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Women in STEM: The Effect of Undergraduate Research on Persistence

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COLLEGE OF EDUCATION

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Abstract

The underrepresentation of women in science, technology, engineering, and math (STEM) careers constitutes a major issue in postsecondary science education. Perseverance of women in STEM is linked to a strong science identity. Experiential learning activities, such as undergraduate research, increase science identity and thus should help keep women in STEM. Most studies on research program development are from 4-year institutions, yet many women start at community colleges. The goal of this study was to fill this gap. Science identity and experiential learning theories provided the framework for this case study at a local institution (LECC). Semistructured interviews determined college science faculty and administrators perceptions of advantages and disadvantages of undergraduate research, the viability of developing a research program, and specific research options feasible for LECC. Transcripted data were analyzed through multiple rounds of coding yielding five themes: faculty perception of undergraduate research, authentic experiences, health technologies/nursing programs, LECC students career focus, and the unique culture at LECC. The most viable type of undergraduate research for LECC is course-based and of short timeframe. The project study advocates the use of citizen science (CS) studies in the classroom as they are relatively short-term and can take the place of lab sessions. The true benefit is that students perform authentic science by contributing to an actual scientific research project. CS projects can effect social change by developing science literate citizens, empowering faculty to create authentic learning experiences, and by sparking interest in science and directing women into STEM careers.

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Dedication

My study is dedicated to my sons, Nick and Scott, the two people who have provided constant support, both in big and small ways, through my doctoral journey. Your belief in my ability to succeed has meant the world to me.

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So many people have given me their time, knowledge, and support. First I want to thank my parents, Rog and Lin, who have shown me unconditional love and been my biggest cheerleaders in this endeavor.

Thank you to Dr. Batiuk who has been the best kind of mentor. Her high expectations and positive comments always brought out my best work and I will miss working with her. The scholarly and professional tone of my study is due to Dr. Reid-Hector's diligent review and excellent writing advice. Next I would like to acknowledge my study participants, who willingly gave me their time and attention, and showed me how dedicated they are to their colleagues and their students.

The fact that I am still sane is due to my wonderful friends who have given me needed perspective and reminded me not to put my life on hold.

Finally a thank you to Dr. Dave Pierce, my friend and mentor, who knew it was just a matter of time before I pursued my EdD as he did. Thank you for your counsel and your comic relief.

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Section 1: The Problem

Introduction

The continuing underrepresentation of women in science, technology, engineering, and math (STEM) careers constitutes one of the major issues in contemporary postsecondary science education (Dabney & Tai, 2014; Gayles & Ampaw, 2014; Glass, Sassler, Levitte, & Michelmore, 2013; Harsh, Maltese, & Tai, 2012; Hazari et al., 2013; Hill & Rogers, 2012; Shapiro & Sax, 2011). The U.S. government has estimated STEM career opportunities will grow at more than double the rate (20.6%) of the overall U.S. labor force (10.1%) through 2018 (MyCollegeOptions, 2012). However, over the past years, the total number of STEM graduates has remained relatively steady (Langdon, McKittrick, Beede, Khan, & Doms, 2011). This deficiency needs to be addressed by increasing the overall number of STEM students in the pipeline. Because women make up more than half of the postsecondary students in the United States, one of the most significant ways to increase the total number of STEM students would be to increase the numbers of women in those majors (NSF, 2011). Additionally, the current STEM talent pool is predominately white and male and not representative of the emerging American labor force (NSF, 2011). Therefore, actively recruiting and retaining underrepresented groups, such as women and minorities, would not only address the shortage but also increase workforce diversity (Hira, 2010).

Diversifying the U.S. STEM workforce will keep the United States competitive in the world economy through better development of products, services, and solutions that represent all users (Hill, Corbett, & St. Rose, 2010). Margolis and Fisher (2002) noted that in product design male cultural models are most often the norm; introducing different viewpoints and models would make products more universally effective. For example, the exclusive use of male prototypes in the development of airbags and heart valves actually resulted in unnecessary deaths among women and children (Margolis & Fisher, 2002).

The sizable gap between the number of men and women active in the STEM academic pipeline and workforce mirrors similar gaps observable in many other occupations like law enforcement, military service, and construction work (Landivar, 2013). Computer science and engineering comprise 82% of STEM workers, yet in the last 40 years the number of women in those careers increased only 12% and 10% respectively (National Science Foundation, 2011). While progress has been made, there is still a long way to go to achieve parity. This situation is also occurs at the international level. A Science and Technology Committee report on women in science from the British House of Commons noted that only 13% of STEM jobs in the UK were filled by women. In the EU, 32% of scientists and researchers were women in 2010 (Commission, 2012; Science & Committee, n.d.). Gupta (2014) reported on the gender disparity in science in India noting that only 16% of scientists in that nation were women.

Definition of the Problem

Women are underrepresented in STEM majors and careers throughout the academic pipeline (Dabney & Tai, 2014; Gayles & Ampaw, 2014; Glass et al., 2013;

Harsh et al., 2012; Hazari et al., 2013; Hill & Rogers, 2012; Shapiro & Sax, 2011). Efforts to ameliorate gender disparities have focused on removing barriers and enhancing the science experience of female STEM students, including undergraduate research experiences. These have shown promise in increasing female persistence in science. However, what is not clear is whether college faculty and administrators have really understood this need and embraced these approaches. This research will clarify the degree to which faculty and administration see the underrepresentation of women in STEM as a problem that can be addressed through modifications in teaching and learning (Dabney & Tai, 2014; Ramsey, Betz, & Sekaquaptewa, 2013).

Breaking down some of the barriers women in STEM majors face involves meeting them where they are, and many female students get their start in higher education at community colleges (Mooney & Foley, 2011). Due to lower costs and greater availability of community colleges, almost half of the students who earned a 4-year STEM degree began at a community college (National Survey of Recent College Graduates, 2010). Focusing on community colleges also makes sense because these institutions experience the largest rate of STEM attrition. At 4-year schools, the STEM attrition rate is 57% between freshman and senior years, while at community colleges, the rate is 86% between the first and second years (Labov, 2012).

Government, individual institutions, and science foundations like the National Science Foundation (NSF), American Association for the Advancement of Science (AAAS), and American Chemical Society (ACS), have all instituted funding programs to help with the projected scarcity of STEM graduates. President Obama's administration initiated a number of specific programs, including "Educate to Innovate" in 2009, "100Kin10" in 2011, and "Race to the Top" in 2009, focusing on bringing STEM opportunities to a broader student population (Improving Science, n.d.). President Obama specifically noted that community colleges are in the front line of action to bring students, especially underserved students, into STEM opportunities, and to this end he pledged $150 million for program development and college infrastructure changes (Improving Science, n.d.). The NSF has directly funded community college initiatives such as STEM Talent Expansion Programs (STEP) and Advanced Technological Education (ATE) Programs designed to increase STEM transfers leading to 4-year degrees (Starobin & Laanan, 2008). NSF also supports two programs aimed at increasing the number of authentic undergraduate research experiences at all types of institutions: the Research in Undergraduate Institutions (RUI) program and the Research Opportunity Awards (ROA) (NSF, 2014). The Gates Foundation funded the Completion by Design program in 2011. This program uses effective existing practices at specific institutions as model pathways to improve the graduation rates at other community colleges (White House, 2010a). Community College Pathways (CCP), aimed at helping college students overcome math difficulties in order to pursue STEM careers, was established in 2009 by support from the Bill and Melinda Gates Foundation, the William and Flora Hewlett Foundation, the Kresge Foundation, Carnegie Corporation of New York, and the Lumina Foundation (Van Campen, Sowers, & Strother, 2013).

Community college and undergraduate research initiatives have shown that opportunities to participate in undergraduate research during the college years prove to be one of the most effective experiences for attracting and retaining women in STEM studies (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Fakayode, Yakubu, Adeyeye, Pollard, & Mohammed, 2014; Hunter, Laursen, & Seymour, 2007; Jackson, 2013b; Thiry, Laursen, & Hunter, 2011). Eagan and Garibay's 2013 longitudinal study of 4154 freshman STEM majors showed that participation in undergraduate research made a significant increase (14-17%) in student intentions to pursue graduate or professional degrees. Harsh et al. (2012) examined gender differences with respect to perceived benefits of undergraduate research. Among 4285 participants responding to a developed survey 47% of women perceived undergraduate research as a key factor in their decision to pursue higher degrees in STEM fields (Harsh et al., 2012). However, most studies on the effects of undergraduate research on student outcomes have occurred at four-year schools, and not at the community college level, leaving a gap in the knowledge. More needs to be known about whether this model can be adapted to community colleges. The purpose of this research is to explore the viability of this model at one community college in the Midwest.

Rationale

Evidence of the Problem at the Local Level

As a scientist, I have always been aware of the underrepresentation of women in science programs. In my years of teaching within the sciences I have seen some progress, but the fundamental issue still exists and the underrepresentation of women is still the norm. Evidence of female underrepresentation in STEM disciplines at the local level comes from both academia and industry. A survey of STEM faculty at local research universities confirms these gender disparities. Of 188 STEM faculty in 11 departments at Cleveland State University, there were only 13 women, representing 14% of total faculty (CSU, n.d.). Numbers at Kent State University (including satellite locations) were slightly better, as women represented 24% of the total STEM faculty (Kent State, n.d.). At nearby Lake Effect Community College Community College, the combined science department faculty (both full-time and adjunct) consists of 31 (66%) men and 16 (34%) women (K. Tarasco, personal communication, February 10, 2015).

A sampling of STEM companies in the local area also reveals gender disparities. At Belpan Corporation in Cleveland, there are 37 engineers/technicians, but only three are women (J. Work, personal communication, November 6, 2014).

Evidence of the Problem from the Professional Literature

In the United States, women hold almost half of all jobs, but comprise fewer than 25% of STEM workers; this number has held steady over the last 10 years (Tsapogas, 2004). Beede et al. (2009) showed that women comprised 24% of the STEM workers in the United States, broken down in the following fields: computer science (27%), engineering (14%), physical and life sciences (40%), and STEM managers (25%) (Beede et al., 2011).

From 2002-2012, The National Science Foundation (NSF) collected data on the numbers of men and women graduating with STEM degrees, and the number of men and women in the STEM workforce. Biology is the only area of science where the number of female graduates outnumbered male graduates, helping to close the gap in the workforce to 20% (National Science Foundation, 2011). In the areas of math and physical science, male graduates exceed female graduates by 25%, and in computer science and engineering, male graduates outnumber female graduates by 75%; the number of female graduates with computer science bachelor's degrees has actually decreased by 36% over 10 years (National Science Foundation, 2011). Except for biology, men still account for 60-70% of PhDs (National Science Foundation, 2011).

The gender gap is also evident in the median income earned by men and women. STEM women are rarely paid more than men. Only in computer science do the numbers approach parity. On average women in STEM careers earn only $0.80 for every dollar a similarly qualified man makes (National Science Foundation, 2011). The field of biology shows the biggest salary difference with women PhDs earning only 74% of male biology PhDs make; this is a difference of $600,000 over a lifetime (National Science Foundation, 2011).

Definitions

CUR: Council on Undergraduate Research. An organization established in 1978; the purpose of the organization is to help establish and promote undergraduate research programs in the United States (Council on Undergraduate Research, n.d.).

NSF: National Science Foundation. A government entity established in 1950 to promote nonmedical scientific endeavors; it is the biggest source for funding in STEM fields (NSF, n.d.)

STEM: An anacronym for the collective subjects of Science, Technology, Engineering, and Math (Brown, 2012; Christie, 2013; Landivar, 2013).

UR: Science research undertaken by undergraduates to contribute to a specific field of study; usually supervised by research faculty (Council on Undergraduate Research, n.d.).

Significance

My research adds to the growing literature on the effects of undergraduate research on retention of female students in STEM degree programs in general, and specifically to local community colleges. It is unique in that the focus would be on women who begin their STEM studies at community colleges. Locally, my research will raise awareness of the low retention rate of women STEM students, as well as provide possible options for amelioration. Hopefully, a change in science education practice would be seen by offering community college students research options as well as integration of a research component into more science courses. Undergraduate research experiences would not only benefit those students who are directly involved, but benefit the science departments as well (Hirst, Bolduc, Liotta, & Packard, 2014). Local businesses and industries would stand to benefit from having a better qualified and diverse workforce (Hill, Corbett, & St. Rose, 2010).

Guiding/Research Question

Researchers have shown that experiential learning opportunities outside the classroom, such as jobs, internships, and undergraduate research, provide gains in personal efficacy and in professional, analytical, communication, and teamwork skills. Strengthening these areas allows students to develop an identity as scientists and members of the scientific community. Identification as a scientist is a key component of persistence (Cundiff, Vescio, Loken, & Lo, 2013; Merolla & Serpe, 2013). Still, not enough is known about whether college faculty and administrators are aware of this research and the potential impact it promises to have on women pursuing STEM majors. The three research questions for this study are:

RQ1: What do college science faculty and administrators perceive to be the advantages and/or disadvantages of developing an undergraduate research program at Lake Effect College to empower female STEM students?

RQ2: How would college science faculty and administrators assess the viability of developing an undergraduate research program at Lake Effect College?

RQ3: What undergraduate research options are feasible at LECC?

A qualitative case study approach will provide the best opportunity to explore and assess the viability of an undergraduate research program at Lake Effect College. Interviews of community college faculty and administrators will explore attitudes and interests about developing undergraduate research at their schools. Interviews with local faculty and experts who currently employ undergraduate research programs will help define the best practices in developing an undergraduate research program for Lake Effect College.

Review of the Literature

In the development of this literature review, access to articles, books and other information emerged via databases at Walden University, Lake Effect Community College, and Ursuline College and included: ERIC, Education Research Complete, Academic Research Complete, and Electronic Journal Center. Keywords included: *apprenticeship, biology education, chemistry education, community college, course-based research, CUR, CURE, education(al) research, engineering, experiential learning, gender, identity, identity theory, Kolb, laboratory, learning theories, learning cycles, learning styles, mentors, Myerhoff, minorities, motivation, NSF, NIH, NSTA, persistence, physics education, research, REU, science, science education, science identity, self-efficacy, STEM, stereotype, undergraduate research, underrepresented, women*.

The review begins with an explanation of the educational and learning theories which form a framework for the study. These theories will aid in the development of specific interview questions for faculty and administrators. The review then summarizes the important role of community colleges within the overall educational landscape of the United States and explores the important role of undergraduate research within the community college context.

Conceptual Framework: Experiential Learning Theory

The traditional, didactic manner of teaching and assessing scientific knowledge, as if science were a collection of discreet bits of factual knowledge that must be memorized and reiterated lessens any inherent student interest in the subject (Wallace, 2012). Experiential learning, in which students generate knowledge based on critical reflection on their own experiences, provides a deeper learning than traditional methods and sustains student interest by connecting to the student's world (Chilwant, 2012; Diaz-Vazquez et al., 2012; Mervis, 2013). Experiential learning has worked at all levels of education and in many different disciplines (Straub, Whalen, & Marsh, 2014). Types of experiential education at the adult education level include internships, field placements, clinical experiences, research and service learning (UTexas, n.d.). A number of theorists have developed models of learning; one of the most versatile is that of David A. Kolb.

Kolb's experiential learning theory. As developed by Dewey, the idea that an individual's experience links new ideas to an existing knowledge framework shaped the thinking of theorists including Piaget, Kolb, Young, Freire, and Rogers (Dewey, 1938; Kolb, Boyatizis, & Mainemelis, 2001). One of the best known contemporary experiential learning theories is that of Kolb who conceptualized learning as a holistic process and not simply an end product (Bechter & Esichaikul, 2008; Kolb, 1984; Kolb et al., 2001; Merriam, Caffarella, & Baumgartner, 2007; Towns, 2001). Kolb realized that learning is often a refinement of previously understood concepts and information is observed and integrated into a learner's previous store of knowledge (Kolb, 1984; Kolb et al., 2001). For Kolb, this happens through the four steps of his learning cycle: experience, reflect, generalize, and test (Kolb et al., 2001; Kolb, 1984). Optimal learning occurs when there is balance between all four stages of the cycle (Abdulwahed & Nagy, 2009; Brown, 2011).

Kolb also realized that individuals process and use the learning cycle in different ways; this leads to his four learning styles. Grasping knowledge happens through watching (reflection) or doing (testing); manipulating knowledge occurs via thinking (generalization) or sensing (experience) (Healey & Jenkins, 2000; Kolb, 1984). Matching a grasping and a manipulating preference results in one of four specific learning styles: diverger, assimilator, converger, or accommodator (Healey & Jenkins, 2000). Each style focuses on a different aspect of a concept and each of the four learning styles correlates to a question (Healey & Jenkins, 2000). Divergers (watch and sense) ask, "Why is this important?" Assimilators (watch and think) want to know, "What is the concept?" Convergers (do and think) ask, "How can this be applied?" Accomodators (do and sense) want to know "What are the possibilities?" (Towns, 2001). The best lessons touch on all components of Kolb's theory, allowing participants to delve into a complete experiential learning situation where all of these questions are both asked and answered (Abdulwahed & Nagy, 2009; Healey & Jenkins, 2000; Towns, 2001). One of the benefits of Kolb's model is that it is general enough to apply in numerous situations.

Applications of Kolb's learning theory. Kolb's theories have been important for curriculum development in many areas of education. In math, Di Muro and Marion (2007) considered how to best serve the four learning styles in various learning components such as problem solving and testing. Felder and Silverman (1988) examined four various learning style scales, including one based on Kolb's theory, in the context of resolving teacher style/learner style mismatch in engineering programs; Lyons and Brader (2005) employed the Kolb's learning cycle in developing three mechanical engineering experiments requiring student input and design. At Lees-McRae College, nursing students analyzed their professional experiences through reflection on the four facets of Kolb's learning cycle (Hartley, 2010). Kolb-inspired geography lessons for both classroom and fieldwork were developed by Healey and Jenkins (2000). With respect to online learning, significant differences between the four learning styles showed up in Bechter and Esichaikul's 2008 research, and Richmond and Cummings (2005) explained how personalization of online courses can happen by identifying student learning styles and incorporating appropriate course activities. Hurst-Wajszczuk (2010) even developed a singing lesson pedagogy based on the learning cycle and learning styles. Finally, with regard to science laboratory experiences (labs), Archavarungson et al., (2011) provided details of a diagnostic biology lab, and Abdulwahed and Nagy (2009) explained how to analyze and modify engineering labs to take advantage of multiple learning styles. Kolb's experiential learning theory (ELT) is not only versatile, it also provides benefits to the students and instructors.

Benefits of experiential learning. Experiential learning has the advantage over traditional classroom learning in that it taps into a student's personal motivation and therefore increases her engagement in the knowledge building activity (Brown, 2011).

Because learning is active, the student is a stakeholder in her own education, exploring her strengths and addressing weaknesses (Barton & Tan, 2010; (UTexas, n.d.). Construction of knowledge via involved learning develops the student's self-direction and agency within a specific environment (Barton & Tan, 2010; "UTexas, n.d.). Improvements due to evidential learning have been documented in participants and include enhancements in technical skills, design skills, presentation skills, communication skills, problem solving/critical thinking, and knowledge retention (UTexas, n.d.; Hawtrey, 2007; Straub et al., 2014). Experiential learning has also been shown to specifically help underrepresented minorities (URM) in their persistence in science education (Brown, 2011; Thiry, Laursen, & Hunter, 2011). Experiential learning is one framework for understanding the benefits of undergraduate research; science identity theory is another.

Conceptual Framework: Science Identity Theory

Identity theory. Science identity provides another lens for understanding the personal changes an undergraduate research experience can produce. There are many ways of defining science identity and the majority of them have their roots in Identity Theory, most notably the model developed by Stryker (1994). For Stryker individuals occupy specific roles in society and within these roles there are certain expectations which need to be fulfilled (Stryker & Serpe, 1994). Sometimes expected roles compete, and salience, or the probability that a role will be enacted, dictates which role is chosen (Stryker & Serpe, 1994). Johnson, Brown, Carlone, and Cuevas (2011) provided the example of a woman who identified both ethnically as a Native-American, and career-wise as a STEM student. Conflict occurred when her STEM course required her to perform animal dissection, something which violated her cultural beliefs. This was especially difficult for her because at this time she was pregnant (salience), and viewed the dissection as a threat to her pregnancy (Johnson et al., 2011). When given an ultimatum to choose between the two roles, she chose her cultural role as a Native American woman and switched majors to a different type of science (Johnson et al., 2011).

Gee (2000) offered a slightly different perspective of identity by viewing it through four different lenses. The first view is what he terms *nature identity* and is an identity element that the individual has no control over such as nationality, gender, or ethnicity (Gee, 2000). An individual's *institutional identity* comes through affirmation by authorities; examples include being a graduate, or a member of a specific profession (Gee, 2000). *Discourse identity* deals with the traits of an individual's personality that is affirmed by others in social contexts; examples might include compassion, assertiveness, loquaciousness, intelligence, and loyalty (Gee, 2000). Finally, *affinity identity* encompasses belonging to a community of others who share similar interests and beliefs (Gee, 2000). Examples here might include being a Boston Red Sox fan, collecting coins, or belonging to a sorority (Gee, 2000). All of these identity components create the overall identity for a person in a specific time and place, with one of the four types of identity predominating depending upon the context (Gee, 2000). The outward portrayal of these four factors is seen as the individual's bid for recognition in that context (Gee, 2000). Three outcomes can result: the bid is accepted, the bid is ignored, or the bid is rejected and unwanted identity elements, out of the individual's control, are attributed to the bidder (Gee, 2000). The idea of a bid for recognition carries over into science identity theory.

Science identity. One of the strongest models of science identity was developed by Carlone and Johnson (2007) who used a grounded theory process in an ethnological study to build a model of a woman of color who persisted in science. Three factors were found to predict persistence in science fields: competence, performance, and recognition (Carlone & Johnson, 2007). By examining interactions between students and science faculty, Carlone and Johnson found that women who were recognized for their science acumen had the easiest path, as this verification built their science self-identity. Some women did not receive requested recognition but still persisted because they viewed science as a vehicle for their altruistic career aspirations; because these women received recognition from those involved in their altruistic interests, they were not affected by lack of recognition for their science skills (Carlone & Johnson, 2007). A final group of women remained in STEM fields even though they did not receive the crucial recognition component from people they considered meaningful; Carlone and Johnson (2007) conjecture that these women possess a factor not measured in their study that promotes persistence. Johnson et al. (2011) called this ability to adapt to an unwelcoming environment “la facultad,” based on Anzaldua’s term from her book *Borderlands/La Frontera: the New Mestiza* (Anzaldua, 1987 as cited in Carlone & Johnson, 2007).

Merolla and Serpe (2013) added to the science identity theory by arguing that the local social structure of the science domain plays just as strong a role as science capability in the persistence of students toward STEM careers. A positive, supporting social context allows science students to be recognized as part of the science community, and to internalize their self-perception as scientists (Merolla & Serpe, 2013). Using data from The Science Study, Merolla and Serpe found that science identity has a significant impact on whether students enter graduate school (California State University San Marcos, n.d.). Additionally, they found that significant positive correlations existed between science identity and undergraduate research, and between science identity and level of interaction with faculty (Merolla & Serpe , 2013). Merolla and Serpe ascertained that when the social (recognition) component is lacking, even highly talented students are driven out of science; a result in line with Carlone and Johnson’s model (2007). Eagan and Garibay (2013) noted that the social engagement with the science community resulting from participation in undergraduate research opened doors for networking and helped students refine their scientific interests, furthering student identification as scientists. They corroborated Carlone and Johnson’s finding that involving STEM students in active science endeavors early in their college career strengthens science identity and has a long term impact on persistence (Carlone & Johnson, 2007; Eagan & Garibay, 2013; Eagan, 2012). Hurtado et al. (2011) also used Carlone and Johnson’s theory to explain results of phenomenological research to understand how underrepresented minorities (URMs) developed science identity and science self-efficacy. Finally, the findings in Chang, Eagan, Lin, and Hurtado's 2011 longitudinal study of persistence in science were explained through the lens of Carlone and Johnson's theory. This viewpoint of persistence can be used when looking at a subset of the student population – women.

Science identity in women. Carlone and Johnson's (2007) grounded theory study showed that for women, a strong science identity leads to persistence in the STEM pipeline. Other research has supported this theory. Cundiff, Vescio, Loken, and Lo (2013) found that a strong science identity negated the gender stereotype factor with respect to persistence. Stout, Dasgupta, Hunsinger, and McManus (2011) speculated that the absence of women role models made women feel like imposters in a STEM environment, and suggested that opportunities for women to embrace both their gender and their interest in science be increased. Harsh, Maltese, and Tai (2012) directly linked research experiences that built women's self-confidence with overcoming the gender stereotype barrier.

Women face unique barriers to developing science identities. Their high school preparation is often a big obstacle; many more males than females take high level mathematics and sciences; more women than men need remedial math and science training upon entering college (Gayles & Ampaw, 2014). Unwelcoming environments also affect identity development. STEM coursework at many colleges is highly competitive, discouraging women who generally have better learning outcomes in collaborative environments (Shapiro & Sax, 2011). Ramsey, Betz, and Sekaquaptewa (2013) conducted two studies to determine what contextual aspects made a difference in women's sense of belonging in the science field and found that environments in which there were constant messages about women in STEM, where there were both professorial and peer role models, and where women carried markers of their STEM identity had a significant difference with respect to science identity. A secondary study introduced these three changes as an intervention and found an improvement in learning outcomes (Ramsey et al., 2013). Studies by Inkelas (2011) and Stout et al. (2011) also showed that female role models and peers boosted confidence, self-efficacy and persistence.

A final barrier in a woman's ability to create a science identity is the perception of others. Johnson et al. (2011) asserted that identity is a social construct and is based on the contextual role the individual sees as well as the role that others assign to them. Limits on science identity construction can be found in the curriculum, family, faculty, and resources (Brickhouse, 2012). Often the role a woman is obliged to take allows her to survive, but not thrive in the science environment (Johnson et al, 2011). In Gee's (2000) three outcomes of an individual's bid for recognition, the last outcome, where the bid is rejected and an unwanted identity is ascribed to the bidder, is the most harmful. Heilman (2012) provides a good example of this in the catch-22 that plagues professional women. Heilman, Wallen, Fuchs and Tamkins' 2004 research provided evidence that if a woman in a male-dominated job showed competence, she was considered difficult and unlikeable; conversely, if a woman had a likeable personality, it was assumed that she was not as competent in her role as a man would be. Unwanted identity elements made this an unwinnable situation.

There are other models for the development of identity. DeRosa studied science identity formation in Black women physicists using critical race theory and feminism as conceptual frameworks; her trajectory for Black women's identity formation starts with invitations to participate in science and math events outside of school, being recruited by colleges because of their unique demographics, negotiating multiple identities, and validating science identity with successes in the field. Similarly, Jackson and Suizzo examined Latinas persistence in science from an ecocultural approach, in which cultural values play a determining role. Eight important factors were identified: home environment, teacher influences, school experiences, contextual factors, media, using your brain, emotions, and career planning; of these, family, contextual factors, and teacher influence were the main drivers of Latina success in STEM. Both studies identified several factors critical for women of color; however, upon examination of the meanings of each factor, they ultimately fit into Carlone and Johnson's model of science identity development acting as specific examples of competence, performance, and recognition. Therefore, Carlone and Johnson's model is the most comprehensive approach to science identity formation.

The abundance of literature linking participation in undergraduate research with the development of science identity, and science identity with persistence in STEM makes experiential learning and science identity theory valuable frameworks for examining results of the proposed study. Background information regarding the essential roles community colleges and undergraduate research play in STEM persistence is presented next.

Community Colleges

During the 2010-2011 school year, the first White House summit on community colleges was held in October, with four regional summits in the following months; the purpose was to discover and implement best practices for improving community college completion (White House, 2011). In her opening remarks, Dr. Jill Biden, a community college professor herself, noted that "Community colleges are at the center of Americans' effort to educate our way to a better economy" (White House, 2011). According to Biden, community colleges are the fastest growing segment of higher education; one big reason is affordability (Brandt & Hayes, 2012; Hoffman et al., 2010; Jackson, 2013; White House, 2011). College tuition has risen four times as fast as the cost of living over the last 30 years with current average costs for a public 4-year college at $7000/year and private 4-year colleges at $22,500/ year, yet the average community college cost is only $2500/year (White House, 2011). Other reasons many women start their STEM careers at community colleges include: convenient locations, small class sizes, and higher levels of diversity than traditional 4-year colleges (Brandt & Hayes, 2012; Hagedorn & Purnamasari, 2012; Hoffman, Starobin, Laanan & Rivera, 2010; Jackson, Starobin & Laanan, 2013; Jackson & Laanan, 2011; Packard & Jeffers, 2013). Community colleges frequently provide child care options; this may explain why 62% of women with children begin their educations at community colleges (Hagedorn & Purnamasari, 2012; Jackson et al., 2013). Additionally, community colleges are community based and often partner with local companies to produce well trained workers for these businesses (Hagedorn & Purnamasari, 2012). Finally community colleges prepare students to matriculate to four-year schools.

The transfer function. An especially important role provided by community colleges is promoting and negotiating the transfer of students from community colleges to 4-year colleges. Packard and Jeffers (2013) note that community college advising can be instrumental in supporting the persistence of students in the STEM pipeline. In a phenomenological study of 40 women and 42 men Packard and Jeffers found five themes regarding the roles for transfer advisors. The first is to provide accurate information, the second to direct students to specific resources, the third understanding of student emotions, the fourth to expose students to career pathways and options they may not know about or have considered, and finally to act as a coach (Packard & Jeffers, 2013). Jackson and Laanan (2011) note that students often perceive their learning environments at community colleges as particularly supportive, encouraging, and collaborative. In addition to academic advisors, faculty were singled out as valuable sources of information, as they provided information on career options, what to expect at 4-year colleges and advice on current academic issues (Jackson, 2013b). Undergraduate research has been shown to have a strong influence on the transfer function at community colleges.

The role of undergraduate research in the transfer function. Within STEM disciplines, undergraduate research has been linked to transfer success and persistence. Fakayode, Yakubu, Adeyeye, Pollard, and Mohammed (2014) showed the early research opportunities positively influence retention rates, and that community college students who engaged with undergraduate research had easier transfer experiences. In a summer research program linked with local 4-year colleges, student participant surveys showed that 89% felt that undergraduate research helped them develop confidence and motivation to transfer, and in some cases aspire to graduate work (Hirst, Bolduc, Liotta, & Packard, 2014). The Council on Undergraduate Research (CUR) has said that community colleges should partner with 4-year colleges and local businesses to develop research programs to help underserved students (including women) (Hensel & Cejda, 2014). A fruitful example of this type of partnership is STEM ENGINES – a consortium of 10 Chicago community colleges and four Midwest 4-year colleges to provide summer research opportunities for disadvantaged students (Higgins, et. al., 2011). From 2005-2012, 228 students have been involved in research, and 66 have transferred to 4-year colleges pursuing their degree in STEM subjects (Higgins et al., 2011). This represent a vast improvement over the previous transfer rate of zero (Higgins et al., 2011). The important role of community colleges in the persistence of women in STEM has been explained, the role of undergraduate research in persistence will now be examined.

Undergraduate Research

In the last decade undergraduate research has been recognized for the benefits it gives students, both personally and professionally. As with other collective endeavors, undergraduate research increases critical thinking, problem solving and research skills; students also begin to view science as a process as opposed to a finite set of knowledge (Hirst, Bolduc, Liotta, & Packard, 2014). Professional skills developed during undergraduate research include interpersonal skills, collaborative skills, and communication skills such as writing and presenting results (Harsh et al., 2012; Hirst et al., 2014; Seymour, Hunter, Laursen, & DeAntoni, 2004). On a personal level, students reported gains with respect to ownership of their research, responsibility to the research group and mentors, a higher level of engagement with the material, and identification as a member of a larger scientific community (Adedokun et al., 2013; Hirst et al., 2014; Hunter et al., 2007).

The idea that participation in undergraduate research leads to higher educational aspirations has generated great interest, and some debate. While most studies relating to the persistence of women and underrepresented minorities in STEM programs are qualitative designs, Pender, Marcotte, Domingo and Maton (2010) used a quantitative approach to study the effect of summer undergraduate research on underserved minorities (URMs) involved in the Meyerhoff Scholarship Program. The Meyerhoff Scholarship Program's goal is to increase the number of URM PhDs; the program involves a number of activities to build academic skills, but the cornerstone of the program is the summer research experience (Pender et al., 2010). Using data on fourteen Meyerhoff cohorts from 1989-2002, Pender used multivariate analysis to determine that students who participate in undergraduate research are 25% more likely to enter graduate school, and the more undergraduate research experiences, the stronger the connection (Pender et al., 2010). On the other hand, Strayhorn (2010), who also conducted a quantitative study of URMs, found that while 77% of participants indicated that undergraduate research kept or increased their aspirations for graduate work, this effect was not statistically significant. Using a comprehensive survey developed through focus groups and student interviews, Harsh et al. (2012), queried more than 2300 science professionals who had participated in undergraduate research with respect to their backgrounds, motivations, and experiences as STEM students and STEM graduates. Results suggest that more women than men participated in undergraduate research, that both genders perceived undergraduate research benefits to the same degree, and that men liked undergraduate research for the authentic research experience, while women appreciated the increased self-efficacy brought on by their undergraduate research; additionally, Harsh et al. found that undergraduate research experiences increased women’s desire to seek a PhD more so than for men (Harsh et al., 2012). More research will hopefully clarify to what extent undergraduate research helps build science identity. The individual roles of community colleges and undergraduate research in STEM persistence has been presented, now the role of undergraduate research at community colleges will be examined.

Undergraduate research at community colleges. Very little research exists regarding the connection between undergraduate research at the community college level and elevating the number of women in STEM. Reasons for this include the fact that community colleges are more focused on instruction and less on research than 4-year institutions, meaning that resources for establishing a program can be scarce; also, for the faculty member, sustaining a research project with a constant turn-over of students can be difficult (Hirst et al., 2014). Additionally, undergraduate research opportunities are often reserved for students in the higher levels of STEM coursework, not introductory courses (Hirst et al., 2014). Hirst et al. (2014) used a phenomenological approach to study a 5-year research partnership between a community college and a 4-year school with the goal of increasing the number of underrepresented minorities who completed STEM degrees; the program was funded by grants. Students whom faculty perceived as underperforming were invited to participate in a summer research endeavor that placed them into existing research groups at the 4-year school; 28 URMs participated over five-year period (Hirst et al., 2014). Results indicated that students came away from the experience with more knowledge and confidence to transfer; results also showed that students acquired aspirations to go to graduate school (Hirst et al., 2014). The few studies we have on undergraduate research at community colleges highlight both benefits and barriers; what this means in real life is discussed next.

Implications

Undergraduate research can be implemented in numerous ways. The three most common include: embedding research into a specific science course, apprenticing undergraduates to faculty members, and creating summer research experiences. Individual/faculty research benefits include an individualized experience and access to a mentor over a lengthy period of time (semesters or years). Faculty members bear much of the burden to train and integrate the student into the research group, often this responsibility comes on top of a heavy teaching load. Summer research options are generally held at 4-year research institutions and the focus is on individual students investigating pieces of an overall research project. These programs need commitment from faculty and staff, and often require special grants such as the Research Experiences for Undergraduates (REU) program, funded by the NSF (Hunter et al., 2007). Incorporating undergraduate research in coursework allows a greater number of students to participate in the research experience, but requires a good deal of up-front effort by faculty to develop or modify curricula; once the courses are up and running, the amount of extra effort is minimized (Auchincloss et al., 2014; Diaz-Vázquez et al., 2012; Nadelson, Walters, & Waterman, 2010; Powell & Harmon, 2014; Rogers, Kranz, & Ferguson, 2013). Integrated research experiences are not as individually focused on the student, and motivational problems might arise as the entire class is required to participate. The best plan for undergraduate research at community colleges will need to take all of these considerations into account, along with pertinent information from local experts.

Summary

The continuing underrepresentation of women in science, technology, engineering, and math (STEM) careers constitutes one of the major issues in contemporary post-secondary science education (Dabney & Tai, 2014; Gayles & Ampaw, 2014; Glass, Sassler, Levitte, & Michelmore, 2013; Harsh, Maltese, & Tai, 2012; Hazari et al., 2013; Hill & Rogers, 2012; Shapiro & Sax, 2011). Resolving this issue is paramount to our nation's ability to remain competitive in the future global economy (Hill, Corbett, & St. Rose, 2010).

There are many interconnected issues that must be reconciled in order to increase the number of women in STEM professions. However, the development of a science identity is crucial for persistence (Carlone & Johnson, 2007; Chang, et al., 2011; Cundiff et al., 2013; Eagan & Garibay, 2013; Eagan, 2012; Harsh et al., 201; Merolla & Serpe, 2013). Undergraduate research experiences have been shown to significantly improve science identity in women (Adedokun et al., 2013; Hirst et al., 2014; Hunter et al., 2007). Additionally, women and minorities most often get their start at community colleges (NSF, 2010). Developing and implementing undergraduate research at community colleges appears to be an effective way to influence the persistence of women in STEM education, but it is unclear if community college science faculty and administrators share this perception.

Exploring the viability of implementing undergraduate research at a community college is best done as a qualitative case study. The singular approach will help focus the data collection and allow me to explore the topic of research experiences for women in depth. Interviewing community college faculty will help me establish a baseline of interest and needs and interviewing local academics who practice undergraduate research will provide the information needed to choose the optimal means of increasing experiential learning opportunities such as undergraduate research.

Section 2: The Methodology

Introduction

Gathering information concerning the perceptions of community college faculty and administration regarding the viability of undergraduate research experiences for community college students lends itself to a qualitative case study research design. Yin (2003) proposed the use of case study design when the case and the context are intertwined. In this study the perceptions of faculty and administrators regarding ways to increase the number and persistence of women in STEM majors is the case and it is inexorably tied to the context, which is a community college in the Midwest. Baxter and Jack (2008) stressed the importance of binding the case; creating the boundary of what the case is and what the case is not to focus the study. Faculty and administration from LECC as well as research faculty from nearby institutions bind this case because they are the key decision makers and experts; they examine appropriate ways to increase the number of women in STEM majors and determine the feasibility of developing an undergraduate research plan. Although an undergraduate research program would directly affect students, they lack both the pedagogical knowledge and the decision making power to provide valuable information about viability. The study was guided by the research questions, and data was gathered through semi-structured interviews with community college faculty and other faculty and experts involved in current undergraduate research endeavors in the local area.

Justification of Research Design

Other types of research designs were considered for this study, but only the case study methodology fit the research goals of evaluating current community college faculty perspectives and current undergraduate research programs. Quantitative researchers generalize their causal or correlational findings to similar populations; however, findings for the proposed study need to be as specific as possible for the context (Bogdan & Biklen, 2007). Survey research would not work in this scenario because my sample would be too small to be statistically significant; there are not enough undergraduate research programs in the area to provide participants (Lodico, Spaulding, & Voegtle, 2010). Bogdan and Biklen, (2007) note that phenomenological approaches try to discern how people understand and make meaning from events, so this design would not help answer my research questions. I am not attempting to discern the spirit and principles of a specific culture as in ethnography (Lodico, et al., 2010). Grounded theory, in which researchers seek to develop a generalizable theory, also does not fit (Lodico et al., 2010). Action research might be a viable option because it looks to solve an educational issue, but this effort tends to be on a school-wide scale (Creswell, 2002). By contrast I will examine a much smaller context bounded by location and time (Laureate Education, 2013). Therefore, case study is the optimal design.

Participants

Selecting the appropriate participants for a study was critical to success, and so was guided by the research questions and focused on the research participants who were able to provide information to answer the research questions. In qualitative studies there are two main sampling strategies. Criterion or a priori sampling involves delineation of sample groups before data collection and include: typical, extreme, maximal variation, intensity, critical, homogeneous, theory-based, and stratified and convenience sampling (Flick, 2009; Nastasi, 2015; Patton, 2002; World Health Organization [WHO], 2004). Snowball or chain sampling comprises the location of information-rich participants who can then suggest other people who may have relevant information to the case; the chain continues until saturation of information occurs (Nastasi, 2015; WHO, 2004). Through the snowball process, potential participants are linked to the study by trusted friends/colleagues and are generally more inclined to participate (Hennink, Hutter, & Bailey, 2010). I started a priori sampling of LECC science faculty and added other participants as suggested by my contacts. This helped me avoid bias from sampling from a single network.

Ethics

Both the NIH Human Subjects training course and Walden IRB plan include the following components of informed consent: explanation of research purpose, statement that participation is voluntary and leaving the study involves no penalty, description of foreseeable risks, description of possible benefits, how confidentiality will be handled, and contacts for question about the research and participant rights. Walden's IRB plan also requires a description of procedures and disclosure of conflicts of interest.

Depending on the source and type of study, different ethical issues may surface. The Belmont Report (1979) broke down ethics into three main principles; in some way or form these apply to any type of research scenario involving human participants (NIH, n.d.). The first is respect for persons; this principle explains that participation in research is voluntary, that anonymity and confidentiality are necessary, that all collected data is truthfully reported and that there must be transparency between researcher and participant (NIH, n.d.). The second principle is beneficence and includes assessment and minimization of risks to the participant (NIH, n.d.). Justice is the third principle dealing with fair selection of participants and fair distribution of benefits (NIH, n.d.). Seidman (2012) cautions researchers to avoid "interviewing as exploitation" when only the researcher profits from the study.

Qualitative research, by its emergent nature, can pose some ethics barriers not associated with quantitative research. While qualitative research lines of inquiry are initially outlined, they are also fluid, and may change based on the data collected; therefore, a specific protocol cannot be assured (Bogdan & Biklen, 2007). The same is true with respect to data collection methods; interview topics may be listed, but the specific questions asked of participants may differ based on context (Bogdan & Biklen, 2007). Because most qualitative research designs involve obtaining information from specific individuals, participant anonymity cannot be assured; however, keeping participant confidentiality is possible (Hennink, Hutter, & Bailey, 2010).

With respect to this specific study, I guaranteed confidentiality to participants by communication via personal Gmail account and transcribing my own interview data. Necessary institutional permissions for research were obtained (please see appendix D).

Additionally, I explained the meaning of informed consent with each participant and had them read and sign a consent form (please see Appendix C). All participants were aware of my dual roles as college science instructor and as educational researcher. Because I am in a subordinate or peer role with my interviewees, coercion was minimized. I did not recruit disabled individuals, facility residents, minors, or my students, and I did not knowingly recruit participants who were pregnant, economically disadvantaged, in crisis, less than fluent in English, or elderly. Because my participants provided information only, risks to these recruits due to their participation in the study was minimized.

Data Collection

My data consisted of 15 semi-structured interviews and were gathered over a period of two months. The participants included LECC Science/Engineering faculty and science professors from two other institutions.

An invitation email introducing myself and my study along with the Participant Consent Form was sent to every full-time science faculty member and the three full-time engineering faculty at LECC. Additionally, five other participants were invited based on recommendations from participants and my own research. A total of 15 participated while nine declined or did not respond.

All interviews with LECC faculty were held in their offices; of the others, one was a phone interview and one took place in the part-time faculty office. Each interview was recorded on a Sony IC recorder and saved to my computer hard drive as an MP3 file; these files were imported to iTunes and downloaded to an iPod for playback during transcription. Each interview was transcribed as a Word document and checked against the recording for accuracy. Every participant was sent a copy of the transcripted interview with a request for corrections, clarifications or further comments.

Of the participants, there were six women and nine men broken into the following areas: biology (n = 7), engineering (n = 3), chemistry (n = 2), physics/physical science (n = 2), and geography/GIS (n = 1). Ten of the participants hold terminal degrees in their fields.

Data Analysis

Coding is the process of interacting with the transcripted text in order to find themes and information that inform meaningful relationships. My first round of coding was based on important points from the interviews as well as predetermined codes from the research questions. These codes were then modified, grouped or new codes added to better match the data. The specific data relating to a specific code was pulled from each interview and grouped together into different subgroups for each code and initial themes were generated. These themes were again revised with respect to the research questions. A Research-to-Date journal was continually updated with respect to new codes and insights. The specific findings for each research question follow.

Research Question 1: What do college science faculty and administrators perceive to be the advantages and/or disadvantages of developing an undergraduate research program at LECC to empower female STEM students?

Research Question 1 explores the advantages and disadvantages of undergraduate research. Faculty shared both their own experiences and perceptions of their students who do undergraduate research. Only a few participants commented on possible disadvantages. Advantages include development of science identity, preparation for future, development of personal relationships, and benefits to others outside of the research lab.

Development of science identity

The first advantage of undergraduate research is that it helps nonscience students view themselves as scientists, and science students improve their science identity and connection to science. One benefit of undergraduate research is that it can help students who have never thought they could do science enter the field. SA described the Stream Analysis research course he developed at LECC:

> It's a real feather in the cap for the college, but in my mind it's a huge gate opener for these non-science people who thought over the years – coming full around now – who were told that they can't do science, and they are doing science, and it's meaningful and fun and they can talk about it. (SA, 2016)

Not only has the course helped nonmajors gain confidence in a science environment, it also changed the career direction of some students. SA noted, "We've had several students who have gone on to change their majors to geology and we've had a couple of students working for Coco-Cola – doing their water testing because they had experience using EPA accelerometers and stuff."

Performing research held a key role in the development of many participant's science identity. I asked the participants when they first felt a part of the scientific community; here are some faculty perceptions:

> I didn't feel like I was part of the science community until my first conference that I went to, where I was presenting a poster on my research … I felt like I was a research scientist and I had something to offer and I could collaborate with others. (CB, 2016)
>
> And so I was very – I think I was published when I was a junior in undergrad, and he let me be the first author listed. It was just crazy – here was this thing I did and it was actually in a journal. And I was – I understood how research worked and I understood how publications worked and that's when I felt like I had a place in that world. (TC, 2016)
>
> It was my first presentation at the Endocrine Society in Seattle. I came home wearing my t-shirt, had my first pub, first presentation. It's when you feel legitimized a little bit. You are distinguished a bit from other things. (AP, 2016)

Preparation for the future

An important function of undergraduate research is that it helps prepare the students for their future careers. RG, who teaches a high school course where students work on actual research projects with professionals in the field, commented on the benefits of the course. "And the class gives the kids a leg up. When they get to college and they are applying for lab jobs, my kids get the job every time. Every time because they have the experience." (RG, 2016)

TC and FB both reported that research helped them focus their studies. FB said, "I did some really good summer experiences working with Fish and Wildlife, Corps of Engineers, Forest Service, so I really knew that was the kind of realm I wanted to be in." (FB, 2016) TC commented, "(Undergraduate research) actually helped me decide what I did and did not want to do." (TC, 2016)

Another participant, CB, felt that lack of an undergraduate experience put her behind during graduate school.

> I did not get that opportunity in undergrad and I think it would have definitely helped me in graduate school if I had more experience … I could tell (my advisor) was surprised at how little I came in with in terms of skill. (CB, 2016)

Personal relationships

A third advantage to undergraduate research lies in the personal relationships that were forged during the experience. As a sophomore student, TC walked into a research lab and asked if she could get involved. It not only helped develop her science identity but also led to important personal connections. "It was really great to work on a personal level with one of the faculty members for three years, because I don't think again that you get that in the classroom…it was a great experience. (TC, 2016)

Another participant, RM, talked about the "greatest mentor" he ever had. "She is not only a great mentor in the lab, but a wonderful person too…My wife and I call her our second mother…she was straightforward, but she was always extremely supportive." (RM, 2016)

CB found her place in a research lab with a very diverse group of students.

> So (my research advisor) had students from other countries and African-Americans that were part of his lab. I was the only Caucasian-family-close-by kind of person in the whole lab. But I think he kind of joked that I was like Lab Mom because I took care of them. (CB, 2016)

SA described the relationships with his research students:

> The ones who you strike a bond with will keep in touch. The other ones, they graduate and you don't see them again. But I've had several, probably five or six that I can think of, that have told me what they're doing – pursuing their masters. (SA, 2016)

Benefits to Others

A final positive of undergraduate research is the benefits to others outside of the research environment. SA explained how his Stream Analysis course is valued by the college. "The college loves it because it's a nice outreach project. We've done two presentations before the Board of Trustees when they have had their meetings. It's a real feather in the cap for the college." Additionally, data collected by students in this course was used in a local court case regarding the protection of river ecosystems. EB also had the experience of his research data being used in court.

> I had gotten involved at age 14. The power company decided they were going to tear it all up and put in a gas line. But I had documented threatened species within the area - that set this firestorm up. Suddenly they had all these rules and regulations – they couldn't do what they wanted to do because of this annoying 14 year old kid. We had hard evidence – I brought a live specimen after one of their biologists claimed there were none of them. That was a pretty damning piece of evidence. (EB, 2016)

Disadvantages

While the majority of the participants saw only positive aspects of undergraduate research, two faculty members expressed their concerns.. RM thought that it would be a disservice to promote women in science at LECC because most of them have a definite career path mapped out which will provide them financial stability.

> I think the problem with women being less involved in STEM – especially the female students that go to community college not thinking about science in the first place. And it is often maybe unfair to them to drag them into science because they are not going to earn a living. (RM, 2016)

Another concern was brought up by ME who thought that unless proper support and backup were in place, having women do undergraduate research made them vulnerable in a male-dominated environment.

Research Question 2: What is the viability of incorporating undergraduate research at LECC?

A number of factors impacting the viability of incorporating undergraduate research came from the data. These include developing science interest, barriers to UR and the nature of LECC students.

Developing Science Interest

In order for any type of research to be viable, there must be student interest. Two factors contributed to this topic, developing interest at an early age and creating authentic learning experiences that the students can relate to.

Interest at an early age. When asked what would be needed to develop student interest in science, the majority of the participants thought that interest needed to be fostered at an early age and by the time students reach college age, it’s often too late. The participants agreed that it was important for parents to give their children opportunities to explore science. “It doesn’t take a special kid going to science camp – but it has to start young.” (PS, 2016) EB encourages his kids to explore nature the way that his parents did with him.

> I’ve got three kids and I really encourage them getting out there, getting muddy, getting dirty. We hear it all the time, my wife and I, about boys being boys, and my wife gets really irked by that statement because really it’s my daughters who are getting out there and getting muddy and grabbing bugs more often than my son is. (EB, 2016)

CB felt that experiences she had when she was young piqued her interest in science; she developed an outreach program at LECC involving local students.

> Our target age was 7th grade. Because that's when the gears start to turn about going to college and what you want to do. It's nice for them to meet people in those career fields and hear their story about how they got to where they are…early exposure is really big and early education in science. (CB, 2016)

She also articulated what a number of other participants said,

> So, college age students to get them interested in science? That would be an age that they may already be decided about what they want to do. I feel like I kind of knew much sooner that I liked science. (CB, 2016)

Authentic learning. One of the interview questions asked the participants to describe their dream course; what they would create if time and resources were no obstacle. The idea of creating authentic learning experiences came to the forefront. Participants felt it was important to make the content relevant to student's daily lives and to have the students learn by doing. CB encourages students to bring in instruments and informative objects from their workplaces. "(I like) really cool stuff that I can incorporate into what we are learning about and how it relates to what career field they are going into." (CB, 2016) SA points out that it's important to make the content relevant to the students' lives. "Hav(e) meaningful labs and activities and to promote in my opinion, things that are practical – the authentic stuff, and then (introduce) collaborative learning." (SA, 2016) AP explains that he makes content relevant to his nursing students by teaching it from a clinician's perspective to put the information into the proper context. FB saw that taking some students out of their comfort zone produces positive results.

> When I have time and when the weather cooperates, biology in the spring, I have them do insect collections. And they really get upset about having to go out and touch bugs, but they really get into it and some of them will be so meticulous and careful, and some of them take pride in it really by the time they are done. (FB, 2016)

It is evident that faculty would like to make learning more meaningful; however, there are quite a few barriers to developing authentic experiences such as undergraduate research.

Barriers to Undergraduate Research

Barriers to developing research based learning include: time and content limitations, student inexperience, student's outside commitments, and lack of institutional support.

Time and content limitations. Experiential and authentic learning require more class time than traditional lectures, and the amount of material that must be covered in a course is often prohibitive. EB commented, "I would need to cut something out to fit this in – you know, it's just torture." (EB, 2016) PS struggles to fit in all the required content, leaving no room for additional activities, "There's a certain amount of material you have to get through and we're seriously struggling right now." (PS, 2016) AP teaches a popular course with a large amount of content, "A&P is one of those courses which is absolutely packed stem to stern." (AP, 2016) FB recognizes the value of authentic learning experiences, but notes, "I do a little bit of that when I have time…those kinds of things are great when we can do them, but they also take more time." (FB, 2016) EE looks at the practical side of the issue; for his students doing research would not make them more marketable:

> I have a hard enough time covering the material so they can get a job where they are functional and the employer is not spending a lot of time retraining them, rather than giving them something that's theoretical and they will probably never see and not get enough experience - they are not employable like that. (EE, 2016)

Student inexperience. Even when there are opportunities for incorporating authentic learning, the inexperience of the students plays a big factor. TC teaches at a college which has research experiences for minority students, but often the openings go unfilled.

> Trying to find the students who meet the requirements – that's the biggest issue. A lot of times I have students who are interested in the program but they don't qualify. And there isn't a similar program to put them in. (TC, 2016)

Additionally, TC notes that even though the students might be interested, they often lack needed skills.

> A lot of the minority students who come here are not ready to study from the get go, so they have a lot of coursework to catch up on. Those are some of the hurdles – finding the students who are well prepared and ready to embark upon a STEM path. (TC, 2016)

Outside commitments. Community colleges are commuter colleges where students often have full-time jobs and family concerns in addition to their studies; this poses another barrier to student research. SA has tried incorporating learning events outside of class time, such as using the telescope at LECC in his astronomy course.

> They could never do it because they had to do it after hours. And after hours never works with community college because they are only here for two years and then they're gone. If it were four years it would be a different story. They all work, they leave here, they go to work. I can't get them back. I can't get them back here at night to go up on the observatory to look at Jupiter. (SA, 2016)

Student interest. Student interest is also a barrier – not only because many LECC students never had science experiences when they were young, but because they don't start at LECC looking to do science. AP notes that most students are looking to do a specific course of study and then get into the workforce. "Community colleges are so vocationally oriented that I don't get that many students who say, "I would like to do more." (AP, 2016) FB explains that most students want to just get prerequisite courses out of the way. "They aren't there because they want to be, they aren't there because they see – not everybody is there because they see the value in it – they are there because they have to be." (FB, 2016) EB has seen declining enrollment in his elective course over the years. "The greatest barrier, then is attracting students to the class – as I see it. So that's a difficult challenge getting students willing to attend." (EB, 2016)

Institutional support. A final barrier to developing research experiences often comes from school administration. RG, who developed a course for high school students to engage in authentic research, noted that even though her course has grown to over 15 students and takes a lot of personal time, administration doesn't see it as valuable.

> I can't get my administration to consider my course a course. I have that as my duty. You brought up have I ever encountered any obstacles and this is my biggest one. I teach it as a sixth course – I have to teach my regular load and then this on top of it because they don't consider it a course. They consider it as almost frivolous. This is what kids are going to do for a living. (RG, 2016)

TC noted earlier that even though her institution offers programs for minority students, the rules for qualification are so strict that very few students even qualify. "It's actually a point of frustration for some of us at the college. Basically we have a couple of programs that run, but they are very, very specific programs." (TC, 2016)

LECC students. The nature and make-up of the students at LECC is the final factor that must be considered when determining the viability of undergraduate research. Three points arose from the data: student comfort level, student demographics, student mindset.

Comfort level. One point brought up by quite a few faculty was that many students are from urban areas and are not used to a more natural environment. SA said that while it can be amusing at times, in the end it is truly a barrier.

> I have seen fully grown guys run for their lives because they saw a water snake swim by. And they're screaming like a little girl. I just have students who have never been outside before and they get very stressed. (SA, 2016)

FB echoes the same sentiment:

> Students, especially in this kind of area, close to the city, I've had students that I've taken out for labs who have never been off the sidewalk before. Have never been in the woods before and it freaks them out. But it's good for them. (FB, 2016)

PS discussed a plant biology class she once taught, "We tried to get them out whenever we could. And it was interesting, you are seeing people who have never dealt with the outside before." (PS, 2016) EB realized that his upbringing in the country was vastly different from that of the majority of his students, "And that was an insight – they live in a world of pavement. Downtown Cleveland they're not seeing a lot of worms." (EB, 2016)

Student demographics. Another aspect of LECC students which impacts the viability of undergraduate research is the make-up of the student body. Unlike a four-year college where the student body is relatively homogenous in terms of age and educational background, LECC boasts a wide diversity of students from many different economic and educational backgrounds and a student age range from teens to 60+. Dual enrollment allows 600+ high school age students to take classes either full or part time and sometimes this equates to a lack of maturity. EE has seen this in the attitudes of his students.

> The problem in general is that most young students don't want to actually do the physical work and they want to be somebody's boss. And so when they come into the curriculum, right away they think they should be in charge. (EE, 2016)

GT reflects that dual enrollment students often don't have an appreciation for their opportunity. "(Dual enrollment) students that don't – a lot of them are really good - but there's a core that just don't have the commitment – maybe their parents have the commitment, but not them." (GT, 2016) TC points out that while it's nice when a student is interested in her field, often they don't have the appropriate educational background.

> This person is interested in chemistry. But when I went to talk to them, they were still in developmental math. So they had never even taken a college level chemistry class. How can I do research with someone in a chemistry environment when they've never taken a chemistry course or been in a chemistry lab? (TC, 2016)

PS similarly notes that students' study skills need refining.

> So that's the most that I can do with these students. They have either never had biology, or they had biology a long time ago, and is now basically worthless. There is an awful lot of developing them as students. (PS, 2016)

Student mindset. A final aspect of LECC students which affects the viability of developing authentic experiences at LECC is their mind set; they view LECC as a path to getting a specific type of job and achieving financial security. EE said, “The reality is that first and foremost they want a job; they want to get in and out and start making money.” (EE, 2016). Nursing is one of the most popular programs at LECC, as RM and FB said.

> Here girls they go to nursing, and that I think, I don’t want to make implications, but most students are single moms, and that is the best way to support family – to go into nursing. You are going to find a job all the time, everywhere. (RM, 2016)

> I personally don’t think there are enough (students) who come to LECC to study science for science sake. I think it’s come to (LECC) for jobs. And those jobs are in nursing. And that’s very much the message that’s out there. (FB, 2016)

Unfortunately the background and outlook of LECC students means that opportunities to develop authentic experiences such as research will be few and far between. Overall, while the majority of faculty would like to incorporate more experiential learning in their courses, time and content constraints and issues with student interest and availability mean that many types of undergraduate research will not work. However, there are opportunities to incorporate smaller, more easily managed authentic experiences into several courses.

Research Question 3: What research options are viable at LECC?

Three types of research were considered possible by the faculty participants at LECC, but the viability of each varied. The first type is the traditional mentorship model where a student works with a faculty member on a research project throughout the semester; the second is incorporating smaller research projects within a course; the third is a course based entirely on research.

Two faculty members described side research projects that they did (or were intending to do) with interested students. AP had two students who asked him about the origin of their toe pain from working out on the step machine. They began to put together a survey research project to investigate whether other people experienced the same issues, but they ran out of time before the two students moved on to a four year college. FB noted that he has had a number of students do summer or semester research just for fun; a student last year did a moth biodiversity survey. He said, "I helped her get set up with it, showed her how to get started with it and she was off…" However, these opportunities are rare and only work if the student if very motivated, interested in the subject matter, and has the time to spare. There isn't a specific program to bring students to research, it's very informal.

The second option for research is considered the most viable by the participants. This category includes short time frame events such as labs or field work. Some of the studies used by faculty include:

- Puzzle labs where students get a mixture of different compounds and have to use techniques learned during the semester to identify the components
- Using an indirect calorimeter to look at personal oxygen utilization
- Teaching students to use a plant identification book and then a field trip to look for specimens

- Analysis of caffeine in energy drinks
- Forest floor sampling to determine the level of damage by earthworms
- Testing on water samples brought in by students
- Mark/recapture lab to estimate the pill bug population in an area
- Insect collections (AC, AP, EB, FB, PS, TC, 2016)

While these experiential learning lessons are often interesting to the students, they don't inspire ownership of the data/results that help develop science identity.

Option three is a course designed around a science research project. One faculty participant developed a stream analysis course out of river sampling work done in basic geology; he wanted to get students involved in meaningful research so they could see that they were capable of doing scientific work. He spends the first two weeks of class training students to perform tests to EPA standards. Then the class travels to endangered tributaries to evaluate the biological, chemical and environmental conditions. Throughout the summer the class returns to their assigned streams for follow-up analyses. At the end of the course the data is analyzed and sent to the Department of Natural Resources Stream Quality Monitoring Project databases. Additionally, the students write up a booklet reporting results and trends over time. Students are given recognition because their names are recorded in the database and they receive letters of accomplishment from the college for their research efforts. The number of interested students has grown over time as participant students praise the course. This type of research builds science identity as the students do all of the data collection, analysis, and reporting. Recognition from both the college and the State of Ohio reinforces the idea that the students' work is seen as valuable by more people and institutions than themselves or their instructor.

The downside of this type of research is the effort required to put it all together. There needs to be a legitimate scientific study to underpin the students' research, the research must be feasible within the timeframe of the school term and student availability, and the course must be fully developed by the instructor and receive institutional approval. Finally, there must be enough student interest to allow the course to run.

While this is course is based on medium to long term research, there are other citizen science projects in which students can do authentic research and submit their data within a few class periods or weeks. This may be the best way to incorporate authentic research experiences into busy classes.

Themes

Five themes emerged from my study; faculty perception of undergraduate research, authentic experiences, health technologies/nursing programs. LECC students career focus and the unique culture at LECC.

Faculty Perception of Undergraduate Research

Faculty who had undergraduate research experiences perceived them as important to their career decisions and to developing their love for their subjects. Many found a sense of belonging in a research group, and peer and mentor support helped develop their science identities. Opportunities to present their findings to the public often came as a direct result of their undergraduate research experiences.

Authentic Experiences

When asked how they would change or modify their current courses, LECC faculty overwhelmingly wanted to incorporate more authentic learning experiences, such as field work, research and open-ended labs. They recognized that when students are allowed to take ownership of their studies, they are much more engaged and a higher level of learning takes place.

Health Technologies/Nursing Programs

LECC's health technologies and nursing programs are the most popular degrees, and as such, the main focus of the biology department is to develop students and get them through the needed prerequisite courses. Therefore, the emphasis for these courses is knowledge building and here is a large amount of required material, leaving the faculty little room for creativity and flexibility in the classroom. This negatively impacts the variety of science course offerings for students who are interested in science, but not on the health technologies or nursing paths.

Student career focus. The vocational nature of the college means that by the time students begin at LECC, they have already decided on their future career, and are mainly focused on checking off all of the courses necessary for their degree, so they can start working. Not many students see LECC as a place to explore their interests, use their experiences to decide on a career path, and then transfer to a four year school to complete their degrees. Thus, students are not overly receptive to the idea of research or side studies.

Most Viable Type of Research

Based on the data collected, the most viable type of research for LECC is short time frame events such as labs or field work; however, the incorporation of citizen science projects can increase the student's science identity and ownership of their results.

Unique Culture

The science faculty's characterization of the learning culture and working environment at LECC as unique was a serendipitous discovery, but almost every LECC participant commented on this in some way. The participants feel that they are surrounded by highly qualified and highly motivated colleagues who all go above and beyond the norm to support each other and support the students. A number of them talked about their peers as "family," and considered LECC as their "home."

Quality Measures

Interpreting the data and documenting reasons for specific interpretations are essential in assuring the quality of the study. Auerbach and Silverstein (2003) identified three key points for managing data interpretation: transparency, communicability, and coherence. Transparency in a study means that the steps a researcher takes from raw text to conclusions are documented so another person can follow the researcher's logic (Auerbach & Silverstein, 2003). Communicability means that the conclusions and the themes that lead to them are understandable by others, and coherence means that the ideas fit together into a coherent whole (Auerbach & Silverstein, 2003). Zickmund ("Qualitative coding 101: Strategies for coding texts and using a qualitative software program," n.d.) pointed out that bias can adversely affect the outcome and suggests using team analysis, member checking and other coders to address the problem. However, if the study is an exploratory study and the researcher has no stake in the findings, the researcher can be the sole coder. Since this study fits the description, the only coder was the researcher.

Study Validity

Validity in this study was enhanced through the following measures. I thoroughly explained my data collection methods and described how I selected each participant for my study (Auerbach & Silverstein, 2003; Lodico, Spaulding, & Voegtle, 2010). With regard to data analysis and interpretation, I employed multiple data types and used triangulation to ensure that my conclusions were valid (Harding, 2013; Lodico, Spaulding, & Voegtle, 2010, Patton, 2002). Member checks confirmed that I used other's perceptions and opinions correctly (Harding, 2013; Lodico, Spaulding, & Voegtle, 2010). Lastly, I practiced reflexivity, examining my role and laying out the logic behind my findings (Auerbach & Silverstein, 2003; Harding, 2013; Hennink, Hutter, & Bailey, 2010). Harding (2013) suggests the use of a methodological memos for this purpose. Harding describes a methodological memo as a note to oneself detailing the rationale behind key decisions such as coding/theme choices, use of different interview protocols or reasons to conduct more interviews; this not only helps researchers stay organized but also provides transparency to the research study (Harding, 2013).

Study Reliability

Reliability was enhanced through the following measures. I personally transcribed all interview data and checked the text against the recording. I reviewed my interview summaries to confirm the consistency of the coding data. Code reliability was maintained through iteration; transcripts were re-coded a number of times to guarantee that the meaning of the codes did not appreciably change from the original meaning. Additionally, a codebook with each iteration of codes was maintained throughout the analysis process to provide code consistency. Saldana (2009) recommends using more than one coder to increase reliability; for solo coders, he recommends discussing the logic used for coding with a mentor or colleague, member checking codes with interview participants, and coding as transcription is taking place. I have a work colleague with research experience who helped me in this process.

Evidence of quality

Before data was collected, I reviewed my interview questions and interview protocol with a colleague/mentor at LECC who did similar research for his EdD. I conducted interviews with as many participants as possible and saturation on most results/findings occurred within eight interviews and was confirmed by the remaining interviews. Transcribed interviews were sent to faculty for member checking, and discrepancies were corrected or clarified. As described earlier, the coding process was iterative and codes and themes were reviewed with my colleague for consistency.

Section 3: The Project

Introduction

In this section, I focus on the project stemming from my research regarding the optimal way to bring research to LECC. First I introduce my project description and goals, and then provide the rationale behind my choice. Next I review the literature regarding course-based undergraduate research experiences (CUREs) and citizen science projects; these two concepts are the basis of my recommendations for implementing research at LECC. I explain the implementation process and how evaluation of the project will be handled, and finish with thoughts about how my project can bring about social change.

Description and Goals

The project that follows from the research data and analysis is a white paper addressed to the faculty and administration at LECC explaining the results of my study and offering options for implementing course-based research into the current curriculum using ongoing citizen science projects. The focus of my research was a case study to determine the most practical way to introduce undergraduate research at LECC. The white paper serves as a way to disseminate the study information to stakeholders and to provide a pathway to implementation of citizen science research into the curriculum.

Rationale

A white paper makes the most sense for this study. One project idea entailed designing research to fit into a specific course, but this would only provide a benefit for one specific group of students; another project idea was designing a new course around a specific citizen science study, but this would be prohibitive with respect to time and effort, and may not be approved by the administration; a final project idea was to develop a workshop to educate faculty and help them implement research into their courses; however, the study showed that most faculty felt that there was no room to add additional material into their courses and a workshop would be a waste of their time. Presenting my findings and recommendations and allowing the faculty determine their level of interest seems a more efficient route. Since so many faculty participated in the study, I am sure they are curious about the results.

In the white paper, I addressed findings on all three research questions and hope to pique faculty interest in incorporating citizen science projects into their courses. I explained that citizen science projects allow students to perform authentic research, building their self-efficacy, science identity, and interest in science while taking smaller amounts of class time than traditional research. The goal is that community college students will become interested enough to pursue science as a career, filling our country's growing need for STEM professionals, and increasing the number of women in the STEM pipeline.

Review of the Literature

Criteria to guide development of research recommendations included faculty perceptions of undergraduate research, authentic learning, barriers to incorporating undergraduate research into the curriculum, and the types of research options faculty considered viable at LECC. Journal articles regarding CUREs (course-based undergraduate research experiences) and citizen science also helped define my recommendations. Experiential learning theory and science identity theory formed the basis of the recommendations.

Based on the study data, the most viable type of undergraduate research for LECC is course-based and requires a relatively short timeframe for completion. CUREs and citizen science projects and their theoretical basis constitute the remainder of the literature review.

CUREs

A CURE (course-based undergraduate research experience) involves incorporating authentic research into the classroom (or lab) setting; this is a relatively new concept, as CUREs do not appear in the peer-reviewed record until the early 2000s. Advantages of CUREs over traditional mentorship approaches to undergraduate research include giving a larger, more diverse cohort a chance to engage in research and providing peer support during the process (Auchincloss et al., 2014; Corwin, Graham, & Dolan, 2015; Desai et al., 2008; Moore & Teter, 2014). Additionally, CUREs allow students to take leadership roles, make decisions regarding how the research should proceed, and help instill ownership of the project outcomes (Auchincloss et al., 2014).

One local example is SA’s Stream Analysis course at LECC. He developed it because he wanted to involve students in meaningful research and show them that they are capable of doing scientific work. He spends the first two weeks of class training students to perform tests to EPA standards. Then the class travels to endangered tributaries to evaluate the biological, chemical, and environmental conditions. Throughout the summer the class returns to the same streams for follow-up analyses. Data analysis occurs throughout the course and is uploaded to the Department of Natural Resources Stream Quality Monitoring Project databases. Additionally, the students write up a booklet for the community reporting results and trends over time. Students obtain recognition because their names are recorded in the DNR database and they receive letters of accomplishment from the college for their research efforts. The number of interested students has grown over time as word spreads about the course. This type of research builds science identity as the students perform all of the data collection, analysis, and reporting. Recognition from both the college and the State of Ohio reinforces the idea that the students' work is seen as valuable by more people and institutions than themselves or their instructor.

A CURE from recent literature include the development of an introductory biology laboratory course at Purdue University in which students design and carry out a microbiology research project (Gasper & Gardner, 2013). The students are required to read scientific literature, work with a team to develop a research plan, carry out the study and then effectively communicate findings to others (Gasper & Gardner, 2013). Students showed a significant increase in their understanding of the nature of scientific research and in their critical thinking skills (Gasper & Gardner, 2013). A second CURE example is the Science Education Alliance's Phage Hunters Advancing Genomics and

Evolutionary Science (SEA-PHAGES) program, which is a multi-intuitional CURE currently being used at 70+ colleges and universities. Participating students isolate unique mycobacteriophages from soil samples, characterize their bacterial viruses using restriction digests and electron microscopy, and then annotate sections of their phage's DNA using computer programs (Cross, 2013).

Studies have shown that CUREs offer the same student benefits as traditional research internships (Corwin et al., 2015; Nadelson, Walters & Waterman, 2010; Shaffer et al., 2010). These gains include, but are not limited to, self-efficacy (Corwin et al., 2015; Vitone et al., 2016), persistence and higher graduation rates (Corwin et al., 2015); Rodenbush, Hernandez, Simmons, & Dolan, 2016), increase in critical thinking ability (Brownell et al., 2015) and interest in and pursuit of scientific careers (Harrison, Dunbar, Ratmansky, Boyd, & Lopatto, 2011).

Shortlidge, Bangera, and Brownell (2016) showed that faculty also see tangible benefits. CUREs connect teaching and research, they contribute positively to promotion and/or tenure, they are enjoyable to teach, they result in publications in basic science and/or science education research, they broadens faculty research interests, they can help in obtaining grant money and are a vehicle to improve faculty relationships with students (Shortlidge et al., 2016).

However, Shortlidge et al. (2016) also identified a number of negatives faced by faculty who develop and teach CUREs. They include substantial time and effort to create and propagate the study, financial constraints, the expanded role required of the instructor, and student resistance to the CURE idea (Shortlidge et al., 2016) These limitations are also found at LECC; faculty just don't have the time or the room in their courses to introduce novel research. A solution to this problem lies with citizen science studies.

While SA's course is based on medium to long term research, there are other citizen science projects in which students can do authentic research and submit their data within a few class periods or weeks. This may be the best way to incorporate authentic research experiences into busy classes.

The effort required to put a course together reflects the downside of this type of research. Identification of a legitimate scientific study to underpin the students' research may require a good deal of time, the research must be feasible within the timeframe of the school terms, and the course must be fully developed by the instructor and receive institutional approval. Finally student interest must be high enough to allow the course to run. Utilizing citizen science projects can make it easier to incorporate research into courses.

Citizen science

Citizen science can be broadly defined as a scientific study using the public as sources of information or data analysis. The efforts of volunteer participants allow for gathering and processing of data sets too large for normal lab capabilities. Citizen science is a new term for an old practice. Scientists have always relied on public volunteers to provide data they could not otherwise obtain. Historical records of grape harvests in France (640 years), descriptions of the cherry blossom bloom in Japan (1200 years), documentation of locust outbreaks (3500 years), tracking the transit of Venus in 1874, and the annual Christmas Bird Count for the Audubon Society (115 years) are testament to the value of public participation in research (Miller-Rushing, Primack, & Bonney, 2012).

Technological progress has made public participation in scientific studies even easier than before. The area of data informatics has evolved dramatically in the last 20 years and the public can participate in citizen science with a device as simple as a smartphone (Pecl, Gillies, Sbrocci, & Roetman, 2015). Advances in computing allow for faster and more efficient data collection and processing. For example, researchers at George Mason University have developed software that uses the power from someone's computer to run a program for Alzheimer's research; the catch is that it only taps into computers that are idle, meaning it doesn't interfere with normal computer use. Computer developments have also allowed the public to analyze data as well as collect it.

Citizen science has become a big enough phenomenon that a new open-access journal, *Citizen Science: Theory and Practice*, was launched in May 2016. Scientists who want to utilize public participation in their studies post their links on various websites devoted to bringing the public and scientists together. SciStarter.com and Citizen Science Alliance (CSA) are two such websites. Galaxy Zoo, a CSA project, became well-known when volunteer researchers noted the appearance of a green cloud below a galaxy, leading to the discovery of an extinguished quasar (Franzoni & Sauermann, 2014).

A logical way to classify citizen science projects is by the type of work the participants do. Bonney et al., (2014) have broken this down into four main types:

- Data collection: participants upload data from local sites to build geographically diverse databases of information for different species. Examples include: The Birdhouse Network, NestWatch.
- Data analysis: a way to evaluate huge amounts of data by using many participants, each analyzing a small piece of the data; another name for this is crowd science. Examples include: Zooniverse projects and eBird (Sullivan et al., 2014)
- Curriculum-Based: this brings citizen science into the classroom as instructors supervise students who collect data for citizen science projects; the projects are based on their level of knowledge and training. Examples include: WINGS – in which students collect butterfly data and GLOBE – in which instructors can find grade-level activities relating to atmosphere, biosphere, hydrosphere and soil. This study is sponsored by the NSF and NASA.
- Community-based monitoring (CBM): citizens collect and analyze data for the purpose of community policy and decision making, usually regarding health or conservation issues. One example occurred in Loma Alta, Ecuador where citizen monitoring of fog recapture and bird populations united the community around saving the Loma Alta tropical rainforest; this led to a higher level of social capital

for the residents (Becker, Agreda, Astudillo, Constantino, & Torres, 2005). With respect to CBM, the efforts of citizen scientists are not viewed as a replacement for professional scientists, but as a cost-effective early warning system for specific ecosystems (Kolok, Schoenfuss, Proper, & Vail, 2011).

Benefits of Citizen Science

Citizen science is symbiotic in that both the scientists and the participants reap benefits. Scientists gain access to data they could not access themselves; additionally, the use of citizen scientists saves money that would normally go to paid sources. Theobald et al. (2014) analyzed 338 citizen science biodiversity projects from around the world and estimated contributions from 1.3 – 2.3 million citizen science volunteers, with each participant spending an average of 21–24 hours collecting data. This equates to $2.5 billion annually (Theobald et al., 2014).

One clear benefit to CS volunteers is a gain in scientific knowledge regarding the focus of the study e.g., invasive plants, bird characteristics and habits (Jordan, Gray, Howe, Brooks, & Ehernfeld, 2011). Another benefit is an increase in environmentally conscious behaviors such as providing habitat requirements for animals, recycling, planting native plants (Jordan et al., 2011). Citizen scientists engage in scientific thinking more often when they are deeply involved with the project (Evans et al., 2015). Some CS projects, particularly the classroom type, help students refine career choices and plans (Quardokus, Lasher-Trapp, & Riggs, 2012). Finally, participation in CS can increase one’s social capital (Becker-Klein, Peterman, & Stylinski, 2016). Citizen-based monitoring (CBM) increases environmental democracy, scientific literacy, social capital, citizen inclusion in local issues, benefits to government, and benefits to ecosystems (Conrad & Hilchey, 2011).

Citizen Science in the Classroom

There is very little peer reviewed information about CS in the classroom. Most existing programs are geared to K-12 students, providing the opportunity to incorporate active learning and increase interest in the scientific process. The CS project GLOBE involves K–12 students, communities, and scientists from 112 countries in ecosystem and Earth-system science studies (Bestelmeyer et al., 2015). Schools appreciate these programs because they are relatively easy to incorporate into the classroom, meet NGSS standards, and help students develop collaboration skills for teamwork, something not often taught in the classroom (Bestelmeyer et al., 2015).

For colleges and universities dedicated to producing scientifically literate graduates, introducing CS into the classroom brings multiple benefits. Because colleges often require at least one science course for most majors, incorporating CS in general science courses exposes a diverse group of students to authentic research, increasing scientific literacy and fostering an appreciation for scientific endeavors. (Egger, 2007). Incorporation of high-altitude balloon (HAB) research into atmospheric science classes at Ball State University resulted in high student motivation and communication, improved time management and teamwork skills, increased daily attendance, and a led to a tripling of enrollment in school's meteorology track (Coleman & Mitchell, 2014). Surasinghe and Courter (2012) incorporated the CS project eBird, a bird surveying venture, into an undergraduate ecology course; the students spent an hour documenting the number and type of species of birds at a specific location and then uploaded their individual data to the eBird database. The students found the activity relevant to their daily lives and made them feel that they were personally contributing important information to a scientific study (Surasinghe & Courter, 2012).

Implementation

Implementing the white paper will require discussion with the dean to determine my audience. The science faculty who participated in the study will certainly be part of that group, but the dean may know of other faculty or administrators who would benefit from the information. I currently plan to disseminate the white paper via email, but if other forums exist for me to present the information, then I would be happy to include them. I will send a copy of my dissertation and the white paper to my faculty participants and the dean as soon as they have been approved by Walden.

Project Evaluation

In my white paper, I provide resources for faculty who wish to implement citizen science into their courses. Additionally, I offered myself and my research as a resource; I would be happy to work directly with an instructor to figure out the best options for their course. Qualitative evaluation of the effect of my research has both short term and long term aspects. In the short term, the amount of interest and feedback from the white paper will indicate whether my proposed idea to incorporate citizen science into the classroom has merit. Long term effects are harder to evaluate because of the extended implementation timeline. Working with a faculty member to integrate a citizen science study and collecting data on whether the approach achieves our goals will take a minimum of two years to accomplish. Evaluation of success at that point will be dictated by the course instructor and the specifics of the course.

Implications Including Social Change

Students at LECC enjoy classes that allow their voices to be heard, are experiential in nature, and have relevance to their daily lives. Citizen science projects cover these three requirements. Specifics regarding how well these aspects are incorporated into the classroom will have to be evaluated on a course by course basis. It may take a while to introduce this type of authentic learning into the curriculum at LECC, but it would fit in with the faculty's desire for more experiential learning and the students' desire for learning to be interesting and tied to real life. Administration would benefit from the positive exposure of utilizing public CS projects as a new and innovative manner of education, and our community would benefit from having a more science literate public to make more informed and logical decisions regarding our country's future.

Conclusion

My project is a white paper detailing my recommendations to LECC concerning the best way to incorporate undergraduate research into the science curriculum. My local research indicated that the only feasible idea would be class-based research that could be done during the time that the students were on campus. Research into CUREs (course-based undergraduate research experiences) led me to citizen science projects; these studies are adaptable to existing courses, are of short timeframe, and provide benefits of undergraduate research. The variety of citizen science projects means that the likelihood of finding a match between a LECC course and a current study is high. I have provided resources for interested faculty, and anticipate a small but genuine response to incorporating CS into one or more LECC courses.

Section 4: Reflections and Conclusions

Introduction

In this section I review my project in terms of its strengths, limitations. and directions for future research. I reflect on what I learned about creating my project and my assessment of myself in the role of project developer. My thoughts and self-assessment on scholarship follow. Next, I address leadership and change and how my experience has changed me as a practitioner. Finally I address how my study might introduce social change.

Project Strengths

The biggest strength of my study and project comes from the case study format, meaning the project participants, the faculty, are also the main project beneficiaries. My project derives from faculty perceptions of undergraduate research and provides a research option that fits within the limitations of time and resources at LECC. An additional strength is that my project is directly based on both experiential learning and the development of science identity, the two conceptual frameworks underpinning my study. CS projects can be used in many different classroom situations and since there are so many CS projects available in so many different disciplines, there is a high likelihood of finding an appropriate project for a specific course (Bonney, Cooper, & Ballard, 2016).

The white paper is a versatile document and can easily be adapted to different audiences and situations. As it stands, it is tailored to the specific needs of LECC science faculty; however, if there is outside interest, it could be made applicable to other institutions or groups such the Holden Arboretum, Great Lakes Science Center, and Western Reserve Land Conservancy. The white paper content lends itself to a PowerPoint format, making it easy to give as a presentation. My dissertation contains more details should more information be desired.

A final strength lies in the fact that this project was tailored for implementing research at a community college, and not a 4-year school where undergraduate research options are more numerous. Using CS allows community college students, who might not otherwise have the opportunity, to explore science and research within their limited time on campus. The majority of the literature describes work at universities where professors focus on their ongoing research more so than their teaching commitments. While the LECC participant faculty appreciates research and would like to pursue their interests in that area, the primary focus is on teaching and helping students learn. Adding a CS project to the curriculum would not detract from this main priority, and may even bring students a new understanding of the concepts they discuss in class.

Limitations, Remediation, and Future Research

A basic limitation of case study research is that the results are often not generalizable to a population outside of the case study school; future research could tailor the main CS application to other schools or learning situations. Also, my current project focuses only on natural science, yet there are CS studies in subjects such as history, psychology and social science. If my project is successful, applying CS to other courses would be a possibility. Bringing CS to subject areas beyond physical science would also address the generalizability limitation of a case study, as a broader section of the student population would have a chance to experience a true scientific study. The long timeframe for implementing and evaluating the worth of a CS project reflects another limitation, as it may take a year or more to evaluate the success of incorporating CS into the curriculum. Currently, only a few peer-reviewed papers address CS in college courses, but as the use of CS projects in college courses becomes more frequent, there will be more literature to draw on for help in streamlining the process (Hiller & Kitsantas, 2014; Masters et.al., 2016; Paige et. al., 2012; Surasinghe & Courtner, 2012).

My project addresses CS studies incorporated into community college courses. Future research might compare the implementation process and successes at 4-year schools, research universities and community colleges. Evaluating how other colleges use CS studies would help refine the implementation of CS projects at LECC. Learning what does and doesn't work for other schools would streamline the integration process and make the CS idea easier for faculty to incorporate into their teaching. The larger the number of CS studies integrated into LECC curriculum, the more generalizable my results become. Another source of possible research lies in the high schools. The majority of my participants thought that exposure to science at the college level was too late in a student's development to make much of a difference. Studying how secondary students respond to CS in the classroom would provide insights on how to influence more students, especially women and minorities, to undertake science careers. Adapting my integration ideas at the middle and high school levels would again expand the range of my study and help minimalize issues with generalizing my results.

Project Development and Evaluation

Aspects of Caffarella's (2013) model of program development were key to developing a sound project. These included context, goals and objectives, instruction, support, and evaluation. The context of my study was a local focus on the institution where I work, consequently, my project needed to reflect the specific culture and environment at LECC. To provide clarity, it was important to base the project on my specific goals and objectives, and to articulate that to my audience so they had a clear framework for my recommendations. The instruction aspect of the project comes from educating my peers with respect to the potential of CS projects; again, the context dictated the manner in which I will approach my peers. I hope to garner support for my recommendations from my colleagues and the administration, and in return I offer my support to them by helping them find and implement possible CS projects. Evaluation is the most difficult aspect of project development because there are a variety of possible outcomes to my proposals. My white paper might generate little interest, or it might make many people curious to know more. If I receive no response within 6-8 weeks after sharing my white paper, I would contact participants who had indicated a desire to incorporate more experiential learning in their courses. I would suggest a number of specific CS studies that I feel would fit their course and offer my assistance for blending it into their class. I feel that the personal touch would succeed if the original white paper did not. Once a CS study has been introduced in a course, the best evaluation would consist of two elements. The first would be from the instructor regarding both the logistics of implementing CS as well as their perception of the value of CS as a learning tool. The student response, the second part of the evaluation, would likely be gauged by either a survey or qualitative responses to questions regarding the CS study.

Analysis of Self as Project Developer

A project developer must be able to adapt to whatever circumstances are present, even if the circumstances are unlike than those expected. This happened to me, as my final project ended up being very different from what I had envisioned. The literature suggested that an apprenticeship model or a summer internship model would be the best way to incorporate undergraduate research, and I anticipated my project to be writing a plan for summer research opportunities. However, my study results indicated that any student research would have to be placed within a course and done when the students were present for that course. Thus, I began to explore SUREs and CS studies to determine their suitability for research at LECC.

My ideas regarding validity and evaluation were also changed because of this project. I now realize the necessity for more formal, substantive conclusions for my projects versus a general idea of the outcome. Having concrete evidence helps define a clear path for decision making. Properly evaluating and assuring validity also ties into my development as a scholar.

A final conclusion about myself as a project developer is that I need to be more efficient with my time and effort. Although I had an overall plan for developing my project, I spent too much time focusing on specific details of CUREs and CS projects, when in reality, I just needed basic information about each study. In the future I will evaluate my progress with respect to the big picture on a more frequent basis, either daily or weekly depending on the scope of the project. This should help me maintain my focus on the important aspects of a project.

Scholarship

Scholarship represents a lifetime commitment to inquiry and learning based on research, synthesis of ideas, testing, and evaluation. It must be approached methodically, much like scientific research, in order to provide a complete and valid product that can evolve as needed; this evidence based approach appeals to the scientist in me.

Scholarship does not apply to one specific project or area of teaching and learning, but rather embodies a specific mind-set. Instead of viewing teaching as an occupation, I now see it as a craft. Scholarship is all about detail and concerns thoughtful and researched application of knowledge to a situation, as opposed to trying something because it sounds interesting.

True scholarship can be time consuming, frustrating, and hard work; only those who are motivated by the personal learning aspect of scholarship will do it well. Applying myself to a topic I have no interest in makes motivation difficult. However, when I am really interested in a topic, such as women in STEM, I can spend hours discovering new information to create novel approaches to teaching and learning that ultimately benefits my students and others.

Peer support is critical to be an effective scholar. When others weigh-in on my work, they offer constructive criticism and help keep my ideas relevant and clear. I have a mentor at LECC who is always willing to listen to my ideas and help me find any flaws in my thinking, or brings up points I hadn't thought of. He has also observed my classes and given valuable feedback regarding the way I present material. Unless I can express myself clearly to my students or other stakeholders, my scholarship will be for naught. One of the best resources I have had in this experience is my cousin Lisa, who has graciously edited much of my work. An editor in Chicago, she is unfamiliar with the specifics of science and educational theory that I write about; thus, if I can express myself in ways that she can understand, I know my work meets my objectives. My peers provide a valuable resource in my scholarship.

Analysis of Self as Scholar

How do I view myself as a scholar? To begin, my researching skills, both in the literature and in practice, have improved tremendously. I am better at synthesizing new ideas and adapting them to a specific situation. Because my knowledge is based on evidence and others' practices, these insights are sound. Due to the sheer amount of research required for my studies, I have become extremely efficient at evaluating research and determining how I can best use the information, a skill which will help me my entire life. Positive feedback from faculty and my mentors regarding the strength and validity of my work gives me motivation to continuously improve my skills and knowledge. When I started at Walden, I knew that I had proficient writing skills, but after working with Dr. Wahl and Dr. Batiuk, my confidence and ability to express myself has soared. Both instructors pushed me to improve in terms of blending research and knowledge into my own unique perspectives. They expected a lot from me, and I benefitted greatly because of it. Another way in which I have become more scholarly concerns my studies of peer reviewed research. I originally found and read journal papers for specific assignments, now it is second nature for me to keep up with the latest research in the areas of women in STEM, science teaching, and undergraduate research including CURES and CS projects. Finally, my growing knowledge and understanding of social forces and the social implications of my work has given me a new level of context for the research I do now and will do in the future.

Leadership and Change

Learning to lead myself constituted the biggest revelation regarding leadership. I realized that I had to step up and do what needed to be done even though I was, at times, out of my comfort zone. I typically like to follow a path, but now I know to forge ahead even though I am not exactly sure of the steps I need to take; I just have to start somewhere and eventually it all comes together. A good example of this is the coding during my data analysis; other than the few initial codes, I really didn't know how my results would coalesce. I just kept coding and recoding, looking for similarities and differences, and eventually the themes appeared. Additionally, I have noticed that my self-efficacy regarding my ability to produce strong scholarly work has improved and given me confidence to be more proactive about putting my ideas into action. I attribute this to the respect and validation others have given regarding my research study.

My life has also changed in unforeseeable ways. I thought that getting my doctorate was the key to continuing to do what I loved, teaching. However, this study has led to a sea change in my thinking about my future. During my study I have met people and learned about organizations who are interested in and can use my skills in new ways. I have realized that I have the potential to effect change for women pursuing STEM careers in more ways than just teaching two classes a semester. I am excited to explore these new avenues for my talents.

Analysis of Self as Practitioner

Even though I consider myself a good teacher because I care for my students and want them to succeed, I have become more reflective of how I teach and the material I provide in an effort to reflect what is best for the students. I have rewritten my syllabus to make it more of a learning document than a list of rules and requirements and provided measureable learning objective for each module allowing each student to evaluate their readiness for a test. I have also incorporated collaborative learning exercises into the curriculum and found that students are much more interactive with each other and with me as a result. Finally, I have learned that students respond positively to autonomy, thus I have provided many supplemental learning tools to them via the course page on BlackBoard so they can learn in the way that best suits them.

The Project's Potential Impact on Social Change

Caffarella (2013) viewed education and training programs as a means to affect change on three levels: within society, within organizations, and individually; these are the three areas I want to address with my project. On a societal level I wish to develop more science literate citizens, people who realize that science is understandable and that it can be employed to address many societal issues. Within LECC, my project will empower faculty to create more authentic learning experiences for their students. On an individual level, I want to spark interest in science and direct students, especially women, into STEM careers. I believe that even though my research and recommendations may not immediately improve the status of women in science, my study has brought this issue to the forefront and made people think, perhaps for the first time, about the lack of women in science. When I get frustrated by how slowly this issue is being resolved, I keep the quote attributed to Lau Tzu forefront in my mind, "The journey of 1000 miles begins with one step."

Conclusion

My doctoral journey has changed me for the better in numerous ways. Not only did I learn about educational theory, I also expanded my knowledge through practical applications, culminating in my research project study. I am proud to say my research produced strong evidential themes which led to recommendations for incorporating research to my case study institution. While every study has its limitations, I have addressed them and provided a focus for future research. Although my project eventually came together, its development led me to realize that only practice would make the process efficient. In my time at Walden I have learned that scholarship has many facets, but the underlying factor is hard work. I am optimistic that my project will bring social change and the societal, institutional, and individual levels and lead more women into STEM careers.

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Appendix A: The Project

White Paper on Incorporating Citizen Science Projects into Lakeland Science Curriculum

My goal is to increase the number of women in STEM to combat the huge disparity in the numbers of men and women in science fields. One of the ways this can be accomplished is through experiential (authentic) learning, specifically activities which help build science identity – the increase in self-efficacy that comes with feeling like a person is a contributing member of the scientific community. Participation in undergraduate research (UR) is one of the most effective ways to do this. Women at community colleges who begin with an intent to go into STEM drop out at disproportionately high rates when compared to four-year colleges; therefore, the community college setting is where I chose to focus my efforts. My specific goal was to assess the learning environment, course requirements and faculty perceptions to determine what, if any, type of research might be incorporated into Lakeland's course curriculum.

Study Details

My data consisted of 15 semi-structured interviews and was gathered over a period of two months. The participants included Lakeland Science/Engineering faculty and science professors from two other institutions. (Please note, all necessary permissions were obtained and ethical treatment protocols were followed).

An invitation email introducing myself and my study along with the Participant Consent Form was sent to every full-time science faculty member and the three full-time engineering faculty at Lakeland. Additionally, five other participants were invited based on recommendations from participants and my own research. A total of 15 participated while nine declined or did not respond.

All interviews with Lakeland faculty were held in their offices; of the others, one was a phone interview and one took place in the part-time faculty office. Each interview was recorded on a Sony IC recorder and saved to my computer hard drive as an MP3 file; these files were imported to iTunes and downloaded to an iPod for playback during transcription. Each interview was transcribed as a Word document and checked against the recording for accuracy. Every participant was sent a copy of the transcripted interview with a request for corrections, clarifications or further comments.

Of the participants, there were six women and nine men broken into the following areas: biology ($n = 7$), engineering ($n = 3$), chemistry ($n = 2$), physics/physical science ($n = 2$), and geography/GIS ($n = 1$). Ten of the participants hold terminal degrees in their fields.

Results

Five themes emerged from my study; faculty perception of undergraduate research, authentic experiences, health tech/nursing programs. LCC students career focus and the unique culture at LCC.

Faculty perception of undergraduate research

Faculty who had undergraduate research experiences perceived them as important to their career decisions and to developing their love for their subjects. Many found a sense of belonging in a research group, and peer and mentor support helped develop their science identities. Opportunities to present their findings to the public often came as a direct result of their undergraduate research experiences.

Authentic experiences

When asked how they would change or modify their current courses, the LCC faculty overwhelmingly wanted to incorporate more authentic learning experiences, such as field work, research and open-ended labs. They recognized that when students are allowed to take ownership of their studies, they are much more engaged and a higher level of learning takes place.

Health tech/nursing programs

Lakeland's health tech and nursing programs are the most popular degrees, and as such, the main focus of the biology department is to develop these students and get them through the needed prerequisite courses. Therefore, the emphasis for these courses is knowledge building and there is a large amount of required material, leaving the faculty little room to incorporate experiential learning in the classroom. This negatively impacts the variety of science course offerings for students who are interested in science, but not on the health tech or nursing paths.

Student career focus.

The vocational nature of the college means that by the time students begin at Lakeland, most have already decided on their future career. Their focus is on getting through their courses as quickly as possible, in order to start working in their field. Not many students see LCC as a place to explore their interests, use their experiences to decide on a career path, and possibly transfer to a four year school to complete their degrees. Thus, students are not overly receptive to the idea of research or side studies.

Unique culture

The science faculty's characterization of the learning culture and working environment at Lakeland as unique was a serendipitous discovery, but almost every Lakeland participant commented on this in some way. The participants feel that they are surrounded by highly qualified and highly motivated colleagues who all go above and beyond the norm to support each other and support the students. A number of them talked about their peers as "family," and considered Lakeland as their "home."

Most viable type of research

Criteria to guide development of research recommendations included faculty perceptions of undergraduate research, authentic learning, barriers to incorporating undergraduate research into the curriculum, and the types of research options they considered viable at LCC. Journal articles regarding CUREs (course-based undergraduate research experiences) and citizen science also helped define my recommendations. Experiential learning theory and science identity theory formed the basis of the recommendations.

Based on the study data, the most viable type of undergraduate research for LCC is course-based and requires a relatively short timeframe for completion. CUREs and citizen science projects and their theoretical basis constitute the remainder of the literature review.

CUREs and Citizen Science

A CURE (course-based undergraduate research experience) involves incorporating authentic research into the classroom (or lab) setting; this is a relatively new concept, as CUREs do not appear in the peer-reviewed record until the early 2000s. Advantages of CUREs over traditional mentorship approaches to undergraduate research include giving a larger, more diverse cohort a chance to engage in research and providing peer support during the process (Auchincloss et al., 2014; Corwin, Graham & Dolan, 2015; Desai et al., 2008; Moore & Teter, 2014). Additionally, CUREs allow students to take leadership roles, make decisions regarding how the research should proceed, and help instill ownership of the project outcomes (Auchincloss et al., 2014).

One local example is Dave Pierce's Stream Analysis course at LCC. He developed it because he wanted to involve students in meaningful research showing them that they are capable of doing scientific work. He spends the first two weeks of class training students to perform tests to EPA standards. Then the class travels to endangered tributaries to evaluate the biological, chemical and environmental conditions. Throughout the summer the class returns to the same streams for follow-up analyses. Data analysis occurs throughout the course and is uploaded to the Department of Natural Resources Stream Quality Monitoring Project databases. Additionally, the students write up a booklet for the community reporting results and trends over time. Students obtain recognition because their names are recorded in the DNR database and they receive letters of accomplishment from the college for their research efforts. The number of interested students has grown over time as participants praise the course. This type of research builds science identity as the students do all of the data collection, analysis, and reporting. Recognition from both the college and the State of Ohio reinforces the idea that the students' work is seen as valuable by more people and institutions than themselves or their instructor.

Two CUREs from recent literature include the development of an introductory biology laboratory course at Purdue University in which students design and carry out a microbiology research project (Gasper & Gardner, 2013). The students are required to read scientific literature, work with a team to develop a research plan, carry out the study and then effectively communicate findings to others (Gasper & Gardner, 2013). Students showed a significant increase in their understanding of the nature of scientific research and in their critical thinking skills (Gasper & Gardner, 2013). The Science Education Alliance's Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES) program is a multi-intuitional CURE currently being used at 70+ colleges and universities . Participating students isolate unique mycobacteriophages from soil samples, characterize their bacterial viruses using restriction digests and electron microscopy, and then annotate sections of their phage's DNA using computer programs. (Cross, 2013)

Studies have shown that CUREs offer the same student benefits as traditional research internships (Corwin et al., 2015; Nadelson, Walters & Waterman, 2010); Shaffer et al., 2010). These gains include, but are not limited to, self-efficacy (Corwin et al., 2015; Vitone et al., 2016), persistence and higher graduation rates (Corwin et al., 2015); Rodenbush, Hernandez, Simmons & Dolan, 2016), increase in critical thinking ability (Brownell et al., 2015) and interest in and pursuit of scientific careers (Harrison, Dunbar, Ratmansky, Boyd & Lopatto, 2011).

While SA's course is based on medium to long term research, there are other citizen science projects in which students can do authentic research and submit their data within a few class periods or weeks. This may be the best way to incorporate authentic research experiences into busy classes.

The effort required to put a course together reflects the downside of this type of research. Identifying of a legitimate scientific study to underpin the students' research may require a good deal of time, the research must be feasible within the timeframe of the school terms, and the course must be fully developed by the instructor and receive institutional approval. Finally student interest must be high enough to allow the course to run. Utilizing citizen science projects can make it easier to incorporate research into courses.

Citizen science

Citizen science can be broadly defined as a scientific study utilizing the public as sources of information or data analysis. The efforts of volunteer participants allow for gathering and processing of data sets too large for normal lab capabilities. Citizen science is a new term for an old practice. Scientists have always relied on public volunteers to provide data they could not otherwise obtain. Historical records of grape harvests in France (640 years), descriptions of the cherry blossom bloom in Japan (1200 years), documentation of locust outbreaks (3500 years), tracking the transit of Venus in 1874, and the annual Christmas Bird Count for the Audubon Society (115 years) are testament to the value of public participation in research (Miller-Rushing, Primack, & Bonney, 2012).

Technological progress has made public participation in scientific studies even easier than before. The area of data informatics has evolved dramatically in the last 20 years and the public can participate in citizen science with a device as simple as a smartphone (Pecl, Gillies, Sbrocci, & Roetman, 2015). Advances in computing allow for faster and more efficient data collection and processing. For example, researchers at George Mason University have developed software that uses the power from someone's computer to run a program for Alzheimer's research; the catch is that it only taps into computers that are idle, meaning it doesn't interfere with normal computer use (). Computer developments have also allowed the public to analyze data as well as collect it. Citizen science has become a big enough phenomenon that a new open-access journal, *Citizen Science: Theory and Practice,* was launched in May 2016. Scientists who want to utilize public participation in their studies post their links on various websites devoted to bringing the public and scientists together. (A list of these sites can be found in appendix x) SciStarter.com and Citizen Science Alliance (CSA) are two such websites. Galaxy Zoo, a CSA project, became well-known when volunteer researchers noted the appearance of a green cloud below a galaxy, leading to the discovery of an extinguished quasar (Franzoni & Sauermann, 2014.

A logical way to classify citizen science projects is by the type of work the participants do. Bonney et al., (2014) have broken this down into four main types:

data collection: participants upload data from local sites to build geographically diverse databases of information for different species. Examples include: The Birdhouse Network, NestWatch

data analysis: a way to evaluate huge amounts of data by using many participants, each analyzing a small piece of the data; another name for this is crowd science. Examples include: Zooniverse projects and eBird (Sullivan et al., 2014)

curriculum-based: this brings citizen science into the classroom as instructors supervise students who collect data for citizen science projects; the projects are based on their level of knowledge and training. Examples include: WINGS – in which students collect butterfly data and GLOBE – in which instructors can find grade-level activities relating to atmosphere, biosphere, hydrosphere and soil. This study is sponsored by the NSF and NASA.

community based monitoring (CBM): citizens collect and analyze data for the purpose of community policy and decision making, usually regarding health or conservation issues. One example occurred in Loma Alta, Ecuador where citzen monitoring of fog recapture and bird populations united the community around saving the Loma Alta tropical rainforest; this led to a higher level of social capital for the residents. (Becker, Agreda, Astudillo, Constantino, & Torres, 2005). With respect to CBM, the efforts of citizen scientists are not viewed as a replacement for professional scientists, but as a cost-effective early warning system for specific ecosystems (Kolok, Schoenfuss, Proper, & Vail, 2011).

Benefits of Citizen Science

Citizen science is symbiotic in that both the scientists and the participants reap benefits. Scientists gain access to data they could not access themselves; additionally, the use of citizen scientists saves money that would normally go to paid sources. Theobald et al. (2014) analyzed 338 citizen science biodiversity projects from around the world and estimated contributions from 1.3 – 2.3 million citizen science volunteers, with each participant spending an average of 21–24 hours collecting data. This equates to $2.5 billion annually (Theobald et al., 2014).

One clear benefit to CS volunteers is a gain in scientific knowledge regarding the focus of the study e.g., invasive plants, bird characteristics and habits (Jordan, Gray, Howe, Brooks, & Ehernfeld, 2011). Another benefit is an increase in environmentally conscious behaviors such as providing habitat requirements for animals, recycling, planting native plants (Jordan et al., 2011). Citizen scientists engage in scientific thinking more often when they are deeply involved with the project (Evans et al., 2015). Some CS projects, particularly the classroom type, help students refine career choices and plans (Quardokus, Lasher-Trapp, & Riggs, 2012). Finally, participation in CS can increase one's social capital (Becker-Klein, Peterman, & Stylinski, 2016). Citizen-based monitoring (CBM) increases environmental democracy, scientific literacy, social capital, citizen inclusion in local issues, benefits to government, and benefits to ecosystems (Conrad & Hilchey, 2011).

Other CUREs include the development of an introductory biology laboratory course at Purdue University in which students design and carry out a microbiology research project (Gasper & Gardner, 2013). The students are required to read scientific literature, work with a team to develop a research plan, carry out the study and then effectively communicate findings to others (Gasper & Gardner, 2013). Students showed a significant increase in their understanding of the nature of scientific research and in their critical thinking skills (Gasper & Gardner, 2013). The Science Education Alliance's Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES) program is a multi-intuitional CURE currently being used at 70+ colleges and universities (Cross, 2013). Participating students isolate unique mycobacteriophages from soil samples, characterize their bacterial viruses using restriction digests and electron microscopy, and then annotate sections of their phage's DNA using computer programs. (Cross, 2013)

Shortlidge, Bangera and Brownell (2016) showed that faculty also see tangible benefits. CUREs connect teaching and research, they contribute positively to promotion and/or tenure, they are enjoyable to teach, they result in publications in basic science and/or science education research, they broaden faculty research interests, they can help in obtaining grant money and are a vehicle to improve faculty relationships with students (Shortlidge et al., 2016).

However, Shortlidge et al. (2016) also identified a number of negatives faced by faculty who develop and teach CUREs. They include substantial time and effort to create and propagate the study, financial constraints, the expanded role required of the instructor, and student resistance to the CURE idea (Shortlidge et al., 2016) These limitations are also found at LCC; faculty just don’t have the time or the room in their courses to introduce novel research. A solution to this problem lies with citizen science studies.

Citizen Science in the Classroom

There is very little peer reviewed information about CS in the classroom. Most existing programs are geared to K-12 students, providing the opportunity to incorporate active learning and increase interest in the scientific process. The CS project GLOBE involves K–12 students, communities, and scientists from 112 countries in ecosystem and Earth-system science studies (Bestelmeyer et al., 2015)(www.globe.gov). Schools appreciate these programs because they are relatively easy to incorporate into the classroom, meet NGSS standards, and help students develop collaboration skills for teamwork, something not often taught in the classroom (Bestelmeyer et al., 2015).

For colleges and universities dedicated to producing scientifically literate graduates, introducing CS into the classroom brings multiple benefits. Because colleges often require at least one science course for most majors, incorporating CS in general science courses exposes a diverse group of students to authentic research, increasing scientific literacy and fostering an appreciation for scientific endeavors. (Egger, 2007). Incorporation of high-altitude balloon (HAB) research into atmospheric science classes at Ball State University resulted in high student motivation and communication, improved time management and teamwork skills, increased daily attendance, and a tripling of enrollment in school's meteorology track (Coleman & Mitchell, 2014). Surasinghe and Courter (2012) incorporated the CS project eBird, a bird surveying venture, into an undergraduate ecology course; the students spent an hour documenting the number and type of species of birds at a specific location and then uploaded their individual data to the eBird database. The students found the activity relevant to their daily lives and made them feel that they were personally contributing important information to a scientific study (Surasinghe & Courter, 2012).

Citizen Science at LCC

Implementing CS into the current LCC curriculum could happen in a number of different ways. One option would be to make participation in a CS project extra credit or minimal credit. This would be a good option for testing out the suitability of a CS study for a particular class. Astronomy students might classify galaxies or look for evidence of a black hole in one of the many Zooniverse astronomy studies. Microbiology students might interact with Fold-It, a study of how various proteins fold set in a computer game format.

Another way to incorporate CS into a course is through the lab component. Surasinghe and Courter’s (2012) use of eBird was mentioned before, but it would be relatively simple to devote a lab session to field work. Studies that might fit this description include the Global Garlic Mustard Field Survey or The Great Lakes Worm Watch at http://www.birds.cornell.edu/citscitoolkit or the Encyclopedia of Life study at http://citizenscience.org/.

A final way to integrate CS studies into the classroom is to make it part of the curriculum. Vitone et al. (2016) utilized two CS projects involving collection and identification of insects in an entomology course. The specific focus of each study were covered in lecture and at the mid-point of the course students were randomly assigned one of two projects to do on their own time (Vitone et al., 2016). Class discussion of results would allow students to see how their data fits into the overall picture.

Finding the right CS study for a specific course might seem daunting given that there are thousands of CS studies. Appendix A compiles information on identifying possible CS candidates for a course listing several papers regarding CS in the classroom along with websites of various CS organizations and their databases of projects. Additionally I am offering my help and my personal resources to any faculty member who is interested. It may take a while to introduce this type of authentic learning into the curriculum at LCC, but it would fit in with the faculty's desire for more experiential learning and the students' desire for learning to be interesting and tied to real life. Administration would benefit from the positive exposure of utilizing public CS projects as a new and innovative manner of education, and our community would benefit from having a more science literate public to make more informed and logical decisions regarding our country's future.

Appendix B: Possible Questions for Semi-Structured Interviews

Background Questions

1. Which area(s) of science is your specialty/interest?
2. What is your background in science?
3. How long have you been involved with conducting science?
4. How long have you been involved with teaching science?

Research Questions

RQ1: What do college science faculty and administrators perceive to be the advantages and/or disadvantages of developing an undergraduate research program at Lake Effect College to empower female STEM students?

RQ2: How would college science faculty and administrators assess the viability of developing an undergraduate research program at Lake Effect College?

RQ3: What undergraduate research options are feasible at LECC?

Interview questions relating to RQ1

1. Do you think the underrepresentation of women in science is a problem?
2. In your opinion, why does the disparity between numbers of men and women in STEM exist?
3. What do you feel are the most productive ways to increase the number of women completing STEM majors?
4. In what ways does your institution promote women in science? What could your institution do better in this regard?

Questions relating to RQ2

1. Do you think that the courses offered at your institution help students develop science identity/persistence?
2. What has been your experience with the effect of undergraduate research on persistence?
3. What barriers are there to this type of research program?
4. What are pros and cons of this type of research program?
5. What kinds of institutional supports would be necessary for the development of an undergraduate research program?
6. What are advantages/disadvantages of implementing a research program at LECC?

Questions relating to RQ3

1. What types of student research have you been involved with? Have you developed any specific programs of research?
2. Please describe your research program.
3. What are the specific goals of your research program?
4. How do you evaluate the progress/success of the program? What
5. barriers are there to this type of research program?
6. What are pros and cons of this type of research program?
7. What kinds of institutional supports would be necessary for the development of an undergraduate research program?

Appendix C: Invitation to Participate and Consent Form for Project Study

Invitation to Participate and Consent Form for Jodi Wilker's Project Study

Hello, my name is Jodi Wilker and I am working on the capstone study of my educational doctorate through Walden University. You may also know me as a science instructor at Lakeland Community College, but my capstone project is not affiliated with my teaching role. I would like to invite you to participate in my study titled, "Women in STEM: The Effect of Undergraduate Research on Persistence.

I am looking to determine perceptions regarding advantages and/or disadvantages of developing an undergraduate research program at Lakeland Community College as a way of empowering female STEM students. Additionally I wish to determine what types of research might be the most feasible at Lakeland. To this end, I will be conducting interviews with Lakeland science faculty and administrators and local experts who are currently running undergraduate research programs.

If you decide to participate, you will be asked to meet with me at a mutually agreed upon time and place for a 60 minute (approximately) interview regarding this topic. The interview will be audio taped and this data will be reviewed only by me; data will be securely kept for a period of at least 5 years, as required by Walden university. I will be happy to provide you with the transcribed interview and I may ask you to review it for accuracy and clarity. All participants will receive a copy of the completed study.

Participation is confidential and your personal information will not be used for any purposes othen than this project. Additionally, nothing that could uniquely identify you will be used in my study reports. Taking part in the study is voluntary, and you may decline to participate or withdraw from the study at any time without any repercussions.

If you want to talk privately about your rights as a participant, you can call Dr. Leilani Endicott, the Walden University Director of Research Ethics and Compliance, at 612-312-1210. Walden University's approval number for this study is **IRB will enter approval number here** and it expires on **IRB will enter expiration date.** I will be happy to answer any questions you may have about the study; please see my contact information below. Please print or save this consent form for your records.

If you would like to participate, please respond to this e-mail. We can then decide upon a convenient time and place to meet. I will have a copy of this form for you to sign and a copy for you to keep.

Thank you for your consideration,
Sincerely,

Jodi Wilker
Jodi.Wilker@waldenu.edu
phone number here

Printed Name of Participant ______________________________

Date of consent ______________________________

Participant's Signature ______________________________

Researcher's Signature ______________________________

Appendix D: Letter of Cooperation from Lakeland Community College

Lakeland
COMMUNITY COLLEGE
Provost's Office
7700 Clocktower Drive • Kirtland, Ohio 44094-5198

October 29, 2015

Jodi Wilker
10629 Rocking Horse Trail
Kirtland, OH 44094

Dear Ms. Wilker:

Based on my review of your research proposal, I grant permission for you to conduct the study entitled "Women in STEM: The Effect of Undergraduate Research on Persistence" at Lakeland Community College. I understand that this project will begin once you have obtained Walden University's Institutional Review Board (IRB) approval. You have agreed to provide my office a copy of the Walden University IRB approval or exemption letter before beginning any research activities.

As part of this study, you will be performing your research activities at Lakeland, including recruiting faculty and staff participants, communicating, and conducting interviews with the participants and conducting member checks of your collected data. The results of your study will be disseminated to all participants and the individuals' participation will be voluntary and at their own discretion. In addition, the data collected will remain entirely confidential and may not be provided to anyone outside of the student's supervising faculty/staff without permission from the Walden University IRB.

I understand that Lakeland's responsibilities include allowing the interviews to be conducted on campus; however, the College reserves the right to withdraw from the study at any time if our circumstances change.

Good luck on your research project.

Sincerely,

Morris W. Beverage Jr., EDM
President and Interim Provost