coleman, 2015; Covacevich, 2013; Hachey & Butler, 2012; Lujan & DiCarlo, 2006; Uttley, 2013).

Problem Statement

Research has shown beneficial effects between undergraduate research student self-efficacy and direct faculty interactions (Aikens et al., 2016; Benson et al., 2016; Brew, 2010; Lin, Liang, & Tsai, 2015). However, a majority of current data analysis for this relationship is established from large public research institutions (Aikens et al., 2016). Large private undergraduate universities that have traditionally maintained a teaching focus seem absent from the literature, although these universities may provide opportunities for UREs (Aikens et al., 2016; Daniels et al., 2016; Lopatto, 2004; Malcolm, 2013; Myatt et al., 2014; Robnett, Chemers, & Zurbriggen, 2015). Recent studies have suggested further research on the effects of different mentoring structures in UREs within varied university types (Aikens et al., 2016; Kortz & van der Hoeven Kraft, 2016). Limited opportunities for directed research in a large undergraduate research setting can reduce intersectionality of student researchers and therefore limit opportunities for students who might excel within a direct faculty student mentor environment (Simmons et al., 2016; Tamer & Stout, 2016). The study site recently developed a student scientific research society (SRS) to provide an opportunity to develop a culture of research with students and faculty (France & Bay, 2010; Horak, Merkel, & Chang, 2015; Houseal, Fouad, & Destefano, 2014; Morales, Grineski, & Collins, 2016). The SRS has developed a framework for experienced research students to mentor inexperienced students in directed research (Estepp et al., 2016; Kessler & Alverson, 2014; Lankford & Saal, 2012). Thus, an opportunity is available to assess the effects of UREs and mentoring structures on self-efficacy at the selected study site (Aikens et al., 2016).

Purpose Statement

The purpose of this causal-comparative study was to quantitatively describe the effect of UREs and faculty mentoring on biology majors' self-efficacy. The sample population consisted of undergraduate, full-time biology students who had varied levels of research experience (e.g. directed research and/or course based research experiences). The study site was a large southeastern private U.S. university. Data was collected with self-efficacy and mentoring structure measures delivered through an online Qualtrics survey. This research study utilized a causal-comparative research design in which the independent variables included faculty mentored and non-mentored experiences along with dependent variables broken down into three subcomponents (Gall, Gall, & Borg, 2007). The difference in scores for three subcomponents included: thinking and working like a scientist, scientific motivation, and scientific identity, as measured by Likert scales within an URE survey instrument (Aikens et al., 2016).

Significance of the Study

By understanding the self-efficacy and mentoring dynamics of undergraduate research students at a large private university, faculty and university policy makers can provide more refined support and vision to promote meaningful learning outcomes from research experiences. Undergraduate biology programs that employ UREs can more fully support career ambitions due to practical experiences (Carpi et al., 2016). In addition, student descriptions of research experiences will provide data that reports social benefits and preferred mentoring constructs. Other outcomes from such data can point towards URE improvement and increased student retention (Gregerman et al. 1998; Seymour et al., 2004; McIntosh et al., 2016; Morales, Grineski, & Collins, 2016). Needful interventions for student success within a program could be identified. Faculty needs, such as release time to focus upon directed research with students, could be supported by the proposed study findings (Aikens et al., 2016). The understanding gained from this study will assist undergraduate science educators with an evaluation of current practices and an identification of best practices for use of UREs with students at a large private university.

This study seeks to explore a gap within the literature that pertains to the self-efficacy of undergraduate biology students in relation to effective practices of collaborative inquiry (Aikens et al., 2016; Myatt et al., 2014). For example, the development of a student-run and faculty sponsored undergraduate research society can provide a means to model best practices in scientific research while at the same time providing opportunities for students to engage in the scientific process (Kogan & Laursen, 2014). This can be exhibited within novel experimentation or theoretically developed research plans that are rooted within peer reviewed literature (Houseal, Fouad, & Destefano, 2014). UREs provide a model for engaging undergraduate biology students by providing direct interaction with peers, graduate students conducting research, or faculty within and from outside the students' academic institution (Berger, Mahler, Krug, Szecsenyi & Schultz, 2016). In this way, the ability to utilize collaborative inquiry to promote self-efficacy is an effective curriculum tool to support the growth of the whole person without relying solely upon a major course of study and can become an integral component in a preferred undergraduate experience.

Research Questions

RQ1: Does faculty mentoring improve undergraduate biology students' gains in how they think and work like a scientist?

RQ2: Does faculty mentoring improve undergraduate biology students' confidence in their scientific self-efficacy?

RQ3: Does faculty mentoring promote undergraduate biology students' sense of belonging in relation to their scientific identity?

Definitions

Biophilia hypothesis – an urge to affiliate or the possession of an innate tendency by mankind to seek out connections with nature and understandings of the living world (Davis, Kellert, & Wilson, 1996).

Collaborative inquiry – an integrated framework that can be a useful tool for a professor and students to develop and implement a research project (Lankford & Saal, 2012; Karban, Huntzinger, & Pearse, 2014).

Faculty mentoring – involves a URE in which faculty respond to varied student needs, set clear rigorous expectations, instruct in technical research skills, provide a sense of community within hands-on mentoring, provide opportunities for peer mentoring, and support professional development through guided research-based activities, written manuscripts, and in oral and poster presentations (Shanahan et al., 2015).

Inquiry or research-based activity – an original or creative intellectual contribution to a specific discipline (Brew, 2010).

Intersectionality – used to described the various degrees of interconnectedness among social categories (e.g. gender, class, ethnicity) and the potential discrimination or disadvantages afforded to the various categories (Aiken et al., 2016; Myatt & Jones, 2015)

Socio-cultural theory – Vygotsky provides a context for the interactions between students and the integration of development and learning. Vygotsky's scaffolding framework assists in evaluating how active student participation with augmented reality can significantly engage cognitive activities (Miller, 2001).

Social learning theory - The experience of undergraduate research does not stand alone as a unique experience, but it is connected to a series of inter-related experiences that begin with each student's childhood, family, peer, and broader societal interactions (Bandura, 1977; Bandura, 1997; Bandura, Barbaranelli, Caprara, & Pastorelli, 2001).

Undergraduate Science Self-efficacy – the personal belief that a student has to not only execute specific behaviors related to a discipline of study, but the abilities to exert specific control over personal motivation, self-confidence, communication skills, and the pursuit of a science career (Daniels et al., 2015).

CHAPTER TWO: LITERATURE REVIEW

Overview

The transition from secondary school to undergraduate studies can be difficult for students (De Clercq, Galand, & Frenay, 2017; Dooley, Payne, Steffler, & Wagner, 2017; King, Fisher, Becich, & Boone, 2017). In some ways, this transition is similar to the transition from middle school to high school (Parkay, Anctil, & Hass, 2014). However, the unique challenges of increased levels of independence for each student along with the rigorous demands of a selected major course of study can become daunting for a wide variety of learners (Hazel, Prosser, & Trigwell, 2002). Specifically, within the sciences, the rigor of biology can become overwhelming for students (Malcolm, 2013). Having the necessary curriculum support structures in place may go a long way to the retention of students, the mastery of content, and acquisition of skills for limited graduate school placement (Lin, Liang, & Tsai, 2015). Within the cross section of curriculum and the relationships among student peer and faculty as mentors, the unique ability to foster collaborative inquiry can be one means to meet students where they are and take them as far as they can go (Lankford & Saal, 2012). This underlying philosophical approach to teaching can tap into the empirical process of scientific discovery to shore up student weaknesses and capitalize upon their individual strengths along the pathway of learning (Cajal, 1999; Davis, Kellert, & Wilson,1996; Horak, Merkel, & Chang, 2015).

This review seeks to explore the literature that pertains to the self-efficacy of undergraduate biology students in relation to an effective practice of collaborative inquiry (Aikens et al., 2016). Specific examples will be sought to tie gains in student self-efficacy to effective mentoring practices (Aikens et al., 2016). For example, the development of a student-run and faculty-sponsored undergraduate research society can provide a means to model best practices in scientific research while at the same time providing opportunities for students to engage in the scientific process (Kogan & Laursen, 2014). Undergraduate research opportunities can be exhibited within novel experimentation or within a theoretically developed research plan that is rooted within peer reviewed literature (Houseal, Fouad, & Destefano, 2014). Such a model for engaging undergraduate biology students could be empowered by providing a seminar series to hear from other scientists that are advanced in their undergraduate program of study, graduate students conducting research, or faculty within and from outside the students' academic institution (Berger, Mahler, Krug, Szecsenyi & Schultz, 2016). In this way, the ability to utilize collaborative inquiry to promote self-efficacy can be an effective curriculum tool to support the growth of the whole person without relying solely upon a major course track (Aikens et al., 2016).

Science, technology, engineering, and mathematics (STEM) fields have a rich pedagogical history of learning by doing (Milner et al., 2014). However, a traditional lecture and laboratory setting can come across to the learner as anticlimactic when the content is not put into practice as part of skill acquisition (Houseal et al., 2014). Such necessary skills can be applied in the process of inquiry so that a student moves from more basic levels of Bloom's Taxonomy to the analysis and development of their own research projects through directed research (Stern, Powell, & Hill, 2014). Applications of having students create their own experiments within a science classroom is not a novel idea (Houseal et al., 2014). The last two hundred years of scientific advancement have refined the process of inquiry by adding to detailed knowledge of the creation while packaging its natural history and biological complexity into textbooks for the consumption of students at all grade levels (Quaye & Harper, 2015). However, the ability to make one's own discoveries with the same empirical practice is often left out of the learning process in order to have a more intentional focus upon objective exams for summative assessment (Cajal, 1999; Trauth-Nare, 2015).

The role of collaborative inquiry and peer mentoring has been shown to be an effective curriculum framework for the integration of content knowledge in the sciences (Trauth-Nare, 2015). As students become more fluent with the content knowledge through direct application in empirical discovery, this experience can affect positive gains in the overall student self-efficacy (Lewis, 2015; Trauth-Nare, 2015). As a biologist in training, self-efficacy can be understood as an individual learner's conception of content mastery along with the abilities to apply the content to empirical studies. Within the sciences, the process of collaborative inquiry can be identified as one or more faculty members committed to the oversight and mentoring of one or more students in the design, development, and dissemination of research (Lankford & Saal, 2012).

In addition to the integration of knowledge, collaborative inquiry in the sciences has been shown as a framework for student motivation and the development of leaders (Lankford & Saal, 2012). The various dynamics of collaborative inquiry assist in the facilitation of a rigorous constructive undergraduate learning period, in which the difficulties of scientific work are overcome, and the production of a young investigator matures with the various strengths necessary for long-term contributions to the field of science, to society, and to the mentoring of new generations of students (Cajal, 1999). Often within the sciences, a mature scientist has one of two paths to pursue: he can pursue a pathway that is isolated among his peers in "educational sterility", or he can take his expertise and training to enlist participants to promote a culture of educational fertility (Cajal, 1999). In support of a pathway to educational fertility, undergraduate collaborative inquiry can provide positive effects on learning for students (Aikens et al., 2016; Houseal, Fouad, & Destefano, 2014; Lankford & Saal, 2012). In recent years, universities and colleges have recognized a need to improve research experiences for undergraduate biology students (Council on Undergraduate Research, 2017). However, the nature of undergraduate programs that have traditionally focused upon teaching rather than research do not tend to actively promote a process of collaborative inquiry between a professor and students (Lankford & Saal, 2012). Historical, social, and theoretical contexts can provide foundational information on the success and failures of collaborative inquiry (Aikens et al., 2016; Auchincloss et al., 2014; Myatt et al., 2014). In addition, an undergraduate setting can provide the flexibility for collaborative inquiry to take many forms (e.g. theoretical, basic, and applied science project development) while invigorating the academic culture of an undergraduate biology program in which the process of inquiry is applied from the textbook and journal to the fingertips of young scientists (Lankford & Saal, 2012). In this way, collaborative inquiry is a unique and essential platform for a holistic biology training and is a support for the continual development of individual learners, which can be assessed for realized student growth (Aikens et al., 2016; Lankford & Saal, 2012).

The challenges of a large student population may be supported in Undergraduate Research Experiences (UREs) with modified mentoring structures among experienced peer mentors (Aikens et al., 2016). Assessing the strengths and weaknesses of such mentoring practices may promote faculty investment in such pedagogical practices so that the development of future scientists is not only found by chance among an elite group of students, but a wider net is cast in order to enlighten a series of pathways for student growth in biology research (Aikens et al., 2016). In relation to such an assessment, the goals of a student focused research experience can be considered so that students begin to see the goals of science research, not in the prizes and awards, but in the labor of creativity needed in the sciences and study outside of the classroom (Cajal, 1999; Karban, Huntzinger, & Pearse, 2014; Louv, 2005).

Mentoring structures and UREs can take many forms (Aikens et al., 2016; Lankford & Saal, 2012). Within the biological sciences, mentoring structures and UREs can be an integral method to both assess and stimulate the growth of young biologists (Lankford & Saal, 2012). The continual development of UREs provides a platform to not only stimulate the growth of individual learners, but also to assess the effect of unique research experiences within individual student populations (Aikens et al., 2016; Lankford & Saal, 2012). The uniqueness of research experiences can be affected in different ways, stemming from mentoring structures (e.g. faculty as mentors, students as mentors, and both faculty and students as mentors of individuals or groups of students) and the types of opportunities available to develop professional scientific skills (e.g. designing, developing, and communicating research findings) (Aikens et al., 2016).

Theoretical Framework

A theoretical framework for the development of this literature review recognizes the antithesis between a naturalistic (reductionist) approach to the sciences and the holistic approach to the sciences associated with a Biblical worldview (Wise, 2015). As a scientist, it is important when applying curriculum to ensure that students recognize the purpose behind the various emergent properties found in mainstream science curricula as purposeful instead of evidence rooted in random chance (Wise, 2015). Often, the pedagogical naturalistic approach to the sciences stems from the parts (micro) to the whole (macro) (Wise, 2015). However, there is a missing component in this naturalistic approach to connect students to a holistic scientific truth (Wise, 2015).

In relation to theoretical frameworks within curriculum design, there are at least three important theories to consider. First, Vygotsky's *Sociocultural Theory*, which identifies the integration of development and learning along with the specific interactions of students, has a context for content mastery (Miller, 2001). Vygotsky provides a context for the interactions between students and the integration of development and learning. Vygotsky's scaffolding framework can assist in evaluating how active student participation with undergraduate research can significantly engage cognitive activities (Miller, 2001). As applied to this proposed study, this theory holds an expectation that the independent variable of undergraduate research experience will influence or help explain my dependent variables of student motivation and student learning because of the enhanced and creative interaction within the experiences of undergraduate research.

Second, Jean Piaget and John Dewey provide a framework for an Experiential Learning Theory that should also be considered in regard to the integration of human development and learning (Miller, 2001). The process of scaffolding knowledge upon prior learning (Miller, 2001) is a necessary means within a collaborative inquiry environment. For example, mentors seek to utilize scaffolding with what individual students know and direct that content base to build doable research projects (Lankford & Saal, 2012). With each project development, students and faculty mentors can begin to broaden and deepen the integration of learning with the developmental progress of students (Hewitt, Kayes, Hubert, & Chouinard, 2014).

Perhaps one of the most notable theoretical frameworks for developing a self-efficacy study would be related to Bandura (1977) and his development of Social Learning Theory. In his work, he has shown how student self-efficacy is intertwined with behaviorist learning theories. As a scientist, the delivery of the detailed content can often overshadow the recognition that individual students have due to their behavioral and social backgrounds and creates barriers within the most detailed and seemingly complete curriculum framework (Bandura, 1997). The collaborative approach to delivering science content and curriculum growth should consider the more recent work of Bandura, Caprara, and Pastorelli (2001) with the monitoring of self-efficacy among undergraduate students. In relation to Social Learning Theory, Bandura (1977) established empirical foundations to connect behaviorist learning theories with the concepts of self-efficacy. Social Learning Theory suggests that the experience of undergraduate research does not stand alone as a unique experience, but is connected to a series of inter-related experiences that begin with each student's childhood, familial, peer, and broader societal interactions (Bandura, 1997). As a researcher examines the data from a self-efficacy study, there are considerations that could be necessary as to the type of major being pursued (e.g. biomedical, zoo and wildlife, etc.…) and how these vocational aspirations are intertwined with the perceived self-efficacy that will be unique to each student (Bandura et al., 2001). However, within the uniqueness of each student, a quantitative study can establish patterns of self-efficacy that may be the result of the directed research learning environment and the interaction(s) with faculty and student mentors (Aikens et al., 2016).

In addition to these specific learning theories, the *Biophilia hypothesis* is connected to how individual learners have an urge to affiliate or the possession of an innate tendency to seek out connections with nature and understandings of the living world (Davis, Kellert, Wilson, 1996). Within the biological sciences, such connections can be absent from the learning process without the intentional use of collaborative frameworks (Aikens et al., 2016). Within the context of UREs and mentoring frameworks, biology students would be expected to reveal greater gains in self-efficacy as they have greater contact with the living world in the process of scientific investigations (Laursen et al., 2010).

Related Literature

Best Practices for Undergraduate Student Self-Efficacy

Perhaps it should be noted that the development of self-efficacy within students begins with the promotion of self-efficacy among instructors (Wiemen & Gilbert, 2014). This self-efficacy development among instructors includes varied topics: curriculum perceptions, instructional settings (e.g. lab/field based sciences), professional development, and professional society networks (Avery & Meyer, 2012; Flores, 2015; Trauth-Nare, 2015; Wiemen & Gilbert, 2014). The overall positive perceptions of science curricula by instructors is essential to the effectual growth of students (Trauth-Nare, 2015). Such self-efficacy promotion would entail taking biology instructors out of a normal lecture hall and into the laboratory and/or field-based setting to instruct a class (Flores, 2015; Trauth-Nare, 2015). In relation to professional development, instructors who are actively seeking to improve themselves in their field of practice have passed on measurable gains in student self-efficacy (Flores, 2015). However, such measurable gains from professional development activity within a specialty can depreciate over time if such experiences are not periodically re-engaged (Avery & Meyer, 2012). While maintaining the need for subject-centered professional development among biology faculty, faculty can help reveal measurable gains in self-efficacy through content oriented professional development (Avery & Meyer, 2012). However, there is little evidence to suggest measurable gains through professional development specific to faculty with terminal degrees who have been actively teaching within the sciences (Avery & Meyer, 2012). However, this perceived gap in professional development is met in faculty association with professional societies (Avery &

Meyer, 2012). Such a line of inquiry in relation to how such involvement improves the instruction received by undergraduate major and non-major biology students could be worth exploring (Aikens et al., 2016). As faculty consider methods to improve student self-efficacy, there is a need for a balanced approach while sustaining professional development training and peer development opportunities for faculty (Avery & Meyer, 2012; Lundstrom, Fagerheim, & Benson, 2014).

Undergraduate biology education is strong in terms of teaching content knowledge and promoting active learning (Auchincloss et al., 2015; Lenz & Willcox, 2012; Lin, Liang, & Tsai, 2014). However, the development of measures to evaluate student self-efficacy can be varied (Aikens et al, 2016; Auchincloss et al., 2015; Freeman et al., 2014). Some of this variation can occur on the basis of subject matter and the application of a discipline-based approach to instruction (Horak, Merkel, & Chang, 2015). Other variation can occur on the basis of focused collaboration between faculty and students which enhances critical thinking and student achievement (Kim, Sharma, Land, & Furlong, 2013; Kogan & Laursen, 2014; Lankford & Saal, 2012) and a potential disconnect between modern research and teaching (Malcolm, 2013). Additional collaboration can occur with the addition of teaching assistants that are peers to the learners or even in the use of postgraduates to facilitate the needs of mentoring (Aikens et al, 2016; DeChenne, Koziol, Needham, & Enochs, 2015; Talbot, Hartley, Marzetta, & Wee, 2015). Taken in a holistic manner, various models have been developed to show the current strengths of student self-efficacy in undergraduate science classes on the basis of fieldwork education and concept-based curriculum models (de Beer & Mårtensson, 2015; Merkel, 2012). In addition, student developed science investigations have been shown to help prepare students for societal situations (Hewitt, Kayes, Hubert, & Chouinard, 2014). Research indicates the need for the development of mentor relationships, research-based curriculum, and student surveys of UREs to prepare and improve student performance (Aikens et al, 2016; Wieman & Gilbert, 2014). However, recent studies also reveal gaps in relation to the intersectionality of studies on UREs (Milner et al., 2014).

Learning Outcomes

In addition to the use of collaborative inquiry and professional development to bolster instructor self-efficacy, the role of collaborative inquiry can support subject area learning outcomes (Kamarainen et al., 2013). For example, a mathematics study in an undergraduate university found that students engaged with inquiry related activities out-performed similar groups of students that did not have inquiry related learning within their curriculum (Kogan & Laursen, 2014). Such successes in collaborative inquiry have led a growing number of universities and colleges to recognize the need to improve research experiences for undergraduate biology students (AAAS, 2011; CUR, 2016). It is evident that the ability to properly identify the academic challenges that undergraduate biology research students face, while bridging the gap between K-12 and undergraduate education, would be important in order for effective collaborative inquiry to take place (Houseal et al, 2014). For a growing number of baccalaureate students with academic accommodations, collaborative inquiry may hold keys to a path of success in research related fields (Pagano, Ross, & Smith, 2015). A current emphasis for the growth of UREs will open up more opportunities for a greater number of students to conduct research (AAAS, 2011; CUR, 2016). However, undergraduate biology directed research has often been offered to a limited number of students due to a lack of resources and disproportionate teaching load (Dawson, 2014). As students within the biology major will now have greater opportunity to pursue research, building a model of success will help to ensure best practices to promote student self-efficacy (Davis et al., 2015).

The positive effects of collaborative inquiry on learning outcomes have been studied in the form of capstone courses for biology and application of advanced technology (Lankford & Saal, 2012; Christmann, 2013). Capstone courses within biology programs have been used to ensure that students partake in the development of a research project under the supervision of a faculty member (Lankford & Saal, 2012). Positive outcomes (e.g. scientific writing improvement) of these types of capstone experiences are similar to directed research opportunities that can be a part of the overall undergraduate learning experience and not simply take place during the final semester of study (Lankford & Saal, 2012). In addition, to the use of capstone courses in undergraduate studies, more recent advances in technology provide new means to engage students with learning outcomes (Lee, 2012; Ozan, 2013; Kamarainen et al., 2013). In particular, field-based biology has made advances in sensors for lab and field based learning activities (Boyce, Mishra, Halverson, & Thomas, 2014; Brunsell & Horejsi, 2013; Christmann, 2013). Certainly, the lack of available technology would be a potential barrier to support learning outcomes that work with technological skills that are familiar to undergraduate biology students. In some ways, a failure to utilize mobile devices and social electronic connectivity (e.g. Office365) with lab groups can effectively stall the progress of greater self-efficacy gains for students (Lee, 2012; Ozan, 2013; Kamarainen et al., 2013). The use and non-use of such technology to communicate with research students could provide a potential study topic related to the effectiveness of collaborative inquiry and student self-efficacy (Lee, 2012; Ozan, 2013; Kamarainen et al., 2013). For example, a great benefit of the Office365 technology is the ability for members to edit and review pertinent research findings and documents which gives them a greater sense of ownership with the research material (Conn, 2012; Houseal et al., 2014). The use of modern technological advancements is a means to study the changes in self-efficacy and effectiveness of collaborative inquiry in a mobile learning environment (Truong, 2014).

The Roles of Collaborative Inquiry

The mentoring framework needed to support collaborative inquiry in an undergraduate setting can be problematic (Lankford & Saal, 2012). A specific plan to incorporate the intentional URE interactions between students and faculty will likely result in the restructuring of a current instructional paradigm (Lankford & Saal, 2012). Such a plan would involve a consideration of the development of a peer mentoring and faculty mentoring system (Aikens et al., 2016). The roles of peer and faculty mentoring can both be an effective means to promote self-efficacy in an URE (Aikens et al., 2016).

The inclusion of peer mentoring in UREs produces positive gains in mentoring relationships, in addition to gains in retention within undergraduate science programs (Chiou, Liang, & Tsai, 2012; Milner et al., 2014). As students engage in opportunities for directed research and move from a first and second year introductory standing to a more established third and fourth year major standing, there should be increasing evidence of peer mentoring to promote student success (Ruff & Jones, 2016). Such evidence can potentially yield quantitative and qualitative gains in student retention and personal identification within the sciences (Cutright & Evans, 2016; Ruff & Jones, 2016). Some research suggests formulating interdisciplinary science courses for first year students to connect them with a mentoring system (Cockcroft et al., 2016). As an educator, it would also be useful to consider the successes and self-efficacy gains of first and second year students so that best practices in both pedagogy and student relationships could be promoted for incoming students (Gregg-Jolly et al., 2016).

Peer mentoring has been shown to be effective, but this effectiveness can be greatly improved with the addition of intentional faculty mentors (Morales, Grineski, & Collins, 2016). Intentionality may be somewhat subjective in terms of the amount of time spent with students (Morales et al., 2016). However, intentionality may be better regarded as a mechanism that shows productivity of faculty and students involved in a research project (Aikens et al., 2016). The motivation of faculty mentors can be negatively affected if there is limited compensation for the investment of time in one or more students (Morales et al., 2016). A unique challenge of UREs at teaching-focused institutions is a lack of faculty willingness to take part in mentoring experiences due to the time needed to recruit and retain committed students (Morales et al., 2016). The literature suggests a need to examine the distinction in undergraduate research students in regard to interest verses commitment to faculty mentored research experiences (Aikens et al., 2016). Perhaps a self-efficacy inventory or similar survey instrument given to students engaged in research with peers and/or faculty mentor experiences would reveal identifiable differences among students (Aikens et al., 2016). Such differences might influence how students and faculty perceive commitment with undergraduate science students (Curtin, Malley, Stewart, 2016). Some undergraduate students merely have a passive interest in doing science, while others have a rigorous level of commitment to learning from a research project; it is clear from the literature that mentoring reveals gains for both types of students (Haeger & Fresquez, 2016). Such mentoring can have far reaching impacts upon students' lives as they refine skills to present to potential graduate advisors or within a limited job market (Haeger & Fresquez, 2016).

Both faculty and peer mentoring promotes the breakdown of barriers to learning that are faced within a regular classroom setting (Curtin et al., 2016). For example, a directed research requirement for undergraduate students would help to draw in more minorities to the formal inquiry process (Carpi, Ronan, Falconer, & Lents, 2016). In addition, the collaborative process can be a means to engage with socio-scientific issues, such as water quality and environmental toxicology (Lenz & Willcox, 2012). Such intentional mentoring can help build toward a holistic approach within the sciences (Wise, 2015).

Effective practices of faculty mentors are developed with students through collegial engagement (Johnson et al., 2015). This collegial interaction can impact students that are actively engaged and those students that are simply passive observers of the URE through the varied faculty-student relationships (Johnson et al., 2015). Clearly defined roles and guidelines for faculty mentoring relationships create boundaries between the personal and professional lives of those involved in UREs (Johnson et al., 2015). Such boundaries promote effective practices which avoid faculty burnout (Johnson et al., 2015). Guidelines by academic administration which provide clear expectations for faculty promotions and rewards establish an academic culture of meaningful productivity and enhanced student engagement (Jaschik, 2015; Johnson et al., 2015). In addition, promoting defined criteria for mentoring excellence (e.g. a balance to both quality and quantity of mentored undergraduates) will aid in developing faculty mentors (Johnson et al., 2015).

There are three key features that can be measured among undergraduate research students to assess if a research program is implementing effective mentoring. These three areas include how students think and work like a scientist, a student's scientific self-efficacy, and scientific identity (Aikens et al., 2016). Obstacles to promoting these areas among undergraduates can be identified in relation to institutional, departmental, and individual faculty obstacles (Johnson et al., 2015). Institutional obstacles to effective mentoring stem from a growing number of adjunct faculty that are not oriented towards mentoring and overseeing UREs (Johnson et al., 2015). Departmental obstacles include the scarcity of resources for undergraduate research use and competition among peers for limited URE placements (Johnson et al., 2015). Another obstacle is a lack of diverse faculty that are capable of facilitating and contributing to interdisciplinary UREs (Johnson et al., 2015). Individual faculty obstacles can vary from lacking faculty interpersonal skills and an unwillingness to invest in undergraduate mentoring without the necessary institutional backing (Johnson et al., 2015). Despite these obstacles, effective mentoring of undergraduates continues to grow as these obstacles are addressed within variable UREs (Aikens et al., 2016, Johnson et al., 2015).

Thinking and Working Like a Scientist

Historically, the development of young scientists has been a multifaceted process (Cajal, 1999). Various facets of scientific student development are found within UREs (Cajal, 1999; Karban et al., 2014). Student development within UREs moves from foundational observations to more formal experimental research designs (Karban et al., 2014; Wilson, 2006). Within a naturalist approach to science there is a simplicity of developing observational skills from time spent in nature (Louv, 2005; Wilson, 2006). While building toward a more formal experimental design, young scientists can begin conducting and communicating research findings within the scientific and broader societal communities (Karban et al., 2014). Undergraduate science programs provide an ideal medium to immerse students in research experiences both within required courses (e.g. Course Based Undergraduate Research Experiences – CURES) and in more independent or team-based research experiences (Horowitz & Christopher, 2012). In developing how undergraduates think and work like a scientist, specific consideration is given to levels of student assertiveness, critical thinking, effective communication, professionalism, research knowledge, and resourcefulness (Shoemaker, Thomas, Roberts, & Boltz, 2016).

The characteristic of assertiveness can be developed as students take responsibility for the design and development of semester-long research projects (Shoemaker et al., 2016). These research experiences can stand alone within a given semester or build upon one another in a long-term experimental design in order to gain sufficient data to begin to answer initial hypotheses (Karban et al., 2014). Research on undergraduates suggests that they should have basic guidelines established for interaction with faculty and research team members, but they must find ways to identify successes and failures from varied research projects as they continually seek out mentor input (Faurot et al., 2013; Karban et al., 2014; Shoemaker et al., 2016). Assertiveness can take additional forms in how decisive they are in the lab or field (Karban et al., 2014). Such decisiveness is furthered with an ongoing commitment to bravely pursue lines of questioning that will often result in failure (Cajal, 1999). A student's ability to respond to failure with an increased confidence and a tenacity to continually grow as a young researcher sustains a long-term trajectory of thinking and working like a scientist (Karban et al., 2014).

Critical thinking is improved by having one or more mentors that can guide undergraduates in modeling the processes of existing research evaluation (Aikens et al., 2016; Karban et al., 2014). In addition, mentors model and critique critical thinking which assists students within UREs to communicate the main ideas of a selected project (Aikens et al., 2016; Faurot et al., 2013; Karban et al., 2014). Due to the research background experiences of faculty mentors, they are more effective than student mentors in developing critical thinking in relation to research project design (Aikens et al., 2016; Faurot et al., 2013). In addition to mentoring, the level of responsibility given to students will vary with research opportunities (Karban et al., 2014). Research suggests that having increasing levels of responsibility as students progress sets the appropriate levels of critical thinking, thus engaging higher levels of thinking (e.g. analytical vs. basic) (Daniels et al., 2016; Watters, 2016). Within the constructs of a collaborative learning environment, UREs can potentially accelerate patterns of critical thinking growth within an interdisciplinary research team (Lee & Conklin, 2017). An interdisciplinary team within the sciences can expose errors of research design and strengthen initial hypotheses (e.g. tying a research design within multiple fields of sciences, such as ecology, chemistry, and histology, to answer broader and deeper lines of questioning on ecological topics) as students work with mentors to build authentic research experiences (Chase et al., 2017).

Effective communication can be developed in UREs as students develop a cohesive literature review, develop posters and oral presentations, and write up findings in the form of peer reviewed research papers with a predetermined goal of submitting findings for publication (Tung & McKercher, 2017). Research experiences can also be a platform for students to assist in writing proposals and documents in support of research projects (e.g. grants and IACUC applications) (Dolby, 2017; Templeton, 2017). Such exposure to developing professional documents will help students as they begin to formalize their individual thinking as a scientist (Dolby, 2017; Norton et al., 2017). Undergraduate students have noted deficiencies in their preparation for the presentation of research (Aikens et al., 2016; Karban et al., 2014). Recent emphasis on developing the presentation of a research thesis in graduate programs in the form of a three-minute thesis presentation has been shown to be effective in assessing student understanding of a research topic, while giving a student greater confidence through repeated practice (Goodwin & Graebe, 2017; Manidis & Addo, 2017). This method could readily be developed and extended within UREs to engage the development of student understanding of a research project and critique communication skills in a more comfortable setting to build student confidence (Manidis & Goldsmith, 2017; Mantai, 2017).

Professionalism in a URE can be examined within student growth in resume development, formal interview experiences with potential mentors, attitudes for success, and evidence of professional language (Lassonde, 2009; Vaughan, Baxley, & Kervin, 2017; Shoemaker, Thomas, Roberts, & Boltz, 2016). There are certainly degrees of responsibility that undergraduates have in relation to their personal professional growth (Thiry, Weston, & Hunter, 2012). However, focused faculty modeling and engagement in these areas of professional growth will add to positive overall URE outcomes (Killpack & Melon, 2016). Such evidence of professionalism within a research experience adds not only to the scientific cultural development, but also to the more long-term outcomes of how undergraduates are networked within a broad scientific community (Cajal, 1999; Thompson, Conaway, & Dolan, 2015).

Research knowledge in a URE is foundational to critical thinking and the necessary content mastery to effectively communicate (Shoemaker, Thomas, Roberts, & Boltz, 2016). Nuances of a student's research knowledge can be examined in the following ways: the foundational knowledge of a topic, an ability to summarize articles related to a topic, avoidance of plagiarism, proper citations, the development of research question(s) based upon prior findings in the literature, methods design, and analysis and interpretation of data (Shoemaker, Thomas, Roberts, & Boltz, 2016). Effective mentoring of research knowledge would include guiding undergraduates in each of these ways of knowing (Dawson, 2014). As such components become refined, mentors can more effectively scaffold upon research knowledge skills, adding to overall undergraduate research student resourcefulness (Dawson, 2014; Shoemaker, Thomas, Roberts, & Boltz, 2016).

Resourcefulness in UREs is similar to aspects of assertiveness (Shoemaker, Thomas, Roberts, & Boltz, 2016). However, resourcefulness is related to how undergraduate students search and seek out available mentor opportunities, the ability to pursue article acquisition for a research topic, commitment to ethical issues of a research topic, and an eagerness to develop collaboration (Shoemaker, Thomas, Roberts, & Boltz, 2016). A commitment to ethical training can be overlooked in an undergraduate setting (Horowitz & Christopher, 2012). However, UREs provide a framework to implement foundational professional training. For example, training within UREs could incorporate Collaborative Institutional Training Initiative (CITI) courses in the care and use of organisms used in research (Horowitz & Christopher, 2012; Johnson, Behling, Miller, & Vandermaas-Peeler, 2015). Ethical training and the commitment needed to fulfill research goals can be developed within a mentorship program (Shoemaker, Thomas, Roberts, & Botz; 2016). Some recent evidence suggests that the value of exposing undergraduates with CUREs is an effective platform to move students into a network of interdisciplinary mentored UREs (Eby & Dolan, 2015; Horowitz & Christopher, 2012).

Additional considerations in developing how students think and work like a scientist involve broader collaborative and interdisciplinary opportunities (Faurot et al., 2013; Horowitz & Christopher, 2012). Undergraduates have noted being wary of collaborating without defined roles and responsibilities of faculty and graduate student mentors (Faurot et al., 2013). However, within large universities, undergraduate research initiatives reveal greater gains in self-efficacy with either appointed research faculty that develop undergraduate researchers or a number of trained graduate faculty to facilitate undergraduate research mentoring and collaboration (Faurot et al., 2013).

Cultural and normal behavior associated with scientists can be advanced with a URE (Lopatto, 2010; Weston & Laursen, 2015). Such behaviors might include collaborative development of research projects, professional society involvement, and career mentoring (Lopatto, 2010; Weston & Laursen, 2015). For example, the thought processes that go into the development of a research project that is based upon gaps in the literature is one way that thinking as a scientist is put into practice with UREs (Weston & Laursen, 2015). Associations of young scientists to a network of professional society connections are noted to be useful to students in how they think and identify as a scientist (Nichols, Ilatovskaya, & Matyas, 2017). Professional societies provide socialization gains and are a platform to develop presentation skills and connect to vocational opportunities (Nichols, Ilatovskaya, & Matyas, 2017). Career mentoring and critical perspectives from a broader scientific audience can support a URE if attended society meetings engage the students (Matyas, Ruedi, Engen, & Chang, 2017). However, the impacts of specific types of scientific meetings on student self-efficacy where undergraduates present experimental biology research is limited in the literature (Nichols, Ilatovkaya, & Matyas, 2017). The extension of how undergraduate research students engage in professional society networks could provide insight into varied impacts of unique professional societies (Aikens et al., 2016; Johnson et al., 2015; Nichols, Ilatovkaya, & Matyas, 2017). National and international society interaction could provide a much more focused catalyst for undergraduate growth in the ongoing development of UREs (Nichols, Ilatovkaya, & Matyas, 2017). However, reviews of student experiences in professional meetings have noted a lack of preparation for large meetings (Nichols, Ilatovkaya, & Matyas, 2017). One avenue to better prepare students to engage in the research process might be focused summer research programs/fellowships instead of during fall and spring semesters (Nichols, Ilatovkaya, & Matyas, 2017).

The necessary connection between thinking and working like a scientist can be a difficulty in an undergraduate setting (Whiteside et al., 2007). Productivity can become stifled in UREs that do not include clearly defined roles, strategies, and practices for both the mentors and the mentees (Whiteside et al., 2007; Aikens et al., 2016). Some URE roles can create confusion (Horowitz & Christopher, 2012). For example, working within a URE should not be confused with a graduate research experience (e.g. the expectations for scholarship in relation to academic standing) (Horowitz & Christopher, 2012). Such confusion has the potential to be destructive to the overall development of an undergraduate researcher (Horowitz & Christopher, 2012). The opportunities to grow as a working scientist can be advanced through having graduate student mentors in addition to faculty mentors (Aikens et al., 2016; Horowitz & Christopher, 2012).

A recent emphasis upon CUREs within non-major courses results in positive gains in how students think and work like scientists (Ballen et al., 2017). Positive gains include a rigorous way to develop scientific literacy, opportunities for empirical based decision making, and the development of support for empirical research across the liberal arts disciplines (Ballen et al., 2017). For a non-science major, such different science experiences from CUREs contribute to work related gains in student assertiveness, critical thinking, effective communication, professionalism, research knowledge, and resourcefulness (Ballen et al., 2017; Horowitz & Christopher, 2012). These gains can be enhanced with broader mentoring and collaborative set ups, in particular the inclusion of graduate students (Aikens et al., 2016; Ballen et al., 2017). However, the degree to which these research experiences with undergraduates are enhanced with graduate student mentoring is unclear (Faurot et al., 2013). Consideration should be given to the background of graduate mentors in relation to selected research topics when assigning mentors for UREs (Faurot et al., 2013; Cajal, 1999).

A student's ability to think and work like a scientist can be promoted from interdisciplinary science research team experiences (Davis et al., 2016). Specific outcomes in terms of work might include an increased ability to independently synthesize scientific literature, comprehension of research findings, improved communication skills, and a noted growth in leadership skills along with a clearer sense of career goals (Davis et al., 2016). Researchers have noted the need for committed faculty to this aspect of academic training in order to promote these outcomes (Davis et al., 2016). Opportunities for interdisciplinary UREs are observed to provide varied benefits in relation to the overall education experience, better grades, and increased retention when compared with peers that are not mentored (Davis et al., 2016; Gershenfield, 2014).

Scientific Self-Efficacy

Collaborative inquiry has been shown as a framework for the integration of knowledge and for the development of leaders in the sciences (Lankford & Saal, 2012; Anne-Barrie, Laursen & Seymour, 2006). Collaborative inquiry can be described as a process in which a professor guides a group of students in the development and implementation of a research project (Karban et al. 2014). The ability of a teacher to impact students in K-12 settings with forms of collaborative inquiry has been shown to provide positive effects on learning (Houseal, Abd-El-Khalick, & Destefano, 2014). However, the nature of many undergraduate biology programs has not actively promoted a process of collaborative inquiry between a professor and students and is therefore missing gains in student self-efficacy (Lankford & Saal, 2012). Universities and colleges have recognized the need to improve UREs to promote self-efficacy (CUR, 2016). It is evident that the ability to properly identify the academic challenges that undergraduate biology research students face, while bridging the gap between K-12 and undergraduate education, would be important in order for effective collaborative inquiry and increased student self-efficacy to take place (Houseal et al., 2014).

The self-efficacy that comes from UREs can be identified in the types of faculty student interactions, extensions of research to non-major courses, interactive scaffolding, and research approaches for students with academic accommodations (Auchincloss et al., 2014; Ballen et al., 2017; Horowitz & Christopher, 2012). Self-efficacy from UREs can extend into CUREs that are for major and non-major students (Ballen et al., 2017). In this way, large undergraduate classes can be approached pedagogically with novel and creative research based assignments and assessments that reveal how undergraduate students think at higher levels of learning (Ballen et al., 2017). Such URE experiences provide varied degrees of influence within disciplines that are not science specific while resulting in an increase in overall self-efficacy to learn and succeed academically by tapping into the social aspect of the learning process (Aikens et al, 2016; Ballen et al., 2017). Certainly, it is important to note the differences between science and non-science majors in terms of interest in UREs (Ballen et al., 2017). The interdisciplinary nature of URE gains in terms of creativity, observational skills, and the development of critical thinking, along with literacy skills, can be empowered with CUREs (Auchincloss et al., 2014; Ballen et al., 2017). The engaged empirical process within UREs and CUREs affects active student participation while also stimulating self-efficacy gains (Ballen et al., 2017; Cajal, 1999). Within this process, CUREs can maintain a broad relevance that may not necessarily be found in an independent form of research (Ballen et al., 2017). In addition, focused collaboration and the development of professional science skills can support creative and critical skill set maturation within project development, project execution, and project dissemination (Auchincloss et al., 2014; Ballen et al., 2017).

Collaboration in the dissemination of findings from UREs and CUREs has indicated gains in self-efficacy (Aikens et al., 2016; Ballen et al., 2017). In the process of disseminating research findings, a lack of additional faculty and peer interaction can be detrimental to carrying over to future gains in self-efficacy from such experiences (Horowitz & Christopher, 2012). Gains in self-efficacy are connected to student foundational knowledge and student ability to ask empirically based questions (Ballen et al., 2017). For example, the use of CUREs to meet individual students where they are and take them as far as they can go is a scaffolding approach to learning, similar to that of Vygotsky's Sociocultural Theory which emphasizes how knowledge is integrated with knowledge (Lankford & Saal, 2012; Miller, 2001). Such interactive scaffolding in a collaborative learning environment provides the context for interactions between students as they actively integrate their individual stages of development (Miller, 2001).

Collaborative inquiry in UREs with students that have academic accommodations can present different challenges for self-efficacy gains (Braun, Gormally, & Clark, 2017). If academic accommodations are related to intellectual disabilities, then more time may need to be designated to ensure a meaningful research experience (Pagano, Ross, & Smith, 2015). The time needed will involve establishing best practices to improve student success in undergraduate research opportunities (Bargerhuff, 2013; Lankford & Saal, 2012; Pagano, Ross, & Smith, 2015). Students with disabilities will need additional support in terms of persistence (Wei et al., 2014), lab environment (Sukhai et al., 2014), engagement (Quaye & Harper, 2015), perceived value for their own work, and for postgraduate opportunities (Burgstahler, 2014). Strategies may include mentorship programs (Ames, McMorris, Alli, & Bebko, 2015), online simulation trainings (Azzopardi et al., 2013), and outdoor environmental fieldwork (Thomas & Munge, 2015; Fiskum, 2015; Louv, 2005).

People were created to have meaningful connections to the natural world (Genesis 1-3, KJV; Wise, 2015). When these connections are cultivated, the result can be growth in creativity (Louv, 2005). Creativity as a means of student self-efficacy can be found and cultivated in all students (Louv, 2005; Pagano, Ross, & Smith, 2015). The recent rise and emphasis on STEM education has developed in response to a waning aptitude among American students (Bargerhuff, 2013). These deficiencies can also be greater for students with learning disabilities (Bargerhuff, 2013). Post-graduate students with accommodations may not pursue STEM related fields without a collaborative plan in place (Bargerhuff, 2013; Pagano, Ross, & Smith, 2015). Collaborative inquiry can be implemented into undergraduate research programs to evaluate growth in students with and without academic accommodations (Bargerhuff, 2013; Pagano, Ross, & Smith, 2015).

Motivation to join an undergraduate research team can be improved with the addition of graduate student mentors (Horowitz & Christopher, 2012). Graduate students that are actively engaged in research dissertations can utilize undergraduates to move their own research forward while providing hands-on experiences for undergraduates (Horowitz & Christopher, 2012). In addition to self-efficacy gains for undergraduates, graduate students gain invaluable mentoring experiences that can be carried on into teaching and research careers (Horowitz & Christopher, 2012). Having both faculty and graduate student mentors available to undergraduate students adds another level to aid in overall student retention by providing needed mentoring that goes beyond intermittent oversight more commonly found in undergraduate faculty (Aikens et al., 2016; Horowitz & Christopher, 2012). The role of mentoring has also been compared and associated with the quality of the mentoring experiences (Aikens et al., 2016; Horowitz & Christopher, 2012). In this way, having a negative mentoring experience can be detrimental, but such occurrences do not outweigh the gains from mentoring as a vital part of academic training (Brownell & Swaner, 2010; Horowitz & Christopher, 2012). Specifically, UREs are recognized as a primary means of both student learning and retention (Brownell & Swaner, 2010).

Enhancing UREs and effective mentoring practices is a means to improve self-efficacy in undergraduate students (Aikens et al., 2016; Pagano, Ross, & Smith, 2015). The ability to measure these improvements can reveal strengths and weaknesses of an undergraduate biology program (Aikens et al., 2016). Gains in self-efficacy can extend beyond the URE and mentoring practices to the overall learning process and retention needs of undergraduate programs (Bargerhuff, 2013; Lankford & Saal, 2012).

Scientific Identity

Undergraduate biology students can find success within a major course of study without engaging in an URE (Faurot et al., 2013; Horowitz & Christopher, 2012). However, the way in which this success translates into the overall shaping of undergraduate biology student scientific identity will vary. Variation can be based upon the type of biology degree, levels of engagement with research fellowships, independent vs. interdisciplinary research experiences, and the infused skills that are needed to move on to graduate school and the workplace environment (Faurot et al., 2013; Horowitz & Christopher, 2012).

Scientific identity can be built upon the types of relationships that are formed among students with research mentors (Weston & Laursen, 2015). As students build upon the work of others, recent implementation of scientific identity growth survey instruments (e.g. Undergraduate Research Student Self-Assessment - URSSA) have enabled faculty and university policy makers to establish the varied attitudes and behaviors of undergraduate researchers (Weston & Laursen, 2015). Specifically, important factors are related to how these experiences support individual creativity, responsibility, and greater independence within the context of UREs (Weston & Laursen, 2015). Such independence is linked to a student becoming a recognized scientist as his or her responsibilities increase in relation to each of these factors of scientific identity (Weston & Laursen, 2015).

CUREs within both major and non-major undergraduate learning environments provide a context to alleviate misconceptions that students have of science as they find varied levels of active engagement in the scientific process (Cotner et al., 2017). In addition, misconceptions of taking students from varied non-science backgrounds in a URE (e.g. not assuming too much in terms of K-12 preparation) should be considered when developing young scientists (Feinstein, Allen, & Jenkins, 2013). Networking with scientists during a CURE has been shown to provide gains in the development of scientific identity (Hanauer & Hatfull, 2015). Such gains can be extended within the context of major and non-major science students (Ballen et al., 2017; Hanauer & Hatfull, 2015). Within the context of an undergraduate liberal arts education, non-majors are expected to obtain gains in a broad scientific context (Ballen et al., 2017). Such foundations can be applied in a scaffolding method with CUREs for majors so that all undergraduate science majors have an opportunity to engage in a URE alongside faculty mentors in the pursuit of knowledge (Ballen et al., 2017). In this way, scientific identity is cultivated along the fertile grounds of scientific inquiry beyond the necessary confines of what is already known (Ballen et al., 2017). Whereas non-majors are noted to need growth in areas of scientific literacy, it should be noted that science majors need to cultivate a similar awareness and foundation by exploring gaps in the scientific literature if they are to build their own scientific identity (Ballen et al, 2017). Scientific literacy can also be promoted through CUREs as these meaningful course based inquiries add to overall scientific student identity (Ballen et al., 2017). For example, extensions might focus upon a test of scientific literacy skills in relation to biology major students that do and do not participate in URE (Gormally et al., 2012). In addition, when UREs are part of the culture of a science major, there is evidence that opportunities to branch away from "cookbook" labs into inquiry based studies solidify the identities of participants as young scientists that can contribute to the relevance of investigative outcomes (Alkaher et al., 2014; Corwin et al., 2015).

Scientific identity develops as an undergraduate student absorbs knowledge from his or her surroundings (Cajal, 1999; Davis, Kellert, & Wilson, 1996; Wilson, 2006). A focus upon knowledge acquisition is necessary, but the training of new generations of scientists would be strengthened through interdisciplinary research experiences (Davis et al., 2015). Such experiences are thought to be rare among research based universities (Davis et al., 2015). The development of interdisciplinary science can provide a needed framework for the collaborative success of UREs and added student scientific identity (Davis et al., 2015). Finding students to participate within these experiences can benefit the growing scientific identity of undergraduates along with the retention of students (Davis et al., 2015).

Summary

Collaborative inquiry has been shown to be an effective model for conducting research with undergraduate students (Aikens et al., 2016). However, there is an evident need for research in regards to the effectiveness of current collaborative inquiry practices in relation to biology student UREs (Aikens et al., 2016). Although the challenges faced by faculty members are not the focus of this present study, the unique challenges of mentoring should not be overlooked in a desire for the measurable gains from UREs (Johnson et al., 2015). As a research program grows and services an increasingly diverse student population within the varied biology programs, the effectiveness of the mentoring practices will strengthen the overall process of teaching and learning (Shoemaker, Thomas, Roberts, & Boltz, 2016). By understanding how undergraduate students can make gains in thinking and working like a scientist, scientific self-efficacy, and scientific identity in relation to UREs and mentoring dynamics of undergraduate research students at a large private university, faculty and university policy makers can provide more refined support and vision to promote meaningful learning outcomes from research experiences (Aikens et al., 2016). Student investment in the learning outcomes of a program of study and career ambitions can be fostered in relation to research experiences (Carpi et al., 2016). In addition, describing current research experiences by students will provide data to compare the social benefits and preferred mentoring constructs to improve student gains and student retention (Gregerman et al. 1998; McIntosh et al., 2016; Morales, Grineski, & Collins, 2016; Seymour et al., 2004). Needful interventions for student success within a program could be identified and the needs to assign release time for faculty to focus upon directed research with students could be supported by the proposed study findings (Aikens et al., 2016). Undergraduate science programs provide an ideal medium to immerse students in research experiences both within required courses (e.g. CURES) and in more independent or team-based research experiences (Horowitz & Christopher, 2012). In developing how undergraduates grow in how they think and work like a scientist, specific consideration is given to levels of student assertiveness, critical thinking, effective communication, professionalism, research knowledge, and resourcefulness (Shoemaker, Thomas, Roberts, & Boltz, 2016). The understanding gained from this study will assist undergraduate science educators with an evaluation of current practices and an identification of best practices for use of undergraduate research experiences with students at a large private university (Aikens et al., 2016).

There remains a gap within the literature that pertains to the self-efficacy of undergraduate biology students in relation to effective practices of collaborative inquiry (Aikens et al., 2016; Gershenfeld, 2014; Myatt et al., 2014). For example, the development of a student run and faculty sponsored undergraduate research society can provide a means to model best practices in scientific research, while at the same time providing opportunities for students to engage in the scientific process (Kogan & Laursen, 2014). This can be exhibited within novel experimentation or a theoretically developed research plan that is rooted within peer reviewed literature (Houseal, Fouad, & Destefano, 2014). Such a model for engaging undergraduate biology students would be empowered by providing direct interaction with peers, graduate students conducting research, or faculty within and from outside a student's academic institution (Berger, Mahler, Krug, Szecsenyi & Schultz, 2016). In this way, the ability to utilize collaborative inquiry to promote self-efficacy can be an effective curriculum tool to support the growth of the whole person without relying solely upon major courses and can become an integral component in a preferred undergraduate experience.

The ability of undergraduate educators to promote self-efficacy in students through collaborative inquiry and more specifically with the use of peer and faculty mentoring has been shown to be effective in the sciences (Eagan et al., 2013). However, there continues to be limited evidence to support how varied mentoring structures within different undergraduate settings promote self-efficacy with science students (Aikens et al., 2016). STEM related fields have a unique opportunity to capitalize on the excitement that students have in pre-collegiate experiences by developing mentor relationships with students in an undergraduate setting (Aikens et al., 2016; Eagan et al., 2013). Within the examined literature there were potential gaps that could be explored further in the form of a dissertation study related to teaching and learning. One apparent gap is the empirical evaluation of a student run and faculty sponsored undergraduate research society that has a goal to foster meaningful UREs. Another gap shows a need to focus on skill acquisition and post graduate success of students who partook in directed research experiences as opposed to students that did not partake in such experiences. A potential application here might be the reconsideration of present curriculum frameworks at this researcher's university in relation to summative assessments in major courses (Kolb & Kolb, 2005). For example, the addition of course based research projects (CUREs) with clear skill acquisition outcomes for students to place upon their curriculum vitae (e.g. training in radio telemetry) and how this skill acquisition affects student self-efficacy could be considered (Ballen et al., 2017). Application towards technology usage in the sciences could focus on the influence of modern science technology (e.g. probeware, Office365 student/faculty connectivity) on the perceived self-efficacy of students and faculty (Lee, 2012; Ozan, 2013; Kamarainen et al., 2013).

With these literature gaps to consider in regard to mentoring structures and self-efficacy in relation to UREs, it becomes clear that there is a great responsibility and opportunity to reach into the lives of undergraduate students (Aikens et al., 2016). In particular, this researcher is seeking to use the biological sciences as a means to effectively train the whole person (Wise, 2015). The collaborative inquiry process can be a potential means to improve and continually change an undergraduate research curriculum framework. Such an inquiry process provides insight to the ever changing needs of students and the continual changes of scientific understanding that must be passed on to undergraduate science students so that they can find academic and vocational success. In this way, the undergraduate biology instructor can promote a collection of best practices by drawing upon theory, established learning outcomes, technology, mentoring, and directed research opportunities for gains in student self-efficacy and the improvement of undergraduate biology curriculum.

CHAPTER THREE: METHODS

Overview

Self-efficacy studies within undergraduate science programs have often employed surveys of participants to gain feedback on how students perceive and respond to curriculum and instruction (Aikens et al., 2016). Within this proposed study, undergraduate biology students are given twenty Likert scaled questions related to thinking and working like a scientist, scientific self-efficacy, and scientific identity in relation to varied levels of research participation. In addition, participants identify mentoring structures that best match with their individual research experiences (faculty mentor or non-mentor experience) within the undergraduate biology program.

Design

This quantitative, causal-comparative study will seek to determine if there is a difference in self-efficacy in undergraduate biology students who participate in research experiences and those who do not participate. A causal-comparative research design would be appropriate as this study seeks to determine how students respond to undergraduate research experiences (UREs) in a large private university (Aikens et al., 2016). Causal-comparative relationships among self-efficacy subscales and mentoring structures will be evaluated with a mentoring and self-efficacy survey (Gall et al., 2007). In this study, students are represented within two groups: those who have participated in a faculty mentor URE or those who identify as having a non-mentor experience within the undergraduate biology program. The dependent variables measured a student's self-efficacy in three subcomponents: thinking and working like a scientist, scientific motivation, and scientific identify (Aikens et al., 2016, Auchincloss et al., 2014). The mentoring and self-efficacy survey instrument included a nine-item Undergraduate Research Student Self-

Assessment (URSSA), a six-item Scientific Self-Efficacy Scale, and a five-item Scientific Identify Scale (Aikens et al., 2016).

Research Questions

The following research questions guided this study:

RQ1: Does faculty mentoring improve undergraduate biology students' gains in how they think and work like a scientist?

RQ2: Does faculty mentoring improve undergraduate biology students' confidence in their scientific self-efficacy?

RQ3: Does faculty mentoring promote undergraduate biology students' sense of belonging in relation to their scientific identity?

Null Hypotheses

The following research null hypotheses were used in this study:

Ho1: There is no statistically significant difference in the thinking and working scores as measured by the 9-item Undergraduate Research Student Self-Assessment of undergraduate biology students who participate in faculty as mentor and non-mentor undergraduate experiences.

Ho2: There is no statistically significant difference in the scientific self-efficacy scores as measured by the 6-item Scientific Self-Efficacy Scale of undergraduate biology students who participate in faculty as mentor and non-mentor undergraduate experiences.

Ho3: There is no statistically significant difference in the scientific identity scores as measured by the 5-item Scientific Self-Efficacy Scale of undergraduate biology students who participate in faculty as mentor and non-mentor undergraduate experiences.

Participants and Settings

The study site will involve a private southeastern university with approximately 15,000 resident undergraduate students. Traditionally, this university has been noted as primarily a teaching university as opposed to a research university. However, recent university changes have begun to encourage more focused undergraduate research efforts and faculty mentoring of undergraduate research students. With new science research labs becoming available for student and faculty use, the evaluation of faculty student research would be helpful to describe the experiences of undergraduate students.

Approximately one thousand students make up the student population within the Department of Biology and Chemistry and includes students not actively participating in any form of undergraduate research. The research study will utilize convenience sampling of biology undergraduate students. Selection criteria for those involved will include student research experiences that range from one to four or more semesters. Participants will also vary in terms of major course of study within the biological sciences (e.g. Biochemistry and Molecular, General Biology, General Biology with Teacher Licensure, Biomedical Sciences Pre-Med, Biomedical Sciences with a Global Studies cognate, Biopsychology, Cell and Molecular Biology, Environmental Biology, Environmental Biology with Teacher Licensure, Forensic Science, Zoo and Wildlife Biology, and Zoology).

Of the total participants, there will be a multi-cultural sample of varied ethnicities (e.g. Caucasian, African-American, and other) in addition to an unknown proportion of male and female participants. In order to have a large effect size with a statistical power of .7 at the .05 alpha level with 2 groups (faculty as mentor and no mentoring experiences), Gall et al. (2007, p.

145) recommends a group sample size of at least 40 from each of the 2 mentor groups for analysis.

Instrumentation

In order to assess and compare the effect of UREs and mentoring structures, biology students will be given an online Qualtrics survey with three subcomponents: thinking and working like a scientist, scientific self-efficacy, and scientific identity. The URE and mentoring structure questionnaire being used was previously implemented and validated by Aikens et al. (2016). Recent shifts in undergraduate education to develop research experiences and practical experience for students have been highlighted by Aikens et al. (2016). Similar studies to further understand the effect of instructional research practices on student growth and retention within the sciences are intended to improve UREs (Auchincloss et al., 2014; Ballen et al., 2017).

Within the first subcomponent of the questionnaire, thinking and working like a scientist, parts of the Undergraduate Research Student Self-Assessment (URSSA) will be used. A nine-item questionnaire is reported with high internal consistency, Cronbach's α of 0.90 (Hunter et al., 2009; Weston & Laursen, 2015). Student responses are based on a five point Likert scale ranging from no gain to great gain. Within the second subcomponent, a Scientific Self-Efficacy Scale will be used to measure scientific self-efficacy (not confident to very confident). A six-item scale is reported with high internal consistency, Cronbach's α of 0.90 (Estrada et al., 2011). The third and final subcomponent of the questionnaire is a Scientific Self-Efficacy Scale which will be used to measure scientific identify (strongly disagree to strongly agree). A five-item scale is reported with high internal consistency, Cronbach's α of 0.86 (Estrada et al., 2011). The means and medians across all items will be calculated for students in relation to student selected research experiences and mentoring structures. See Appendix A for a copy of the survey and Appendix B for the student consent form.

Procedures

Participants in this study will be undergraduate resident biology major students from a large southeastern private university. Once the researcher has submitted his proposal to the Institutional Review Board (IRB) and obtained permission to proceed with the study, a letter explaining the study along with a copy of the mentoring and self-efficacy survey instrument will be sent to the Department of Biology Chair and Dean for review.

After receiving approval from the Department of Biology Chair and Dean, the researcher will send a letter explaining the study to the Department of Biology Chair and Dean for review. Enclosed information will include a copy of the participant's rights and assent form, the mentoring and self-efficacy survey instrument, along with the proposed administration date(s) of the study. The participants consent form to sign for use of their anonymous data in the study will also be included (Appendix B). After review from the Department of Biology Chair and Dean, the researcher will (1) use a convenience sample of current undergraduate biology students; and (2) identify the characteristics of the sample with demographic collection sheets and the mentoring and self-efficacy survey. The researcher will prepare an introduction to the online survey to explain the purpose of the questionnaire and procedures for completing it including explaining the anonymity of the students' responses. The researcher will inform participants that the completed survey data will be used to constructively promote meaningful interventions and positive opportunities for UREs in biology programs. The promotion of the survey will be emphasized within the Department of Biology and Chemistry Scientific Research Society (SRS).

Data will be collected during the fall 2017 semester to assess current research experiences and mentoring structures on student self-efficacy. Students will rate their experience based upon completed experiences. In order to ensure a higher completion rate from students, faculty will be requested to promote the completion of the survey. In addition to obtaining the students' efficacy responses, the gender and demographic data will be provided on the questionnaire; these will be the only identifying marks on the survey. Once the students have submitted the online survey, results will be accessed by the researcher and reported to the Department Chair for review. The students' responses to each question along with major course of study and group designation (1 = non-mentor, 2= faculty as mentor) will be entered into the SPSS Statistics program for analysis.

Data Analysis

Collected data from the instruments on self-efficacy will be coded (1 = non-mentor, 2 = faculty as mentor) and entered into SPSS software for normality assessment and comparison of group scores. The descriptive statistics will provide distinct means and medians from the three variables being studied for the different mentoring groups. In addition, the 25^{th} and 75^{th} quartiles for medians will be identified. The alpha level for this research design will be set at .05 (α = .05). The alpha level represents the probability of rejecting the null hypothesis assuming that it is true. Data screening will be conducted on the independent variable (non-mentor and faculty mentor) in relation to the dependent variables (thinking and working like a scientist, scientific self-efficacy, and scientific identity). The researcher will search for irregularities in the data for each variable. A box and whiskers plot representing the median, maximum, minimum, upper quartile, and lower quartile for the average score from each dependent variable will be used to identify outliers. Any outliers would represent part of the overall 1-5 responses and should remain in the analysis as they would not be suspect data. The responses will be assessed for normality with a Kolmogorov-Smirnov (sample >50) or Shapiro-Wilk's test (sample <50). The selected normality test will be run on each group (faculty mentor and non-mentor) to test for the assumption of normality. The Levene's test of equal variances will be used to test for the assumption of equal variance within the levels of mentor (treatment) and non-mentor (control) groups if the assumption of normality is met. An independent samples *t* test will be used to calculate any statistically significant difference(s) in the groups (faculty mentor and non-mentor experience control group) if the means are normally distributed between groups (Warner, 2013). If the responses are not normally distributed, then a nonparametric form of a *t* test (Mann-Whitney *U* test) will be used to compare the median scores from each group. A *t* test or nonparametric form (Mann-Whitney *U* test) would be appropriate for this research design in that the sample population will have means and medians for each non-mentor and faculty mentor group that can be assessed for differences between the two groups. Results will be used to either reject or fail to reject the null hypotheses.

CHAPTER FOUR: FINDINGS

Overview

A sample of 121 undergraduate biology major students responded to an online survey during the fall of the 2017-2018 school year. The respondents answered survey questions on the effect of undergraduate biology research experiences and mentoring structures on student perceptions regarding how they are able to think and work like a scientist, scientific self-efficacy, and sense of scientific identity. Respondents were categorized based upon student-identified experience within one of two groups: faculty as mentor or non-mentor undergraduate experiences. Thinking and working like a scientist (no gain to great gain), scientific self-efficacy (not confident to very confident), and scientific identity (strongly disagree to strongly agree) were scaled from 1-5. The responses were assessed for normality with a Shapiro-Wilk's test and median scores from each group were compared using the nonparametric Mann-Whitney *U* test. Findings revealed statistically significant gains in each of the three categories for faculty mentored students.

Research Questions

RQ1: Does faculty mentoring improve undergraduate biology students' gains in how they think and work like a scientist?

RQ2: Does faculty mentoring improve undergraduate biology students' confidence in their scientific self-efficacy?

RQ3: Does faculty mentoring promote undergraduate biology students' sense of belonging in relation to their scientific identity?

Null Hypotheses

Ho1: There is no statistically significant difference in the thinking and working scores as measured by the 9-item Undergraduate Research Student Self-Assessment of undergraduate biology students who participate in faculty as mentor and non-mentor undergraduate experiences.

Ho2: There is no statistically significant difference in the scientific self-efficacy scores as measured by the 6-item Scientific Self-Efficacy Scale of undergraduate biology students who participate in faculty as mentor and non-mentor undergraduate experiences.

Ho3: There is no statistically significant difference in the scientific identity scores as measured by the 5-item Scientific Self-Efficacy Scale of undergraduate biology students who participate in faculty as mentor and non-mentor undergraduate experiences.

Descriptive Statistics

Data obtained for the independent mentor variable (faculty mentor and non-mentor) in relation to each of the three dependent variables (thinking and working like a scientist, scientific self-efficacy, and scientific identity) for undergraduate biology students can be found in Table 1. The mean value is for all of the questions answered within each category (9-item thinking and working like a scientist, 6-item scientific self-efficacy, 5-item and scientific identity).

Table 1. *Descriptive Score Statistics Across Non-Mentor (1) and Faculty Mentor (2) Groups for Undergraduate Biology Respondents*

	Mentor Characteristic	Mean	Standard Deviation	25th Median Quartile	Median	75th Median Quartile	N
Thinking and Working Like a Scientist	1	3.606	0.858	3	4	4	73
	2	4.040	0.601	4	4	5	47
Scientific Self-Efficacy	1	3.391	0.732	3	3.5	4	75
	2	3.833	0.563	3.5	4	4	45
Scientific Identity	1	3.701	0.677	3.375	4	4	76
	2	4.120	0.711	4	4	5	45

Table 2. *Descriptive Distribution of Gender Across Non-Mentor and Faculty Mentor Groups for each Subcomponent*

	Thinking and Working Like a Scientist		Scientific Self-Efficacy		Scientific Identity	
Gender	Non-Mentor	Faculty Mentor	Non-Mentor	Faculty Mentor	Non-Mentor	Faculty Mentor
Male	24	20	29	19	31	18
Female	49	27	46	26	45	27

Table 3. Descriptive Distribution of Ethnicity Across Non-Mentor and Faculty Mentor Groups for each Subcomponent

	Thinking and Working Like a Scientist		Scientific Self-Efficacy		Scientific Identity	
Ethnicity	Non-Mentor	Faculty Mentor	Non-Mentor	Faculty Mentor	Non-Mentor	Faculty Mentor
White	57	46	62	43	63	43
Black or African American	6	0	5	0	5	0
American Indian or Alaska Native	0	0	0	0	0	0
Asian	6	1	5	1	5	1
Native Hawaiian or Pacific Islander	0	0	0	0	0	0
Other	4	0	3	1	3	1

Table 4. *Descriptive Distribution of Classification Across Non-Mentor and Faculty Mentor Groups for each Subcomponent*

	Thinking and Working Like a Scientist		Scientific Self-Efficacy		Scientific Identity	
Classification	Non-Mentor	Faculty Mentor	Non-Mentor	Faculty Mentor	Non-Mentor	Faculty Mentor
Freshman	21	1	16	0	16	0
Sophomore	11	2	12	2	13	2
Junior	18	4	19	4	19	4
Senior	26	40	28	39	28	39

Demographic data obtained from mentor categories concerning gender distributions for each subcomponent with the total number of male and female respondents can be found in Table 2. Representative ethnicity among the respondents based on non-mentor and faculty mentor groups within each subcomponent can be found in Table 3. Distribution of classification across mentor groups for each subcomponent can found in Table 4.

Results

Data Screening

Data screening was conducted on the independent variable (non-mentor and faculty mentor) in relation to the dependent variables (thinking and working like a scientist, scientific self-efficacy, and scientific identity). The researcher organized the data on each variable in SPSS and searched for irregularities. No data errors or inconsistencies were determined. Box and whiskers plots were used to identify outliers on each dependent variable. Each box and whiskers plot represents the median, maximum, and minimum values as well as the upper (75%) and lower (25%) quartiles from the average scores for non-mentor and faculty mentor groups. Noted outliers represent part of the overall 1-5 responses and were kept in the analysis as they are not suspect data. See Figures 1-3 for box and whisker plots.

Figure 1 *Box Plot Based on Average Scores for all Questions for Data Screening in the Category of Thinking and Working Like a Scientist.*

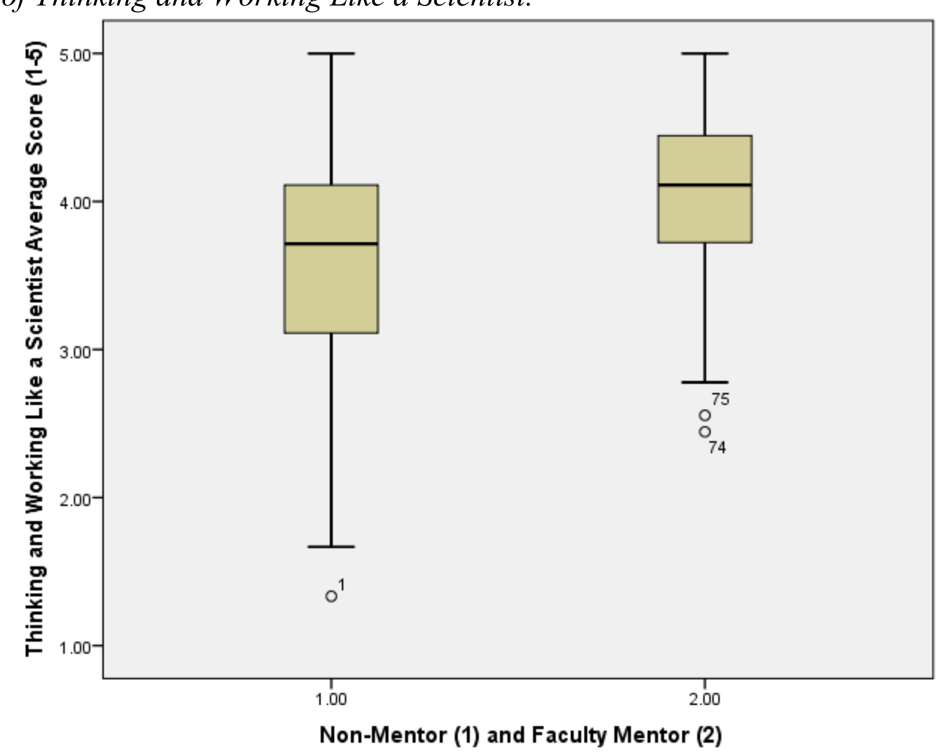


Figure 2 *Box Plot Based on Average Scores for all Questions for Data Screening in the Category of Scientific Self-Efficacy.*

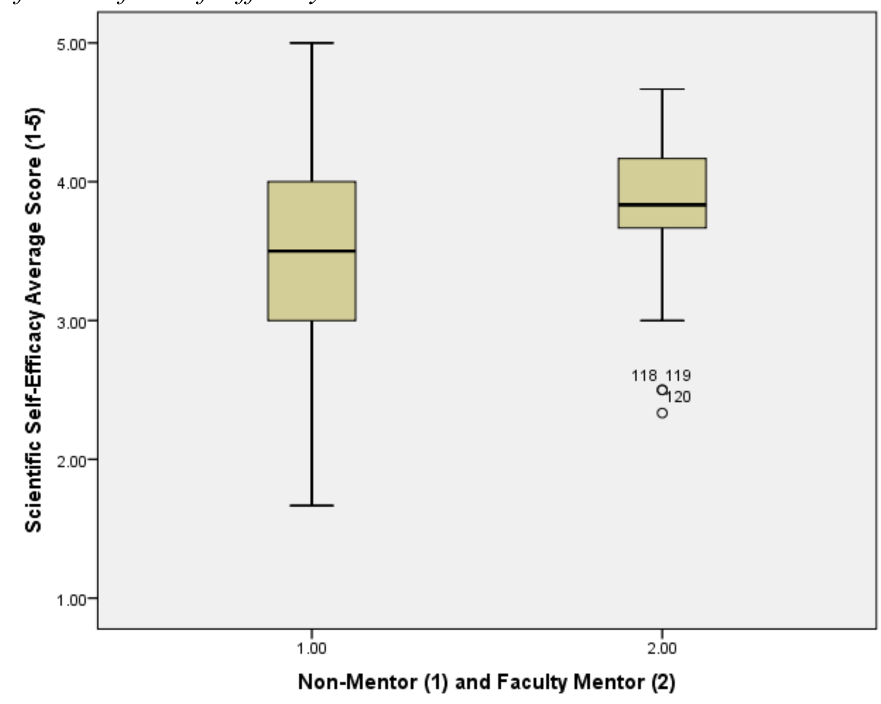
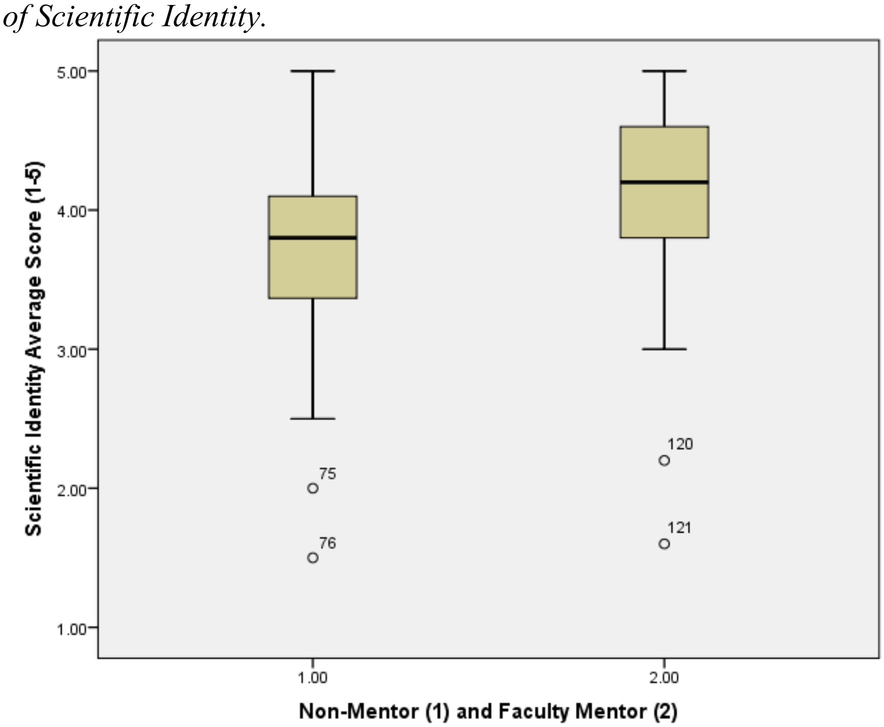


Figure 3 *Box Plot Based on Average Scores for all Questions for Data Screening in the Category of Scientific Identity.*



Assumptions

Assumptions of normality were not met using the Shapiro-Wilk test. Shapiro-Wilk was used since the faculty as mentor sample size was less than 50 participants. The normality assumption was violated with a $p < .05$ among each of the dependent variables.

Table 5. *Shapiro-Wilk Test of Normality Across Non-Mentor (1) and Faculty Mentor (2) Groups for Undergraduate Biology Respondents*

	Mentor Characteristics	Statistic	df	Sig.
Thinking and Working Like a Scientist	1	0.957	73	0.013
	2	0.930	47	0.008
Scientific Self-Efficacy	1	0.980	75	0.289
	2	0.930	45	0.009
Scientific Identity	1	0.970	76	0.070
	2	0.879	45	0.000

a. Lilliefors Significance Correction

Research Question One

The Shapiro-Wilk test indicated issues with normality of data, so medians from each mentor category were compared by a Mann-Whitney *U* test for non-parametric data analysis. In the first research question, the Mann-Whitney *U* test evaluated the null hypotheses that there is not a statistically significant difference in the faculty mentor and non-mentor scores as measured by the thinking and working like a scientist 9-item Undergraduate Research Student Self-Assessment (1-no gain to 5-great gain). A Mann-Whitney *U* test indicated that the Thinking and Working like a scientist score was significantly greater for faculty mentor (*Mean Rank* = 69.53) than for non-mentor (*Mean Rank* = 54.68), *U* score=1291.00, $n_{non\text{-}mentor}=73$, $n_{mentor}=47$, $p = 0.015$ (Table 3).

Table 6. *Mann-Whitney U test Across Non-Mentor (1) and Faculty Mentor (2) Groups for Undergraduate Biology Respondents*

		N	Mean Rank	Sum of Ranks
Thinking and Working Like a Scientist	1	73	54.68	3992.00
	2	47	69.53	3268.00
	Total	120		
Scientific Self-Efficacy	1	75	53.21	3991.00
	2	45	72.64	3269.00
	Total	120		
Scientific Identity	1.00	76	54.23	4121.50
	2.00	45	72.43	3259.00
	Total	121		

Test Statistics[a]

	Thinking and Working Like a Scientist	Scientific Self-Efficacy	Scientific Identity
Mann-Whitney U	1291.000	1141.000	1195.500
Wilcoxon W	3992.000	3991.000	4121.500
Z	-2.436	-3.045	-2.985
Asymp. Sig. (2-tailed)	0.015	0.002	0.003

a. Grouping Variable: Mentor Class

Research Question Two

In the second research question, the Mann-Whitney *U* Test evaluated the null hypotheses that there is not a statistically significant difference in the faculty mentor and non-mentor scores as measured by the 6-item Scientific Self-Efficacy Assessment (1-not confident to 5-very confident). A Mann-Whitney *U* test indicated that the Scientific Self-Efficacy score was significantly greater for faculty mentor (*Mean Rank* = 72.64) than for non-mentor (*Mean Rank* = 53.21), *U* score=1141.00, $n_{non\text{-}mentor}$=75, n_{mentor}=45, $p = 0.002$ (Table 3).

Research Question Three

In the third research question, the Mann-Whitney *U* Test evaluated the null hypotheses that there is not a statistically significant difference in the faculty mentor and non-mentor scientific identity scores as measured by the 5-item Scientific Self-Efficacy Assessment (1 strongly disagree to 5 strongly agree). A Mann-Whitney test indicated that the Scientific Identity score was significantly greater for faculty mentor (*Mean Rank* = 72.43) than for non-mentor (*Mean Rank* = 54.23), *U* score=1195.00, $n_{non\text{-}mentor}$=76, n_{mentor}=45, $p = 0.003$ (Table 3).

CHAPTER FIVE: CONCLUSIONS

Overview

Faculty mentoring in undergraduate research experiences (UREs) have been identified as a means to improve student self-efficacy (Lopatto, 2010). However, the significance of faculty mentoring structures and the dynamics of varied mentor practices are not as well understood (Aikens et al., 2016). In order to identify notable differences between such groups, this study sought to understand how faculty mentors within three subcomponents (thinking and working like a scientist, scientific self-efficacy, and scientific identity) affect undergraduate biology student self-efficacy. For this study, a nonparametric equivalent of a *t* test (Mann-Whitney U test) was performed to compare scores between faculty-mentored and non-mentored students. The conclusions of this study highlight the statistically significant effect of faculty mentoring in all three categories. Within this chapter, findings of this research are compared with other studies, implications and limitations are presented, and recommendations for future research are noted.

Discussion

Assessing and identifying ways to improve undergraduate learning experiences can be challenging (Laursen, 2015). However, effective mentoring practices within the sciences are a useful tool to prepare students for vocational demands beyond the rigors of an undergraduate biology degree (Weston & Laursen, 2015). The purpose of this study was to describe the effect of undergraduate research experiences (UREs) and mentoring structures on biology majors' self-efficacy at a large southeastern university. Previous studies have shown the beneficial effects of faculty mentoring and UREs on student self-efficacy (Aikens et al., 2016; Benson et al., 2016; Lin, Liang, & Tsai, 2015; Lopatto, 2010). Many large universities offer ways to engage in

UREs, but the ongoing assessment of effective types of mentoring structures, and course based undergraduate research experiences (CUREs), may not consistently be considered for effective student learning outcomes (Aikens et al., 2016; Daniels et al., 2016; Myatt et al., 2014). Constructing, assessing, and improving mentoring practices will ensure ongoing curriculum support structures to not only add to student retention, but to also obtain a greater mastery of content when applied to the design and development of projects in the sciences (Laursen et al., 2010; Myatt et al., 2014).

Research Question One

The first question focused upon whether or not faculty mentoring improves undergraduate biology students' gains in how they think and work like a scientist. A total sample of 73 non-mentored and 47 faculty mentored students responded to a 9-item Undergraduate Research Student Self-Assessment (1-no gain to 5-great gain). This assessment examines how a student understands both the nature of scientific knowledge and the process of scientific research (Weston & Laursen, 2015). A Mann-Whitney *U* test was used to compare the ranked data for each group. The mean rank of the faculty mentored group when compared to the non-mentored respondents was significantly greater ($p = 0.015$). In a similar study, mentoring practices in the sciences were assessed using the same 9-item Undergraduate Research Student Self-Assessment (Aikens et al., 2016). Aikens et al. (2016) identified the strengths of mentoring in a triad form, which included faculty and post-graduate mentors working with undergraduate students. Indications from this study suggest that a diverse group of graduate and post-graduate mentors for UREs can further enhance how undergraduate biology students grow in both the process of scientific research and the nature of scientific knowledge. Furthermore, notable best practices in undergraduate research include how mentors provide strategic planning, expectations, and support throughout a URE (Shanahan et al., 2015). Therefore, having mentors in place is not enough to ensure that students will excel in research (Aikens et al., 2016; Shanahan et al., 2015). Considerations in establishing mentor frameworks that affect growth in the thinking and working category must also reflect the relational needs of students, clear expectations, and social-emotional support in the mentoring process (Behar-Horenstein, Roberts, & Dix, 2010; Shanahan et al., 2015).

Research Question Two

The second question focused upon whether or not faculty mentoring improves undergraduate biology students' confidence in their scientific self-efficacy. A total of 75 non-mentor and 45 faculty mentored students responded to a 6-item Scientific Self-Efficacy Scale (1 not confident to 5 very confident). This assessment examines student perceptions of their abilities to complete scientific tasks. Such scientific tasks might include the ability to generate a question or create explanations from the results of a study (Estrada et al., 2011). A Mann-Whitney *U* test was used to compare the ranked data from each group. The mean rank of the faculty mentored group when compared to the non-mentor respondents was significantly greater ($p = 0.002$). Effective mentors have been shown to be individuals that take time developing and modeling research procedures for undergraduate students (Shanahan et al., 2015). In relation to scientific self-efficacy, this can include the teaching of specific techniques or technical skills needed for success in undergraduate research (Shanahan et al., 2015). The added effect of a mentor would include, but would not be limited to, the personalized nature of such skill training around individual student goals (Hernandez et al., 2013). Aikens et al., (2016) described a greater effectiveness in mentoring within a closed-triad (this triad being a direct connection in mentoring structures involving undergraduates, faculty, and postgraduates) when compared to mentoring triads that did not include direct connections between undergraduates and faculty (Aikens et al., 2016). The effectiveness of the "closed network" involved direct communication and guidance in the direction of a research project between mentor and students (Aikens et al., 2016). Aikens et al., (2016) connects her findings to the development of relationships within a closed research group. Noted faculty mentor relationships promote student access to needed resources for success in research and leads to greater trust and sense of obligation among students involved in research (Aikens et al., 2016; Coleman, 1988). Aikens et al. (2016) further identifies the benefits of faculty mentored structures as a source of social capital (Coleman, 1988) and the need to have faculty directly linked to undergraduate students conducting research. Conversely, students conducting course-based research (e.g. students that have completed upper level biology courses that include research experiences) do report gains in scientific self-efficacy, as they should, but the gains are significantly greater for undergraduates within faculty-mentored research groups. The ongoing development of UREs with faculty and postgraduates can further these scientific self-efficacy gains (Aikens et al., 2016).

Research Question Three

The final question focused upon whether or not faculty mentoring promotes an undergraduate students' sense of belonging in relation to their scientific identity. A total of 76 non-mentor and 45 faculty mentored students responded to a 5-item Scientific Self-Efficacy Assessment (1 strongly disagree to 5 strongly agree). This assessment examines the extent to which students think of themselves as scientists, their connection to the community of scientists, and whether or not the field of science is appealing to them (Estrada et al., 2011). A Mann-Whitney *U* test was used to compare the ranked data from each group. The mean rank of the faculty mentored group when compared to the non-mentor respondents was significantly greater

($p = 0.003$). This same 5-item scale was used to assess scientific identity gains for students that had direct contact with a faculty mentor in comparison with those students being mentored by postgraduates (Aikens et al., 2016). Aikens et al. (2016) found that students with faculty mentors reported great gains in scientific identity. Recognition of student work in UREs from faculty has been shown to improve the scientific identity of students by added gains within student social capital (Aikens et al., 2016; Coleman, 1988). Lopatto (2004) noted statistically significant gains in student efficacy in one-on-one faculty mentoring with research students. However, growing evidence supports notable gains in scientific identity stemming from diverse research team environments (Aikens et al., 2016; Morales et al., 2016; Myatt et al., 2014; Shanahan et al., 2015). Such gains in scientific identity can come from research team community building, scientific networking, and opportunities for students to mentor (Shanahan et al., 2015). Current research team dynamics are often complex and contain a collaborative research environment where multiple faculty may be mentoring the same student or group of students as they seek to answer research questions (Shanahan et al., 2015). Subsequently, the established pattern of a principal faculty mentor that meets regularly with a research team helps to establish a clear direction for undergraduate research (Shanahan et al., 2015). The role of a faculty mentor is an essential component to cultivate gains for individual student roles and personalized growth within a research project (Aikens et al., 2016; Shanahan et al., 2015). Furthermore, the ability of a faculty mentor to connect students to a broader network of scientists establishes an environment in which students can grow professionally (Shanahan et al., 2015). Such networking might involve opportunities to present at research meetings with oral or poster presentations (Shanahan et al., 2015).

Implications

The results of this research have direct implications for the support and development of faculty mentored research as an essential component of undergraduate biology training. This study presents three outcomes which highlight only a portion of the statistically significant effect of faculty mentoring on undergraduate biology students. The findings of this study support the published works of Aikens et al. (2016) and Shanahan et al., (2015), which report evidence of how faculty interactions within mentored undergraduate research provides a necessary foundation for maximizing student growth, retention, and persistence within the sciences.

Previous studies have noted the challenges of providing faculty mentored UREs (Shanahan et al., 2015). Such challenges are related to the availability of resources (e.g. faculty release time, departmental resources, and compensation) that can support a long-term commitment to both faculty and students (Shanahan et al., 2015). Such evidence contains implications for instructional practice and administrative support to develop a reputable and productive research program. One such additional outcome of faculty mentored research in UREs provides students with guidance through the process of disseminating their research findings to the scientific community (Shanahan et al., 2015). However, the ability of a faculty mentor to develop student growth in this area takes considerable time that can be overshadowed by the demands of faculty teaching responsibilities. Such teaching responsibilities can then limit the availability of opportunities for undergraduates to present and network at scientific conferences (Behar-Horenstein et al., 2010).

The development of a pedagogical model that promotes a balance between teaching and research verses the current major paradigm of one over the other, may be one way to apply best practices in faculty mentored undergraduate research. Such a pedagogical model would seek to maximize the gains from both rigorous content-based courses and hands-on research-based learning experiences. At present, teaching-based and research-based positions are more commonly viewed independent of one another (Shanahan, et al., 2015). In addition, within an ever-changing and competitive undergraduate learning environment, finding ways to promote student gains is necessary in order for graduates to compete in a global job market and to develop the applied skills for vocational success (Lopatto, 2007; Thiry et al., 2012). The development of a model which combines faculty release for mentoring undergraduates and course-based instruction would seem to be a proper platform to optimize the efforts of both faculty and students. Collaborative, and at times interdisciplinary team-based approaches to conducting undergraduate research, is one way to utilize the strengths of a faculty mentor to develop undergraduates with real world preparations (Shanahan et al., 2015).

There is an indication that faculty mentoring techniques seem to have been effective in how biology students at the study site perceive gains in their scientific thinking, scientific self-efficacy, and scientific identity. The researcher would suggest that there are mentor practices unique to the faculty mentored students and not prevalent in the non-mentored group. Such practices would include weekly research meetings with students. In addition, faculty mentors routinely guide the development of oral and poster presentations for local, regional, and national scientific meetings. Faculty mentoring includes concerted time with students in both the field and lab settings while also helping students develop Curriculum Vitae, pursue internships, and identify graduate schools. Finally, faculty mentored students are provided opportunities to mentor peers that are interested in pursuing UREs. Such faculty mentor practices should be considered as a means to promote statistically significant gains in undergraduate biology students' efficacy at the selected study site.

Limitations

There are two main limitations within this study. The first limitation is the sample and short-term nature of the data collection. The research used as a model for this present study obtained survey data primarily from research universities which also utilized postgraduates in mentoring (Aikens et al., 2016). Whereas the present study focused upon faculty-undergraduate interactions at a primarily teaching based university. Participants were recruited from all students classified as biology majors within a private university in the Southeast United States. The survey contacted 1005 students and approximately 12% (121 students) completed the survey. Sampling error could have occurred for multiple reasons. The researcher collected data over a short period of time (four weeks) during the beginning of the fall semester. Had the researcher obtained his sample from students as a part of course ending surveys or end of year assessments, it is possible that there would have been increased participation. Focused survey requests within specific classes that are aligned with student classification would potentially have provided an increase in responses balanced across student classifications (freshman, sophomore, junior, and senior standing). Within the groups (faculty mentored and non-mentored), there may have been students that did not classify themselves according to the correct group category. In addition, students may not have considered their non-mentor course based research experiences when responding to the survey. There may be students in the non-mentor category that report high medians due to their outgoing interaction with faculty outside of research experiences. Thus, there may be close associations between some non-mentor respondents with faculty that resulted in higher scores. Furthermore, one sample does not provide a long-term assessment of student gains from faculty mentoring. A longer study which applies the same survey over a duration of multiple years would generate data to identify trends from faculty mentoring.

Variable investment from faculty mentors could also be a threat to internal validity as faculty have varied responsibilities that support or detract from the time necessary to be effective mentors. For example, the promotion of faculty release time to engage in oversight of student projects is limited and relatively the same across the study site.

A second limitation would include the way in which students self-report scores. There may be instances in which students inflated scores or did not fully understand specific questions. However, the average outcomes of this present study are similar to other studies evaluating the effect of mentoring structures on undergraduate biology students (Aikens et al., 2016, Estrada et al., 2011).

The demographic information may also provide insight to limitations in the results. There was clearly a lack of intersectionality in the sample in which a majority of the ethnicities were white and there was a poor representation of diverse ethnicities within the faculty mentored group (Table 3). This lack of intersectionality is an apparent weakness within the faculty mentored URE (Table 3). However, it is noteworthy that there is a proportionate number of males to females in mentored UREs (Table 2). Another demographic consideration would be that the largest groups of student respondents were freshman and seniors (Table 4). The freshman students at the time of the survey in their first semester may not have had the best context for answering the efficacy scaled questions while the senior students should have been selecting the faculty mentor category as students that have completed an upper level biology course with a URE. Interestingly, the freshman efficacy scores were as high as the senior scores. Identifying trends within these class groups will require further investigations.

Recommendations for Future Research

This study presents three effects on undergraduate biology students, which highlight only a portion of the effect of faculty mentoring. Considerations for future research to strengthen pedagogical practices related to UREs and mentoring structures would include the following:

1. Faculty Collaboration Effects on Student Gains: To increase an understanding of faculty mentoring in a growing number of collaborative research projects, conduct a similar study, which differentiates the type(s) of faculty mentoring encountered by undergraduate researchers (Aikens et al., 2016). Are there notable strengths/gains for students involved in collaborative projects and/or are there notable weaknesses/losses that need to be addressed in collaborative faculty mentor undergraduate research? Such a study would likely need to include multiple study sites in order to obtain an adequate respondent sample.
2. Faculty Perceptions of Mentoring Best Practices: The focus of this study was to assess student perceptions of faculty mentoring and student growth. The literature also suggests that faculty perceptions of best practices in undergraduate research can affect noted gains in students. Further studies to assess faculty perceptions of mentoring practices in relation to student responses are needed.
3. Peer Mentoring Effects: This study recommends a long-term assessment of student gains in relation to faculty mentored UREs. Such a study would also take into account a growing number of student peer mentors that are serving to guide student growth in the sciences. Further studies to assess how the addition of student mentors affect both the mentors and mentees' personal and professional growth are needed.

4. Long-term Trends in Faculty Mentor UREs: There were several recent studies that noted the importance of studying UREs to assess the growth of students (e.g. how they think of themselves as scientists, perceptions of their abilities, understanding of the nature of scientific knowledge and the process of scientific research). Studies that focus on finding meaningful ways to move beyond the acknowledgment that faculty mentoring results in gains for undergraduate students to the improvement of pedagogical practices which promote the strengths of such relationships are needed.

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APPENDIX A: Survey Questions

The self-efficacy survey includes characteristics of participants and responses to three question sets on (1) thinking and working like a scientist, (2) scientific self-efficacy, and (3) scientific identity. Characteristic questions and the described question sets were entered and administered through the Liberty University approved online Qualtrics survey system.

Participant Characteristics

Q: Please identify the mentoring structure that most closely identifies your research experiences as a student within the biology program:

Responses: faculty-mentor, student-mentor, faculty and student mentor, and non-mentor

Q: Please identify your gender:

Responses: Male, Female

Q: Please identify your race/ethnicity:

Responses: White, African-American, Other

Q: Please identify the duration (semesters completed) of your research experience:

Responses: 0, 1, 2, 3, 4+

Q: Please record your overall GPA: _._ _

Responses will vary.

Question Sets (Aikens et al., 2016 self-efficacy survey):

Outcome	Stem	Item	Response options
Thinking and working like a scientist (Hunter et al., 2009; Weston and Laursen, 2015)	Please indicate the extent of the gains you have made within each category.	Analyzing data for patterns.	1=No gain; 2=Little gain; 3=Moderate gain; 4=Good gain; 5=Great gain
		Figuring out the next step in a research project.	
		Problem-solving in general.	
		Formulating a research question that could be answered with data.	
		Identifying limitations of research methods and designs.	
		Understanding the theory and concepts guiding my research project.	
		Understanding the connections among scientific disciplines.	
		Understanding the relevance of my research to my coursework.	
		Defending an argument when asked questions.	
Scientific self-efficacy (Estrada et al., 2011)	Please indicate your level of confidence in your ability to…	Use technical science skills (use of tools, instruments, and/or techniques).	1=Not confident; 2=A little confident; 3=Somewhat confident; 4=Confident; 5=Very confident
		Generate a research question to answer.	
		Figure out what data/observations to collect and how to collect them.	
		Create explanations for the results of the study.	
		Use scientific literature and/or reports to guide research.	
		Develop theories (integrate and coordinate results from multiple studies).	
Scientific identity (Estrada et al., 2011)	Please indicate your level of agreement with the following statements.	I have a strong sense of belonging to the community of scientists.	1=Strongly disagree; 2=Disagree; 3=Neither agree nor disagree; 4=Agree; 5=Strongly agree
		I have come to think of myself as a "scientist."	
		I feel like I belong in the field of science.	
		I derive great personal satisfaction from working on a team that is doing important research.	
		The daily work of a scientist is appealing to me.	

APPENDIX B: Participant Letter

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

CONSENT FORM

The Effect of Undergraduate Biology Research Experiences and Mentoring Structures on Student Self-Efficacy
Kyle J. Harris
Liberty University
School of Education

You are invited to be in a research study of the impacts of undergraduate research experiences (UREs) and mentoring structures on student self-efficacy. You were selected as a possible participant because you are enrolled as an undergraduate biology student at Liberty University. Please read this form and ask any questions you may have before agreeing to be in the study.

Kyle J. Harris, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this research is to study the effect of various types of undergraduate research experiences (e.g. 0, 1, 2, 3, 4+ semesters) and mentoring structures (e.g. faculty only, student only, both faculty and student, non-mentor) on student self-efficacy.

Procedures: If you agree to be in this study, I would ask you to do the following things:

1. Complete the anonymous participant information section. (5 minutes)
2. Complete the nine item Thinking and Working Like a Scientist Questionnaire. (5 minutes)
3. Complete the six item Scientific Self-Efficacy Questionnaire. (5 minutes)
4. Complete the five item Scientific Identity Questionnaire. (5 minutes)

Risks and Benefits of being in the Study: The risks involved in this study are minimal, which means they are equal to the risks you would encounter in everyday life. No foreseeable risks are associated with participation in this study. While this study does not extend any direct benefits to you, information gained in this study may contribute to undergraduate research experience reform.

Compensation: Participants will not be compensated for participating in this study.

Confidentiality: The records of this study will be kept private. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely, and only the researcher will have access to the records. The questionnaires will be anonymous, data from the questionnaires will be aggregated in a password protected Excel spreadsheet, and all data will be deleted after 3 years.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with Liberty University. If you decide to participate, you are free to not answer any question or withdraw at any time prior to submitting the survey without affecting those relationships.

Contacts and Questions: The researcher conducting this study is Kyle J. Harris. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact him at kjharris@liberty.edu. You may also contact the research's faculty advisor, Scott Watson, at swatson@liberty.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd., Green Hall Ste. 1887, Lynchburg, VA 24515 or email at irb@liberty.edu.

Please notify the researcher if you would like a copy of this information for your records.

Statement of Consent: I have read and understood the above information. I have asked questions and have received answers. By completing the anonymous participant information, Thinking and Working Like a Scientist, Scientific Self-Efficacy, and Scientific Identify Questionnaires, I consent to participate in the study.