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STEM Influence on Career Choice Variables of Middle School Students Based on Gender and Ethnicity

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Abstract

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MA, Walden University, 2006

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Science, technology, engineering, and mathematics (STEM) are growing fields in both global job markets and educational spaces. The problem related to this study was the lack of understanding of how gender and ethnicity might relate to differences in the science self-efficacy, outcome expectations, and task interest of students who have participated in STEM intervention programs at the middle school level. The purpose of this quantitative study was to explore the extent to which there were differences between the dependent variables of science self-efficacy, outcome expectations, and task interest in U.S. middle school students based on the independent variables of gender and ethnicity after participating in a citizen science STEM intervention program. Social cognitive career theory was the theoretical framework for the study. This study was a nonexperimental comparative investigation based on survey responses from students who had participated in a water quality, citizen science STEM intervention from 2017-2019. The participating students' school district has a history of multiple, systemic STEM learning experiences. The results of two-way MANOVA indicated that there were no statistically significant differences in career choice variables between male and female students and between non-Hispanic and Hispanic students after participating in a citizen science intervention program. This study has the potential to help students from underrepresented populations to envision success in their STEM educational and career pathways by seeing other students experience success in those areas. Educators may also be better able to design programs that address the specific needs of underrepresented student populations, which may lead to better student outcomes for those groups.

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Chapter 1: Introduction to the Study

Introduction

STEM is an acronym that is receiving global attention in the spheres of public policy making and education. The letters in this acronym represent the separate, but related, disciplines of science, technology, engineering, and mathematics. STEM disciplines are connected by a shared set of critical-thinking and problem-solving skills that are deemed critical for economic success and innovative competitiveness by many world leaders (Breiner, Harkness, Johnson, & Koehler, 2012; English, 2017; White, 2014; Xie, Fang, & Shauman, 2015). In the United States, the National Science Foundation (NSF) has played a major role in advocating for the funding of research projects that are focused on science, technology, engineering, and mathematics (Holmlund, Lesseig, & Slavit, 2018), and the recent presidential administration of Barack Obama called for educating a new generation of innovators and thinkers to help negotiate future issues that the United States will face in the future (Office of the Press Secretary, 2009).

Discrepancies exist between the demographics of the U.S. population and the demographics of the students currently entering these STEM educational and career pathways (Jones et al., 2018). Underrepresented categories of STEM students, based on person inputs such as gender and ethnicity, have been shown to be affected by learning experiences like citizen science STEM intervention programs (Hiller & Kitsantas, 2014). These experiences can mediate the development of career choice variables of science self-efficacy, task interest, and outcome expectations for students at various stages along

STEM educational pathways (Fouad & Santana, 2017; Lent et al., 2018). Awareness of the factors that lead to the discrepancies in the demographics of students entering STEM pathways allows for the development of more effective learning experiences along those pathways.

The purpose of this quantitative study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest are present in middle school students based on their gender and ethnicity after participating in a citizen science STEM intervention program. This study has implications for many categories of educational stakeholders, including students, teachers, and policy makers. Increased understanding about how underrepresented categories of STEM students develop career choice variables that can lead to career choice actions in STEM career pathways is important because it supports the development of STEM educational pathways that meet the needs of a diverse population of STEM-capable students (Lent et al., 2018; Steenbergen-Hu & Olszewski-Kublilius, 2017). The development of such pathways allows the employers in the United States to tap into a more representative talent pool of critical and creative thinkers to retain global competitiveness in STEM industries.

Chapter 1 begins with an overview of the background literature for the themes of this study. The research problem, the purpose of the study, and the research questions follow. The chapter also contains an introduction to the nature of the study and some of the major terminology used throughout the study. Chapter 1 terminates with discussion of the assumptions, scope and delimitations, and limitations of the research as well as its significance to the discipline of education.

Background

Some scholarly researchers studying STEM topics have uncovered gaps in the types of students who have access to STEM courses and careers during their formative schooling years. Fouad and Santana (2017) completed a literature review of recent studies which feature social cognitive career theory (SCCT) as a framework for examining race and gender discrepancies in STEM career choice by age-group level. The results of the literature review showed that the SCCT model is a stable predictor of STEM career choice across the variables of gender, ethnicity/race, and age level with math and science self-efficacy and realistic outcome expectations as critical intervention focal points for involving more underrepresented subpopulations in advanced STEM coursework. Le and Robbins (2016) tracked a large cohort of middle school students through their high school and college years and found that interest and ability, stimulated by environmental factors, served as strong predictors of STEM degree attainment across gender groups. Gaps in the number of underrepresented ethnic/racial students entering STEM college course tracks and pursuing entry-level STEM jobs show up in Carpi, Ronan, Falconer, and Lents' (2016) study of undergraduate STEM research experiences. My study adds to the research literature, in support of the relationship between intervention program participation and science self-efficacy, outcome expectations, and task interest in underrepresented groups.

The literature related to STEM educational and career pathways outlines the existence of traditional STEM pathways from education to the workforce, the STEM pipeline as a metaphor for these pathways, gaps in a leaky pipeline, and environmental supports for STEM pathways (Bergeron & Gordon, 2017; Doerschuk et al., 2016). Data from study results in the past five years have led researchers to come to the conclusion that increasing student knowledge of STEM career pathways should happen at an early age when students are beginning to develop occupational interests (Blotnicky, Franz-Odendaal, French, & Joy, 2018). Researchers have also found that students enter into the traditional STEM career pipeline, which leads from educational settings into STEM careers, at an early age (Ball, Huang, Cotten, & Rikard, 2017). The metaphorical STEM career pipeline is a useful tool for understanding how students may progress from educational spaces into the world of STEM occupations (Le & Robbins, 2016), but there are recognized leaks in this pipeline where certain populations of STEM-capable students are choosing to leave STEM career pathways and pursue other types of careers (Jones et al., 2018).

Most of the research surrounding the underrepresented populations in the STEM pipeline has focused on traditional STEM interventions for high school and early college aged students (e.g., Angle et al., 2016; van den Hurk, Meelissen, & van Langen, 2019). The gap that remained was to determine which types of informal, out-of-school environmental supports may help encourage students to enter and persist in the STEM pipeline during their middle school years. Addressing this gap was important because finding a way to encourage students to stay in STEM career pathways is highly time-sensitive (Morgan, Farkas, Hillemeier, & Maczuga, 2016). Developing STEM interest at the earliest point of entry into the pipeline possible may allow educators and policy makers to retain and develop STEM talent and help those students transition into STEM careers. Some researchers have explored how increasing STEM interests as early as eighth grade may increase the number of students obtaining STEM-related college degrees (Maltese & Tai, 2011), while others have identified how informal learning experiences might serve as positive environmental supports in shaping student attitudes toward STEM careers (Ozis, Osman Pektas, Akca, & DeVoss, 2018). My study was positioned at the leaky junction where STEM-capable females and ethnic/racial minorities exit the pipeline. Specifically, I explored how participation in the citizen science STEM intervention program may have changed the science self-efficacy, outcome expectations, and task interest for middle school aged students. Data from my study expands current research knowledge about self-efficacy, interests, and outcome expectations in underrepresented subpopulations of middle school students. My study also provides quantitative data on environmental supports at early entry points into that pipeline which may create successful learning experiences in STEM career pathways for those students.

In my review of the literature related to underrepresented STEM populations, the themes that emerged were the existence of stereotyping and bias as barriers to entry into STEM pathways for females and ethnic/racial minorities, the value of early experiences in STEM as supports for encouraging STEM persistence for females and ethnic/racial minorities, and STEM ability and performance as indicators of STEM-capable females and ethnic/racial minorities. Researchers have primarily focused on the contextual barriers and supports which impact underrepresented populations based on the person and background contextual inputs of gender and ethnicity/race (Cheryan, Ziegler, Montoya,

& Jiang, 2016; Fouad & Santana, 2017; Lent et al., 2018; Saw, Chang, & Chan, 2018) and examined high school and college level participants using large, longitudinal database studies and small, qualitative case studies. There were several gaps that remained. One was the use of a research methodology that was located in the middle of the large, quantitative studies and the very small, qualitative studies. Another gap was the lack of research that focused on middle school aged students who were near the beginning of their STEM educational pathway (Morgan et al., 2016). Better understanding these gaps will allow for a more complete description of how females and ethnic/racial minorities were influenced by environmental supports and barriers after early STEM experiences.

STEM intervention and enrichment programs existed in the scholarly literature under the categories of types of STEM intervention and enrichment programs, indicators of STEM program effectiveness, the importance of authentic STEM experiences in these programs, the influence of community building STEM experiences, and the impact of STEM-specific college experiences. The research primarily focused on STEM Intervention Programs (SIPs) at the college and university level and researchers have explored the contextual supports that may help students to transition from high school into college-level STEM programs and eventually, into STEM careers (Carpi et al., 2017; C. E. George, Castro, & Rincon, 2018; Rincon & George-Jackson, 2016b). There were several gaps that remained. Out-of-School Time (OST) programs exist in middle and high schools across the United States but they have not been well-studied for effectiveness (Young, Ortiz, & Young, 2017). Another gap was the lack of research that had been done to understand how underrepresented student populations at the middle school level were experiencing these types of OST programs. These gaps were important because middle school was a crucial time in the process of science identity and self-efficacy formation (Kim, 2016). My study expanded on current research about how OST citizen science enrichment programs served as environmental contextual supports at the middle school level for underrepresented female and ethnic/racial minority students as they transitioned into the high school phase of STEM educational pathways.

Literature on citizen science ranged from volunteer community programs for adults to formal and informal programs for young adults. Data from study results in the last five years have led researchers to conclude that citizen science programs helped engage a wide range of ages of citizens in participatory science with positive learning outcomes. The gap that remained was a lack of citizen science research that focused on ongoing monitoring, curriculum-based, collaborative middle school citizen science programs. This gap was important because middle school was a crucial leakage point in the STEM career pipeline so interventions and enrichments at this point could help recruit and retain students into STEM educational pathways (Morgan et al., 2016). While some studies explored sense of community and awareness of conservation goals and actions in citizen science programs (Ballard, Dixon, & Harris, 2017), and the impact of citizen science programs on science content literacy and process skills (Brannon, Brannon, & Baird, 2017), in my study I explored the nonacademic learning outcomes of citizen science. My study expanded on current research by exploring the self-efficacy, task interest, and outcome expectations of underrepresented populations of STEM-capable participants who had participated in place based citizen science program and added understanding to the gap by collecting data on extended, week-long citizen science experiences at the middle school level.

Problem Statement

The problem related to this study is the lack of understanding of how gender and ethnicity might lead to differences in the science self-efficacy, outcome expectations, and task interest of students who participate in STEM intervention programs at the middle school level. The United States is facing challenges in ensuring that its STEM workforce adequately represents the diverse subpopulations in the country. Although 52% of the nation is female and minority groups represent 31% of its citizens, those same groups are underrepresented in STEM career fields and education courses (Fouad & Santana, 2017). According to some researchers, structural racism and gender stereotypes in STEM educational spaces discourage ethnic minorities and females from participating in STEM experiences, which limits opportunities for those subpopulations of students to develop outcome expectations that might lead to careers in science, engineering, and mathematics (McGee & Bentley, 2017).

Finding ways to create a shift in the STEM career pipeline for females requires the implementation of intervention strategies that address the needs of that subpopulation of people and the unique perspectives that they bring to STEM disciplines (Falk, Rottinghaus, Casanova, Borgen, & Betz, 2017; Heybach & Pickup, 2017). Intense STEM interventions over the last 30 years are showing success in increasing the numbers of females and ethnic/racial minorities represented in a few STEM careers, like physician and veterinarian, yet there remains a deficit of those subpopulations in many science and engineering occupations, especially engineer, scientist, and pharmacist (Fouad & Santana, 2017). Innovative STEM instructional and learning interventions such as citizen science programs are starting to address the specific needs of underrepresented students populations in STEM educational pathways, however (Hiller & Kitsantas, 2016).

Current research indicates that the problem of underrepresentation is both relevant and meaningful to the field of STEM education. Innovative instructional strategies and learning opportunities in STEM education provide a lens for addressing this problem. Integrating underrepresented subpopulations into scientific career contexts in such a way as to mirror the demographics of the general population is an important goal for stakeholders in the STEM career pipeline (Smith-Doerr, Alegria, & Sacco, 2017). Predictors of STEM career choice following the SCCT model include added supports in the form of role models and sensitivity to perceptions of career environments as well as the removal of barriers which lead to increased self-efficacy, outcome expectations, and task interest in the areas of math and science (Lent et al., 2018). There are strong links between gender, self-efficacy, and career choice which can be supported by school and community STEM interactions and programs (Turner, Joeng, Sims, Dade, & Reid, 2017). The use of innovative citizen science instructional curricula may provide role models, career environments, and school and community partnerships that may influence the science self-efficacy, outcome expectations, and task interest of females and ethnic/racial minorities. Middle school is a crucial age for providing students with learning experiences that include exposure to STEM interventions and advanced science and math coursework to develop positive self-efficacy and outcome expectations towards math and science careers (Fouad & Santana, 2017; Prakash & Tobillo, 2017). Research which addresses the equity gap in STEM education may help uncover ways to remove the barriers which may be negatively influencing the science self-efficacy, outcome expectations, and task interest of certain students and may lead to a more diverse and representative STEM workforce.

The study is significant to efforts to provide innovative STEM education in the K-12 setting. Addressing the gap in the literature about how citizen science, middle school STEM enrichment and intervention programs serve as a tool for engaging students in STEM career pipeline extends the literature in the area of STEM career-related, learning experiences. By expanding what is understood about effective STEM instructional strategies, my study may have positive academic ramifications for the underrepresented students who participate in these types of programs during their STEM educational pathways. Addressing issues with the success and retention of these students may increase the likelihood that the diversity of students in those pathways will one day be similar to the diversity of the population of the United States.

Purpose of the Study

The purpose of this quantitative study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender and ethnicity after participating in a citizen science STEM intervention program. To accomplish this purpose, I developed a series of research questions, based on the gap in the research, concerning the differences in the dependent variables of science self-efficacy, outcome expectations, and task interest by gender and ethnic/racial minorities after participation in a citizen science STEM intervention program. Understanding differences in self-efficacy and content knowledge may help educators to guide traditionally underrepresented groups in the STEM career pipeline to develop their career goals and choices, which may lead to positive social change for these populations of students.

Research Questions and Hypotheses

To address the problem and purpose of this study, I developed the following research questions (RQs) and hypotheses.

RQ1. Do self-efficacy scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0$1: There is no statistically significant difference in self-efficacy scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

$H_1$1: There is a statistically significant difference in self-efficacy scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

RQ2. Do task interest scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0$2: There is no statistically significant difference in task interest scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

$H_1 2$: There is a statistically significant difference in task interest scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

RQ3. Do outcome expectation scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0 3$: There is no statistically significant difference in outcome expectation scores by gender or ethnicity for middle school students participating gin a citizen science intervention program.

$H_1 3$: There is a statistically significant difference in outcome expectation scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

Theoretical Framework

The theoretical framework for this study was Lent, Brown, and Hackett's (1994) SCCT. Lent et al. developed SCCT to integrate many previous career development theories which share conceptual themes like self-efficacy, outcome expectations, abilities, and career interests. The development of this theory relied heavily on Bandura's (1986) social cognitive theory (SCT), which seeks to explain how the interaction of environmental factors, personal traits, and human behaviors affects a person's choices and actions.

In the development of SCCT, Lent, Brown, and Hackett (2002) explored the pathways between self-efficacy, outcome expectations, and interests as variables that connect to career choice and action. The three main goals of SCCT are to explain (a) how career and academic interests develop, (b) how career choices are made and then acted upon, and (c) how performance outcomes are actually achieved (Lent et al., 1994). The original theory was developed as a series of 12 propositions, each with multiple supporting hypotheses, which created a dimensional framework for understanding the career development process (Lent et al., 1994). These propositions were supported by data which organized person, contextual, and experiential factors into a model of direct and indirect influences (Lent et al., 1994). Figure 1 shows the SCCT model for the interactions between these career choice variables.

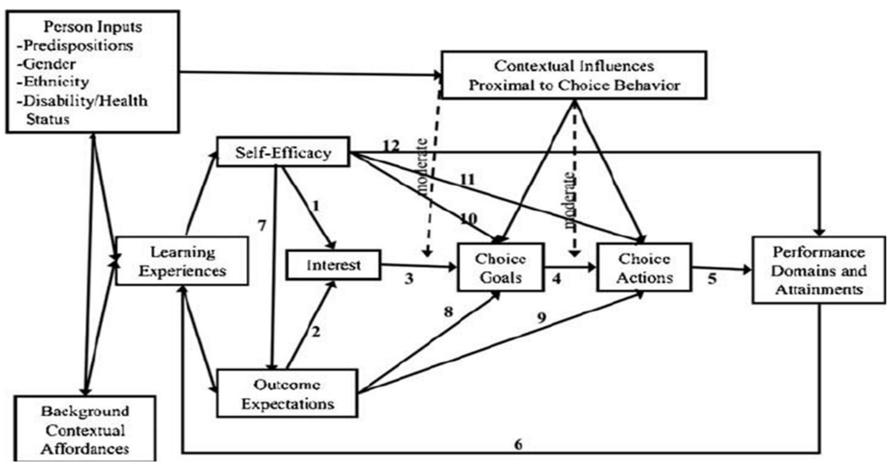

Figure 1. Model of social cognitive career theory. From “Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance” by R. W. Lent, S. D. Brown, & G. Hackett, 1994, *Journal of Vocational Behavior, 45*, p. 93. Copyright 1993 by R. W. Lent, S. D. Brown, and G. Hackett. Reprinted with permission of R. W. Lent.

Lent et al. (1994) noted that their model might be particularly useful when investigating career development for females and ethnic/racial minorities as long as the model was fine-tuned to take into account the specific contextual factors and challenges faced by these groups. Personal inputs like gender and ethnicity/race as well as background contextual affordances are the foundational variables for the SCCT model of career development; as such, they must be delineated during the research process (see Thompson & Dahling, 2012). In Chapter 2, I will provide a more in-depth explanation of the interaction between self-efficacy, interests, outcome expectations, and career goals and choice actions. I used six of Lent et al.'s original 12 propositions from their SCCT as a framework for my research into the career choice variables of middle school students from these underrepresented student populations.

In recent years, SCCT has been extensively applied to career choice in the area of STEM-related fields. Current researchers have focused on how self-efficacy, interests, and outcome expectations vary among underrepresented subpopulations of middle and high school-aged students based on gender, ethnicity/race, geographic locality, and socioeconomic status (Fouad & Santana, 2017; Lent et al., 2018). I used Hiller and Kitsantas's (2016) Citizen Science Self-Efficacy Scale (CSSES), which was developed using the SCCT propositions. The tool was validated using a three-part process: (a) consulting with scientific experts in the field for authoritative feedback on the types of questions which should be included, (b) factor analysis to revise the questions, and (c) confirmatory factor analysis to provide statistical credibility for the chosen assessment items (Hiller & Kitsantas, 2016). After they completed the validation process, Hiller and Kitsantas used the CSSES to quantitatively assess the influence of citizen science intervention programs on participant self-efficacy, outcome expectations, and task interest that can lead to career goals within the SCCT framework. The hypotheses developed for this study aligned with the career choice variables measured in the CSSES, which are aligned with variables in the SCCT.

Nature of the Study

I used a quantitative paradigm for this study. Specifically, I used a quantitative, nonexperimental comparative design and analyzed survey responses from students who had participated in a citizen science STEM intervention from 2017-2019. In my study, I explored the differences between the dependent variables of self-efficacy, outcome expectations, and task interest after participation in a citizen science STEM intervention program for the independent variables of gender and ethnicity in middle school students. The data were analyzed using a two-way MANOVA test since I was looking for differences in two independent variables across three dependent variables (as suggested by Warner, 2013). More detail about the data collection and analysis is given in Chapter 3.

This quantitative study was justified for several reasons. Due to the real-life context of the chosen research topic and the vulnerability of the research subjects, it was not appropriate for the establishment of a control group and random assignment of subjects to an experimental group, and as there was no manipulation or random assignment of groups, the nonexperimental comparative research design was best suited for this study (Babbie, 2017; Campbell & Stanley, 1963). After excluding any research subjects with potential conflicts of interest, a sample size of 96 students was obtained which met the assumptions for statistical hypothesis testing in a quantitative study design (Frankfort-Nachmias & Leon-Guerrero, 2015). This type of methodology was consistent with the methodology used in other studies which have examined career choice variables for underrepresented student populations in STEM settings (Fouad & Santana, 2017; Lent et al., 2018).

Definitions

Background contextual affordances: Any one of a series of external conditions or experiences that might influence the learning experiences of a student (e.g., socioeconomic status, availability of resources, technological access, family and community cultural influences, and education; Lent et al., 2001).

Environmental barriers: Any factor that has the potential to hinder or prevent a person from their educational and/or career choice goals (e.g., financial status, family influences, and cultural norms; Lent et al., 2001).

Environmental supports: Any factor that has the potential to assist or aid a person in achieving their educational and/or career choice goals (e.g., role models, mentors, family influences, and financial support; Lent et al., 2001).

Outcome expectations: A personal belief in the probable consequences of participating in a particular activity along with the values that are placed on each of those outcomes; these beliefs include the likely effects of one's actions (Lent et al., 1994).

Person inputs: Any one of a series of innate, personal attributes or characteristics that might influence the learning experiences of a student (e.g., gender, ethnicity/race, talents/abilities and disability/health; Lent et al., 2002).

Science self-efficacy: A belief in one's ability to successfully perform the tasks and thought processes associated with science; this belief is dynamic in nature and depends on a complex interaction of internal and external factors (Lent et al., 1994).

STEM: An interdisciplinary approach to education that combines problem-solving, creativity, and critical thinking skills with real-world applications across two or more of the areas of science, technology, engineering, and mathematics in partnership with community and industry stakeholders to prepare students to be successful on a global scale (Hemmingway, 2015; Nathan & Nilsen, 2009).

Task interest: A personal liking for certain activities due to the extrinsic and intrinsic rewards that will be provided by completing those tasks (Lent et al., 1994).

Assumptions

I based this study on several assumptions. Students in the study were responding to a survey about their experiences after participating in a citizen science program. Therefore, there was an underlying assumption that those students responded honestly and openly about their perceptions of their own self-efficacy, task interest, and outcome expectations for this study to produce any meaningful results about the relationship between those career choice variables and the person input of gender and ethnicity. Since the participants in this study included cohorts of students from three different years of the STEM intervention program, there was also the assumption that the student experiences and the citizen science curriculum were similar for each of those cohorts.

Scope and Delimitations

The scope of this study was based the certain study boundaries. One of those boundaries was the purpose of this quantitative study, which was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender, and their ethnicity after participating in a citizen science STEM intervention program. The initial portion of Lent et al.'s (1994) SCCT model defined the scope of this study by providing science self-efficacy, outcome expectations, and task interest as career choice variables that were applicable at the middle school level. Another boundary was the geographic situation of the citizen science program that the student participants experienced. The program was a partnership between a single school district and a private college in the northwestern United States.

The delimitations of this study involved the selection of student subjects for participation in the study, the emphasis on certain person inputs, and the quantitative methodological approach of this research. I only collected data from the eighth-grade component of the STEM intervention program since the seventh-grade portion did not place any emphasis on citizen science. Each student participating in the study was influenced by a variety of person inputs and background contextual affordances, but this study focused only on the impact of gender and ethnicity on the learning experiences of those students. While individual perceptions of this citizen science experience were valuable in nature, time and limited resources prevented the collection of that type of qualitative, interview data so the conclusion of the study was bounded by quantitative, survey responses.

Limitations

The research design of a study often creates limitations. One of those limitations was the use of a posttest only design. Since the study participants had already participated in the citizen science STEM intervention before the survey data were collected, no pretest of their self-efficacy, task interest, and outcome expectations was recorded before participation in the program. This study design lead to some distortion in the data but met the available time frame for the data collection (Trochim, 2006). Another limitation for this study was the fact that a significant amount of time had passed since participation in the citizen science intervention for the 2017 and the 2018 cohort of students. This passage of time caused some of the participants to not have a clear memory of their participation in the STEM intervention but allowed for the assessment of perceived gains in career choice variables for the students in each cohort (Trochim, 2006). The last limitation for this study was the fact that some modifications were made to the CSSES instrument in order to make it fit the parameters of the STEM content of the citizen science program (Hiller & Kitsantas, 2016). The original instrument was designed and validated for use with a horseshoe crab program and included a science content measure with separate pretests and posttests. The version that was used in this study was reworded to be applicable to a water quality program, excluded the science content measure, and used only a posttest measure in the design. These modifications influenced the validity scores for the CSSES.

Significance

This study may contribute to the field of STEM education by providing insight into how innovative citizen science learning experiences can support the STEM career goals and choices of underrepresented student populations. As shown in the work of Fouad and Santana (2017) and Prakash and Tobillo (2017), the use of STEM intervention strategies which impact science self-efficacy, outcome expectations, and task interest in these disadvantaged students could allow them to overcome environmental barriers which might disrupt their career choice pathways. However, little is known about the career choice variables of middle school aged female and ethnic/racial minority who have participated in citizen science programs. This study filled a gap in the literature of my discipline by providing informative quantitative data regarding the differences in science self-efficacy, outcome expectations, and task interest scores that occurred between students, specifically underrepresented populations, involved in innovative STEM instructional practices, like citizen science.

The results of this study may inform the professional practice of STEM educators when it comes to choosing innovative curricula which provide social and emotional connections to the content material to engage nontraditional student populations with STEM courses and career pathways. Other educational stakeholder groups, like industry and community partners, may use the data from this study to gain insights into how to better support the development and implementation of high quality, impactful STEM intervention programs which increase STEM literacy and enrich the diversity and representation of all student populations in the STEM career pipeline. Moderating science self-efficacy, outcome expectations, and task interest helped traditionally underrepresented groups in the STEM career pipeline to develop their career goals and choices which lead to positive social change for these populations of students.

Summary

In this chapter I described my quantitative research study. In the background section, I provided an overview of the research that supports this study. My problem and purpose statements helped to focus this study on the difference in scores by gender and ethnicity of the career choice variables of science self-efficacy, outcome expectations, and task interest for middle school students that have participated in a citizen science STEM intervention program. I used the proposed RQs to direct my study within the quantitative paradigm and in the theoretical framework section, I outlined the SCCT model (Lent et al., 1994) that guided the scope and nature of this research. In the nature of the study section, I highlighted my rationale for the nonexperimental comparative design of this research study. The definitions section allowed me to clarify key terminology to help create context for the application of those words to this study. In the assumptions, scope and delimitations, and limitations sections, I have set the boundaries for this study. I concluded Chapter 1 by explaining the significance of this study and the potential impact that it had in professional practice within my educational discipline. In Chapter 2 I will describe my literature search strategy, provide a more in-depth overview of my theoretical framework, and provide a thorough review of current literature as it pertains to the theme of this study.

Chapter 2: Literature Review

Introduction

The purpose of this quantitative study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender and their ethnicity after participating in a citizen science STEM intervention program. Specifically, this study focused on the interactions of variables from the SCCT framework to understand how person inputs such as gender and ethnicity influenced career choice predictors like self-efficacy, outcome expectations, and task interest when mediated by learning experiences like citizen science STEM intervention programs (Lent et al., 1994). The problem was a lack of understanding of how gender and ethnicity might lead to differences in the science self-efficacy, outcome expectations, and task interest of students who have participated in STEM intervention programs at the middle school level. Researchers have demonstrated that there are strong correlations between the career choice variables of self-efficacy, task interest, and outcome expectations and person input variables of gender and ethnicity/race (Fouad & Santana, 2017; Lent et al., 2018; Turner et al., 2017). However, these studies do not address how learning experiences mediate the influence of those person input variables on career choice variables. In this study I examined underrepresented populations of middle school students who had participated in citizen science STEM programs as they engaged in STEM career choice behaviors to address the issue of females and ethnic/racial minorities leaving the STEM educational and career pipeline.

Chapter 2 begins with the literature search strategy and theoretical foundation for the study. In the literature review section, I will outline relevant concepts from current research related to the problem and purpose of this study. First, I will describe the SCCT constructs that served as a framework for this work as they applied to my research variables. Next, I will develop a definition of the term *STEM* that incorporates the history of the topic, the ways in which the term is used in educational and policy contexts, perceived problems with the acronym, and the ways that the individual disciplines are integrated in practice. Then, I will present an overview of STEM educational and career pathways with an emphasis on the metaphor of a leaky pipeline with gaps that require environmental supports. Additionally, I will discuss underrepresentation of certain demographics of the population in these pathways and provide details about the stereotyping, bias, and experiential barriers faced by these subpopulations and their STEM-capable strengths and abilities. Following that discussion, I will characterize effective STEM enrichment programs by explaining the types of programs and indicators of their effectiveness as well as presenting the shared authentic, community-building, and STEM-specific experiences of these programs. Finally, I will define citizen science programs by specifying the learning outcomes of these experiences, describe concerns about these programs, and consider the role of place-based citizen science. I will end by introducing the CSSES (Hiller & Kitsantas, 2016) as a useful instrument for collecting data on my study variables and by addressing the gap in this body of literature that my study filled.

Literature Search Strategy

I used a variety of scholarly sources in this review of current literature. These sources included empirical research articles from peer-reviewed journal articles, books, stakeholder policy statements, and published reports. Databases accessed included IEEE Explore Digital Library, PsycARTICLES, Google Scholar, SAGE Journals, EBSCOhost, Science Direct, ERIC, Directory of Open Access Journals, Taylor and Francis Online, Education Source, and Expanded Academic ASAP. Relevant documents from the past five years uncovered several key themes for this research study: issues with defining STEM, STEM educational and career pathways, underrepresented populations in STEM, effective STEM intervention and enrichment programs, and citizen science. Search terms for these topics included *social cognitive career theory*, *underrepresented STEM populations*, *self-efficacy*, *STEM education*, *science education*, *outcome expectations*, *task interest*, *middle school*, *career goals*, *person inputs*, *background contextual affordances*, *gender, ethnicity*, *STEM policy*, *STEM skills*, *STEM literacy*, *science literacy*, *STEM career pathways*, *STEM pipeline*, *STEM gap*, *women and STEM*, *STEM intervention program*, *STEM enrichment*, *effective interventions*, *out-of-school*, *formal STEM interventions*, *informal STEM interventions*, *citizen science*, *crowd-sourced science*, *public participation*, *community-based monitoring*, *place-based citizen science*, and *citizen science self-efficacy scale.* As an article was identified as pertinent to this study, it was printed and color-coded by major theme and filed in a binder. I used a literature review matrix to catalogue studies and public documents by framework, purpose and problem, methodology and design, findings, and relevance to the current study concepts. Key terms and reference sections from the printed documents were used to extend previous search results. Once the same author names started repeatedly showing up and no new ideas were shared, saturation was reached.

Theoretical Foundation

The theoretical framework for this study was SCCT (Lent et al., 1994). Lent et al. (1994) developed SCCT to create a unifying theory of how social-cognitive processes affect career decision-making process. The authors of the theory attempted to combine many existing career choice theories which shared common conceptual themes like self-efficacy, learning experiences, and outcome expectations.

History and Use of the Social Cognitive Career Theory

SCCT has its foundation in the work of Albert Bandura in the area of behavioral and cognitive psychology (Lent et al., 1994, 2002). Lent et al. (1994, 2002), the authors of SCCT, drew heavily on Bandura's self-efficacy theory as well as his later work with SCT (Bandura, 1977, 1986). Bandura (1977) theorized that self-efficacy in any context is affected by four primary factors: performance accomplishments, vicarious experiences, verbal persuasion, and physiological states. SCCT incorporates all these factors into the career decision-making model as a single variable called *learning experiences* (Lent et al., 1994). Bandura (1986) later focused self-efficacy inputs into a more complex explanation of how learning and behavior are affected by social contextual influences like self-efficacy (the belief that one is capable of performing a task); behavioral feedback (like receiving positive responses from family, peers, and mentors); and environmental aspects (like supports and barriers). In developing SCCT, Lent et al. (1994, 2002) extended those social-cognitive influences into the realm of career development and adapted and applied SCT to explain how academic and career choices develop and are made by individuals. Lent et al. (2002) acknowledged that some pathways and connections in their theory do not directly follow SCT but included them, nonetheless, because they wanted to focus on how learning experiences could guide academic and career choices.

SCCT has been used by researchers to understand how self-efficacy, learning experiences, and environmental factors play a role in the underrepresentation of career interest and choice in STEM career fields by culturally diverse subpopulations of students (Alhaddab & Alnatheer, 2015; Flores, Navarro, & Ali, 2017; Fouad & Santana, 2017; Garriott, Navarro, & Flores, 2017; Navarro, Flores, & Worthington, 2007). The applicability of the SCCT model to research on middle and high school aged students across gender and ethnic/racial subgroups has been well established, and the relationship between interventional learning experiences and self-efficacy and outcome expectations in the areas of math and science has been confirmed (Fouad & Santana, 2017; Lent et al., 2002), which supported the use of this theory in my study of a similar student population. SCCT has served as the major foundational theory for addressing the lack of diversity and representation in STEM career fields because it emphasizes the importance of self-efficacy and student preparation early in the educational process before career choice actions take place (Alhaddab & Alnatheer, 2015; Fouad & Santana, 2017). Collecting data about student career choice variables in middle school and high school aged students during my study aligned with the emphasis that prior researchers using SCCT have placed on self-efficacy and STEM career choice goals at the precollege level for underrepresented student demographics (Flores et al., 2017; Garriott, Navarro, et al., 2017).

Theoretical Propositions

Lent et al. (1994) developed a social-cognitive model for understanding the pathways of influence, both direct and indirect, among different variables which impact the career choice and decision-making process. The SCCT model consists of 12 propositions for explaining the mechanisms behind how people develop academic and career goals and how they act upon those goals (Lent et al., 1994, 2002). Each of these paths is causal in nature and the model is a composite representation of interlocking performance, interest, and choice models.

Proposition 1 of Lent et al.'s (1994) SCCT states that there is a direct relationship between the occupational/academic interests of an individual and his or her self-efficacy and outcome expectations. Proposition 2 stipulates that occupational interests are influenced by the vocational abilities as mediated by self-efficacy. Proposition 3 indicates that self-efficacy beliefs lead to career choice goals (aspirations or plans to enter a certain career) and choice actions (entry actions like declaring a major). Proposition 4 mirrors that pathway with the statement that outcome expectations also increase the likelihood of selecting and obtaining a particular career. Proposition 5 predicts that occupational task interests influence people to develop occupational or academic goals in which those tasks are useful. Proposition 6 states that if career goals are clearly expressed near the time of career choice, those goals will influence which occupational or academic field the person selects. Proposition 7 indicates that career task interests will indirectly influence career choice actions through the choice goals pathway. Proposition 8 is foundational to the performance component of the model since it claims that self-efficacy and outcome expectations influences academic and career performance attainment due to their impact on career goal setting. Proposition 9 outlines the connection between ability and career/academic performance attainment through the mediator of self-efficacy beliefs. Proposition 10 predicts learning experiences as the major source of self-efficacy beliefs and outlines the four types of experiences: performance accomplishments, vicarious learning, social persuasion, and physiological reactions. Proposition 11 mirrors that pathway by implying that outcome expectations are also derived from those learning experiences. Proposition 12 ties the quality and level of performance attainment to the relationship between outcome expectations and self-efficacy beliefs. In my study, I focused on six of the 12 propositions because the CSSES had only been validated with proposition pathways 1, 2, 3, 7, 8, and 10. The participants for my study were middle and high school aged students so they had not yet made it to the career choice action or performance attainment portions of the flow chart SCCT model.

The authors of the SCCT have detailed 10 different career choice variables in their model (Lent et al., 1994, 2002). Lent et al. (1994) chose to conceptually represent their SCCT with a flow chart model which shows each of the career choice variables and connecting proposition pathways moving from left to right to show the influence between the variables. The first variable is *Person Inputs* (Lent et al., 1994, p. 93). Individuals enter the SCCT model with defined Person Inputs like gender, ethnicity/race, and health as well as the second variable, *Background Contextual Affordances* like socioeconomic status, family experiences and resources, social policies and cultural norms (Navarro et al., 2007, p. 322). With the mediating effects of these variables, individuals continue along pathways through the model by way of the third variable *Learning Experiences*. These Learning Experiences fall into four principle areas: performance accomplishments (experiencing success or failure in mastering a task), vicarious experiences (watching another person model a task), verbal persuasion (having influential peers, parents, or teachers offer praise/encouragement or criticism surrounding a certain activity), and psychological states of arousal (experiencing emotional conditions like depression, stress, or pleasure while participating in a task; Bandura, 1977, p. 195). Success or failure during these Learning Experiences leads to *Self-Efficacy* and *Outcome Expectations*, variables four and five, which foster *Interests* or likings for certain activities, identified as variable six. The CSSES refers to this variable as Task Interests (Hiller & Kitsantas, 2016, p. 551). Interests provide a path toward career *Choice Goals and Actions* for people who are considering their career and academic options. Along the right-hand side of the SCCT flow chart model are *Contextual Influences Proximal to Choice Behavior*, variable seven (Lent et al., 1994). These influences come in the form of supports and barriers which occur close in time to the career decision-making process. While *Performance Attainment* is often depicted as the terminal step in the SCCT model, Lent et al. (1994) posited a bidirectional link between that end result and the performance accomplishments category of Learning Experiences, thus completing a closed and repeating feedback loop for each individual based on their level of accomplishment. In my research, I examined the career choice variables on the left-hand and central portions of the SCCT flow chart model because the CSSES had only been validated with those variables. The subjects of my study were middle and high school aged students, so they had not yet made it to the career choice action or performance attainment portions on the right-hand side of the model.

Lent et al. (2002) consider self-efficacy, outcome expectations, and choice goals as the central variables of their career development model. Self-efficacy is seminally defined by Bandura (1986, p. 391) as an individual's belief about their capability "to organize and execute courses of actions required to attain designated types of performances" and translates to a dynamic interaction of personal beliefs about the ability to be successful in a chosen career-related activity when placed in the context of the SCT (Lent et al., 2002). Outcome expectations are "personal beliefs about the consequences or outcomes of performing particular behaviors" (Lent et al., 2002, p. 262). Choice goals are conceptualized by Lent et al. (1994) as a "dynamic enterprise" which are "the intention to engage in a particular action or series of actions" (p. 94). Goal intentions are distinct from and serve as modifiers for choice actions such as career entry behaviors.

Rationale for Theory Use

The SCCT was a good choice as the theoretical framework for my study for several reasons. First, the SCCT was justified because it aligned with the purpose of the study. The purpose of this study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender, and their ethnicity after participating in a citizen science

STEM intervention program. The authors of the SCCT framework developed their interlocking interest, choice, and performance models to assert that relationships between person inputs like gender, and ethnicity and variables which mediate career choice, like self-efficacy, outcome expectations, and interests exist for people who are developing career goals and actions (Lent et al., 2002). Next, the SCCT provided a justification for studying specific variables. I looked at the self-efficacy, outcome expectations, and task interest of underrepresented populations of middle school students who had participated in citizen science learning experiences. Since the SCCT model was an existing theory for the interactions between the career choice variables that I was interested in and since there was already a validated measurement instrument available, the use of this theory as the framework for my study was appropriate (see Figure 2).

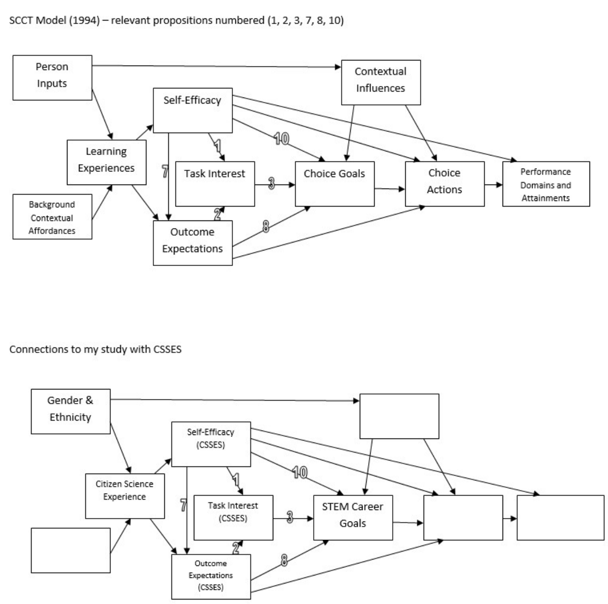

Figure 2 Comparative model showing relationship between social cognitive career theory with the predicted paths from Lent, et al. (1994) and the variables which are relevant to the current study.

Last, the SCCT provided a validated, established theory on which data analysis could be examined. SCCT has been shown to be a stable model across a wide range of sub-populations, including gender and ethnic/racial status, for predicting STEM career interest and choice (Fouad & Santana, 2017). Lent et al. (1994) note that their theory can serve as a useful framework for expanding current understanding of how females and minority groups experience the career choice process and offer their work as a lens through which further research can elaborate on the mechanisms of career choice and development for these populations. By scrutinizing data on the career choice variables of self-efficacy, outcome expectations, and task interest, my research used the well-accepted work of Lent et al. (1994, 2002) to support and help interpret my findings for underrepresented student populations who had participated in STEM intervention learning experiences.

In the following sections, I will summarize the literature relating to the major themes and concepts of my study. I will begin with defining the STEM acronym as it is currently used by educators and policy makers and then I will identify the way that I will use the term in my research. Next, I will use a pipeline metaphor to explain traditional educational and career pathways for students from early childhood through career attainment. The next section of my literature review will identify the categories of students who are underrepresented in these STEM pathways and identify some barriers that prevent them from entering and persisting in the STEM educational and career pipeline. My review of the literature will then explore various types of STEM intervention and enrichment programs and outline the characteristics of an effective program. The final section of my literature review will define citizen science and provide background information on how citizen science programs affect the people who participant in those experiences.

Definition of STEM

STEM (science, technology, engineering, and mathematics) skills and competencies are current buzzwords in the world of education as well as in the public policy area. National and global attention is being paid to finding ways to increase the number of STEM employees who are being produced by educational systems to meet the growing demand for innovation and technology in the 21st century (Breiner et al., 2012; English, 2017; White, 2014; Xie et al., 2015). STEM occupations are a growth sector of the international job market and require workers who have the creative, problem-solving skills needed to fill these job openings (Oleson, Hora, & Benbow, 2014; Siekmann & Korbel, 2016). In this section of the literature review I will provide a history of the use of the term STEM and then move to a discussion of the current definition in policy and educational spheres. I end the section addressing the problematic elements of the acronym STEM itself, as well as a discussion on the practice integrated STEM education.

History of STEM

STEM education has existed in various formats for a long time. As early as the 1980's, organizations like the NSF, the American Association for the Advancement of Science and the National Commission on Excellence in Education expressed interest in increasing science, mathematics, and technology literacy in the United States in order to help the country be more competitive in the global economy (Breiner et al., 2012). The

NSF is credited with adding the discipline of engineering into this educational reform movement and created the acronym SMET in a policy paper in 1996 (M. D. George et al., 1996). This newly-crafted acronym was met with criticism in the early 2000's due to the potential confusion with vulgar words like "smut" so an NSF division director named Judith A. Ramaley suggested that the order of the letters be rearranged to form the now familiar STEM term (Breiner et al., 2012; Holmlund et al., 2018; Lucietto, Russell, & Schott, 2018; Sanders, 2009). The push for STEM education continued during the Obama-Biden administration with the rollout of the Educate to Innovate Initiative and its partner programs like Change the Equation, 100Kin10, and the creation of a STEM Master Teacher Corps (Office of the Press Secretary, 2012).

The STEM movement is not only a national phenomenon but also an international one. Current literature that addresses the need for the education of a STEM-literate population of citizens comes from a wide variety of developing and industrialized nations as each country seeks to educate a generation of critical-thinkers who can solve real-world problems using 21st century skills like creativity and collaboration (Corlu, Capraro, & Capraro, 2014; Kennedy & O'Dell, 2014; Knipprath et al., 2018; Siekmann, 2016). STEM competencies and skills are viewed by many nations to help their youth become competitive and fill the high-tech jobs required by an innovative and ever-changing world (English, 2017). STEM as an educational acronym and as a national policy strategic focus has become part of the global landscape.

Current Definitions in Policy and Educational Spheres

Although frequently used in educational and political settings, the STEM acronym has no commonly agreed upon, functional definition. Any type of educational or vocational program with a connection to science, technology, engineering, or mathematics can be included in the umbrella term of STEM so the definitions for the acronym vary depending on which stakeholders are doing the defining (Slavit, Nelson, & Lesseig, 2016). Policy makers concerned with employment and productivity and some educational policy groups view STEM as a listing of individual disciplines which are often taught in individual silos while some progressive educators opt for multidisciplinary (learning skills in separate disciplines and classes but within a common theme) and transdisciplinary (using skills from multiple disciplines in a single class to address a real world problem) linking of two or more of those content areas (Breiner et al., 2012; English, 2017). Other definitions include the integration of 21st century competencies like creativity, critical thinking, and resilience in the STEM definition (Hemmingway, 2015; Siekmann, 2016; Siekmann & Korbel, 2016). With its ability to impact a wide variety of sectors across educational and occupational interest groups, different goals and methodologies have muddied the waters when it comes to the creation of a definition for STEM and STEM education.

The NSF, acting as a policy-setting leader in the world of STEM, uses a broad definition for STEM that includes the natural sciences, computer and information sciences, engineering, and math, as well as social and behavioral sciences (Breiner et al., 2012; M. D. George et al., 1996). Any NSF-funded proposal or activity can fit into one of the major STEM disciplines and still be considered as a STEM project under this general definition of STEM (Holmlund et al., 2018; Sanders, 2009). NSF’s approach to defining

STEM creates a list of distinct and individual fields which fall underneath the STEM acronym without distinguishing the need for any interaction among those fields.

One of the major stakeholder interests in the STEM acronym comes from the enormous potential that STEM occupations hold for economic success and innovation in the global forum (Carnevale, Smith, & Melton, 2011; Oleson et al., 2014; Siekmann & Korbel, 2016). Xie et al. (2015) make the statement that a STEM-educated worker has a more universal set of skills than one who does not have that STEM training, so a STEM education plays a role in social mobility for disadvantaged populations of persons. Defining the term STEM also requires the creation of a definition for STEM occupations. Several major systems are used in the United States for the classification of job categories. These systems include the Bureau of Labor Statistics' Standard Occupational Classification system, the U.S. Department of Labor's O*Net system, the NSF's Science and Engineering occupations listing, and the Center on Education and the Workforce at Georgetown University (Carnevale et al., 2011; National Science Board, 2018b; Oleson et al., 2014; Siekmann & Korbel, 2016). All these databases are following the national trend of categorizing occupations based on the types of knowledge, skills, and education needed to perform the job rather than just relying on the types of tasks that each job entails (Carnevale et al., 2011; Oleson et al., 2014). Depending on how each agency defines STEM, the number of detailed STEM occupations can range from 62 to 184 and the major grouping categories for STEM occupations goes from three (computer & mathematical; architecture & engineering; life, physical, & social science) to 10 (architecture & engineering; management; education, training, & library; business &

financial operations; life, physical, & social science; arts, design, entertainment, sports, & media; office & administrative support; computer & mathematical; community & social services; healthcare practitioner & technical; Oleson et al., 2014, p.7). The Idaho Department of Labor uses a broad definition and lists four categories of STEM occupations (life & physical science, math, engineering, and information technology; social science; architecture; and health care) with 184 detailed occupations (Hemmingway, 2015). Defining STEM occupations in such a wide range of categories and specific occupations poses a challenge for estimating job numbers, occupational trends and needs, and estimated educational requirements and wages.

Developing STEM literacy is a crucial criterion for many stakeholder groups as a definition for STEM is created as there are differing viewpoints for which STEM literacy encompasses. Components of scientific literacy include the knowledge and skills needed to explain natural phenomena and make evidence-based conclusions about STEM topics, understand the key features of each of the STEM disciplines as they contribute to inquiry and design, an awareness of the impact that STEM disciplines have on culture and in the material world, and a willingness to address STEM related issues as a concerned and reflective member of society (Bicer et al., 2017; Bybee, 2013; Kennedy & O'Dell, 2014; Knipprath et al., 2018; Siekmann & Korbel, 2016). The concept of STEM literacy is becoming an increasing educational priority as countries acknowledge the growing need for STEM innovation and advancements in order to remain competitive with other countries (Knipprath et al., 2018; Siekmann & Korbel, 2016). Developing STEM competencies in the workforce allows countries to prepare their citizens with the technical expertise, the higher-order cognitive skills, and the socioemotional skills that will be required to succeed in the 21st century (Oleson et al., 2014; Siekmann & Korbel, 2016). Defining the components of STEM literacy, skills, and competencies can be a useful step in exploring the definition of the STEM acronym.

STEM education is a specialized branch of the STEM acronym. The National Research Council helped to establish boundaries for the way in which the STEM term would be defined and applied in educational settings with their STEM education goals (Holmlund et al., 2018). Successful STEM programs in the United States align with three overreaching goals: (a) increase the number of STEM innovators and people entering STEM professions, (b) develop a stronger STEM and STEM-related workforce, and (c) inclusively improve STEM literacy for all citizens (National Research Council, 2011). This approach to defining STEM education requires stakeholders to critically look at the acronym from a professional lens, a workforce development lens, and a literate citizenry lens.

A Problematic Acronym

While STEM is a popular acronym in the world of education and policy, it is not without issues. Criticism for this term comes internally and externally. External critics of the term STEM are concerned by the fact that the current emphasis on STEM is diminishing or ignoring the importance of the humanities in the educational process (English, 2017; Oleson et al., 2014). There is a movement among STEM educators to adapt the STEM acronym to be more reflective of interdisciplinary connections and to specifically address the need for innovation and creativity in STEM fields (Bicer et al., 2017; Conradty & Bogner, 2018; English, 2017). Educators from around the world are adding an A to form STEAM and include the arts into STEM (English, 2017; Holmlund et al., 2018). Bicer et al. (2017) argues that this is a misnomer since STEM fields are inherently creative. Other educators are interested in expanding the acronym even further by adding an R for technical reading and language to make STREAM (Ostler, 2012). Conradty and Bogner (2018) address the fact that the inclusion of artistic and creative subjects into STEM instruction will increase critical-thinking skills, all for more real-world applications, and even help encourage more students to be interested in what might be perceived as a dull subject area. Redefining STEM as STEAM or even STREAM could make it more reflective of the way in which scientists and engineers function.

STEM often receives internal criticism as well. Oleson et al. (2014) make the claim that STEM links too many unrelated and incomparable subject areas, each of which have their own skill and education requirements. The definition for STEM education seems to change based on the grade level at which it is being taught and the training of the educators who are providing the instruction (Lucietto et al., 2018; Xie et al., 2015). Elementary STEM classrooms are focused on curricula which are rich in science and math instruction while middle school and high school STEM courses use elective courses to pull in experiences in social sciences, engineering, and technology (Srikoom, Hanuscin, & Faikhamta, 2017; Xie et al., 2015). Post-secondary STEM instruction is built around individual disciplinary strands and varies widely in both experiences and outcomes (Xie et al., 2015). Finding commonalities among STEM subject areas remains a challenge for educators and policy makers.

Although the STEM acronym always consists of the same four letters, some critics make the argument that not all the letters are equally emphasized and sometimes letters are even missing from the term (English, 2017; White, 2014). Many researchers say that it is common in educational settings for STEM to be used interchangeably with science education and scientific literacy (Bybee, 2013; English, 2017; Srikoom et al., 2017). Srikoom et al. (2017) argue that practice is problematic since science teachers and STEM teachers require different skill sets and background knowledge in order to successfully do their jobs. Science and mathematics are emphasized in K-12 education, but the engineering and technology are underrepresented as individual disciplines and as part of integrated STEM curricula (White, 2014). There is also a general trend to equate the technology T with the use of computers or a similar technological tool rather than bringing in the problem-solving and design elements which are central to coding and computational thinking (English, 2017; White, 2014). While computer science, the study of computers, hardware, and software, falls underneath the STEM acronym, it is important to recognize the existence of computational thinking, or abstract problem-solving using pattern identification into the essence of STEM (Jacob & Warschauer, 2018). Engineering has been relegated to elective courses at the middle and high school grades rather than being an integral part of STEM classrooms and the engineering design process is not being adequately used to allow students to engage with real-world problems (English, 2017). The way in which the STEM term is currently being used in educational settings means that some of the letters in the STEM acronym are being taught in isolation from the rest of the disciplines or not being taught at all.

Understanding the relationship between the various components of STEM has been addressed by many researchers. Bybee (2013) proposed nine models of STEM integration that ranged from a single discipline with either math or science as the focus, to science as the core concept with technology and/or engineering as a supporting discipline, to the combination of two or three of the separate disciplines into an integrated approach, to a true transdisciplinary approach where all of the components are equally emphasized. Clearly defining the theoretical framework for this acronym is problematic due to the training and personal experiences of the educators and policy makers who are driving the advancement of STEM. One study of in-service teachers in Thailand found that only 20% viewed the STEM acronym through Bybee's transdisciplinary integrated lens and only 14% were familiar with STEM educational practices (Srikoom et al., 2017). A similar study of in-service teachers in the United States yielded a low initial number of teachers who had conceptualized STEM as an integrated program prior to an intensive STEM professional development program (Ring, Dare, Crotty, & Roehrig, 2017). STEM is not well conceptualized as a framework for understanding how teachers interact with the skills and knowledge bases which are inherent in science, technology, engineering, and mathematics content areas.

The Next Generation Science Standards (NGSS) were written by a consortium of content and pedagogical experts to drive educational reform in the area of science education in the United States (National Research Council, 2012; NGSS Lead States, 2013). Foundational to the publication of the NGSS was the concept of integrated STEM disciplines though the standards were still written as a means of increasing scientific literacy among elementary, middle, and high school students (English, 2017). Engineering finds a place in the document as part of the practices that scientists and engineers must be proficient at to do real problem-solving though the emphasis is still heavily on science content as the vehicle for learning these practices (Campbell & McKenna, 2016; Yager, 2018). The NGSS are furthering conversation about the definition and impact of STEM in public schools and for the future of the nation but the acronym is still being used to describe a program that is not a holistic representation of STEM disciplines (Campbell & McKenna, 2016).

Integrated STEM Education

Educators and policy makers follow the lead of the NSF in using a broad general definition for the STEM acronym that recognizes the individual disciplines of science, technology, engineering, and mathematics (Breiner et al., 2012; English, 2017; Hemmingway, 2015; Holmlund et al., 2018; Sanders, 2009; Siekmann, 2016). While this practice outlines the explicit meaning of the STEM term, this simplistic definition does not adequately conceptualize the innovative nature of STEM in industry and educational spaces (Sanders, 2009). Educators, both nationally and internationally, are moving towards a definition for STEM that captures the integration of content knowledge and process skills (Breiner et al., 2012; Corlu et al., 2014; English, 2017; Holmlund et al., 2018; Kennedy & O'Dell, 2014; Knipprath et al., 2018; Nathan & Nilsen, 2009; Siekmann, 2016; Srikoom et al., 2017).

One of the issues with the broad and general definition of the STEM acronym is that it creates a discrepancy between the way that educators are teaching STEM and the ways in which STEM is done by people who hold STEM occupations. Tillotson and Young (2013) performed a study of over 100 science teachers and found that when teachers and students are asked if they are “doing” STEM in their classes, many say that they are but on further inspection, most of what they are doing is memorizing facts and concepts about STEM. Corlu et al. (2014) addressed the need to reduce the gap between the compartmentalized and isolated method of teaching STEM subjects and an integrated STEM model which links content knowledge with authentic STEM competencies and skills. STEM educators must find a way to avoid uncoupling doing STEM and learning STEM as they model true STEM practices (Campbell & McKenna, 2016). Integrated STEM education may expose students to an environment which might encourage them to become innovative STEM professionals in the workforce and members of a STEM-literate population of citizens who can understand and do STEM.

Deconstructing the acronym of STEM allows for a better understanding of the holistic definition of integrated STEM. Siekmann (2016) developed a “House of STEM” analogy which places foundational literacy skills (e.g. numeracy), socioemotional skills (e.g. resiliency, curiosity, empathy), technical occupational skills (e.g. coding, design), higher-order thinking skills (e.g. critical thinking, creativity), and the improvement of economic innovation and productivity in a hierarchy underneath the roof of the STEM acronym. This model connects the education and employment components of STEM with self-efficacy and engagement within the sub-sets of STEM skills. Tanenbaum, Gray, Lee, Williams, and Upton (2016) outlined six interconnected segments of STEM education that include engaged communities of practice, accessible learning activities with risk and play, interdisciplinary approaches to solving "grand challenges", flexible and inclusive learning spaces, innovative and accessible measures of learning, and a culture which promotes diversity and opportunity in STEM. This model from the U.S. Department of Education places emphasis on inquiry and discovery in order to create engagement with STEM teaching and learning practices. Both Siekmann's and Tanenbaum et al.'s deconstructions of STEM into component pieces lead to a more in-depth conceptualization of how STEM content and skills fit into a rapidly changing global society.

When searching the literature for a useful, working definition of integrated STEM, researchers have turned to the work of the Southwest Pennsylvania STEM network (Holmlund et al., 2018; Slavit et al., 2016). Nathan and Nilsen (2009) brought together stakeholders from a variety of STEM interest groups to create this definition:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lesson where students apply science, technology, engineering, and mathematics in context that make connections between school, community, work, and global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (p. 3)

The state of Idaho has legislatively developed a similar definition of STEM which indicates a need for the integration of STEM content across all major disciplines with community and industry partnerships, 21st century skills, and real-world opportunities and practices (Idaho STEM Action Center Act, 2015). Following the lead of this legislative definition, Idaho's STEM Action Center has defined STEM to require the integration of at least two of the four STEM disciplines in interdisciplinary projects that align STEM education with the way that it is practiced in the workplace (Hemmingway, 2015). When defined this way, integrated STEM creates a bridge between the classroom and the world outside of those classroom walls.

Integration of STEM content areas creates an acronym which is no longer a simple listing of potential bodies of content knowledge and process skills which might be useful in a classroom or to an employer. Integrated STEM does not mean teaching science, technology, engineering, and mathematics nor does it mean adding technology and engineering ideas into a traditional math or science curriculum (Kennedy & O'Dell, 2014). Instead, it is an innovative pedagogical approach to instruction that transcends its constituent components and becomes a "metadiscipline" (Kennedy & O'Dell, 2014, p. 253). This superdiscipline allows students to explore complex and authentic problems and then to develop the skills necessary to innovatively solve them (Ring et al., 2017). The definitions of integrated STEM from the Pennsylvania STEM workgroup and the Idaho STEM action center served as the working definitions for my research study.

STEM Educational and Career Pathways

Developing a STEM-capable workforce and a STEM-literate citizenry is crucial to ensuring that the United States remains globally competitive (National Science Board, 2018a). STEM-capability and STEM-literacy are terms that are commonly used in the literature by educators and policymakers to discuss student proficiency in STEM contexts. For the purpose of this study, I defined STEM-capable and STEM literate students as those that have the aptitudes and abilities necessary to use STEM content to understand complex problems and to innovate solutions to those problems. STEM educational and career pathways play a fundamental role in helping to develop STEM-capable talent and then to retain and transition those students into STEM careers (VanIngen-Dunn et al., 2016). Encouraging students to enter STEM career pathways at an early point and then finding ways to help them to persist in those pathways are possible solutions for the current shortages that the U.S. STEM workforce is experiencing (National Science Board, 2018b; Noonan, 2017). In this section of the literature review I will provide an overview of traditional STEM pathways from education into the workforce and then move to a discussion of the use of the STEM pipeline as a metaphor for STEM pathways and the gaps in this leaky STEM pipeline. I end the section addressing the environmental supports that are available for students in STEM career pathways.

Traditional STEM Pathways from Education to the Workforce

The United States is experiencing a dynamic shift in the requirements of a forward-thinking workforce based on the demands of global competitiveness in the areas of innovation and productivity. Employment in STEM-related job fields has grown at a much faster rate during the last decade than non-STEM-related job areas and that growth trend is predicted to continue for the next decade (Noonan, 2017). The U.S. Bureau of Labor Statistics stated that in 2015, there were 8.6 million STEM jobs in the United States, which represented 6.2 percent of the employment market and that 93 percent of these STEM jobs had wages above the national average (Fayer, Lacey, & Watson, 2017).

Having a STEM-capable workforce is essential to ensuring that the United States maintains a competitive economic and social advantage in the global arena since STEM research, development, and educational indicators correlate strongly with other measures of a healthy and well-educated nation (Connors-Kellgren, Parker, Blustein, & Barnett, 2016; National Science Board, 2018a, 2018b). STEM skill sets help create a nation that is innovative and competitive with other countries, like China, which are developing a similar set of high-tech industries and STEM-capable workers (National Science Board, 2018a). The United States trails other industrialized nations, including China, in granting 4-year college degrees in STEM career fields (Diekman & Benson-Greenwald, 2018; Sahin, Ekmekci, & Waxman, 2017). While the number of international students graduating from STEM doctoral programs is growing, the number of domestic students successfully competing these programs has remained flat (Diekman & Benson-Greenwald, 2018). Ignoring these trends in education and workforce development could put the United States at a disadvantage in the future. STEM career knowledge development is crucial for ensuring that the United States retains and develops STEM-capable students and then transitions them into STEM career fields.

Development of STEM career knowledge often happens in conjunction with student progression along STEM educational pathways. Traditional educational pathways to STEM career fields often include early interest in STEM content and continue on to participation in a series of rigorous mathematics and science courses during high school before moving on to the declaration of STEM majors during post-secondary schooling (Ashford, Lanehart, Kersaint, Lee, & Kromrey, 2016; Blotnicky et al., 2018; Maltese &

Tai, 2011). STEM career pathways often follow the components of the Science Foundation Arizona model outlined by VanIngen-Dunn et al. (2016) in transitioning from a recruitment phase to a retention phase and then culminating in the workforce phase. Successful STEM educational outreach and career exploration leads to the foundational knowledge and skills needed to engage students with continuing enrollment in STEM programs and eventually creating transferable certifications and STEM degrees which are recognized by business and industry (VanIngen-Dunn et al., 2016, p. 160).

STEM career knowledge develops as students explore their perceptions of STEM careers. In a quantitative study of Canadian public school students in seventh and ninth grades using mathematics self-efficacy scores, the data showed that the relationship between the intention to choose a STEM career and student positive attitudes and motivation towards STEM content is highly time-sensitive with middle school and early high school being crucial gates in the timeline for STEM career pathway development (Blotnicky et al., 2018). This window of opportunity is clouded by the fact that STEM career knowledge is very limited in middle school students. Blotnicky et al. (2018) used a survey administered to 1448 students to determine that 70 percent of middle school students indicated that they were interested in STEM careers, those same students were unclear about how technical, scientific, creative, and expressive skills were related to pursuing those STEM careers. In a different qualitative study of five public high school students from underrepresented STEM populations, an analysis of the interview data indicated that students who have clear perceptions of STEM as their future occupation are able to better plan for and achieve those goals than students who have not made connections between their current situation and their future occupation (Zhang & Barnett, 2015). Taken together, the works of Blotnicky et al. and Zhang and Barnett demonstrate the importance of clear perceptions of STEM content and skills for students contemplating future career options. Zhang and Barnett's (2015) data also showed that interactions with parents, peers, and friends played a major role in influencing career perceptions. A quasi-experimental research study performed by Knowles, Kelley, and Holland (2018) on a cohort of engineering and science teachers collected data which indicated that teachers play a significant role in helping create awareness of STEM career pathways with situated STEM learning for students but they often do not understand STEM pathways in real practice. The disconnect between the steps in the traditional STEM career pathways and the development of STEM career knowledge requires further study.

There are several variables which may influence career pathway choices for students who are transitioning from the education system into the workforce. Variables of self-efficacy, task interest, and outcome expectations fall into Bandura's (1977) domains of individual, behavioral, and environmental influences (Blotnicky et al., 2018). In a longitudinal study of student data starting with tenth graders and following them eight years past high school graduation, the research data showed that math self-efficacy and personal perception of science preparation were statistically significant predictors of enrollment in a STEM college major for students from all major demographic subgroups, including females and ethnic/racial minorities (Alhaddab & Alnatheer, 2015). An exploration of persistence in STEM degrees at the college level extends Alhaddab and

Alnatheers's work with high school students and STEM major choice. In a quantitative study of 130 college engineering students, the results indicated engineering-related learning experiences predicted outcome expectations that the student would earn a bachelor's degree in engineering, which in turn predicted persistence in the pursuit of the engineering degree (Garriott, Navarro, et al., 2017). Research conducted with high school students indicates a similar linkage between career choice variables like outcome expectations and persistence in STEM courses and career decisions. A quantitative study of 366 urban high school students from tenth through twelfth grades explored the interrelatedness of career choice variables and found that self-efficacy and outcome expectations were positively associated with STEM interests and that the three variables predicted career choice actions for students in the form of persistence in rigorous high school courses in math and science (Turner et al., 2017). Researchers have investigated the impact of these career choice variables on students who are at the high school and college level milestones in STEM occupational pathways but research regarding younger students and the early steps in those traditional pathways is currently lacking.

Researchers who study STEM career pathways tend to fall into two dominant groups, those who use the SCCT and those who use Expectancy Value Theory (EVT). Each have their own strengths and weaknesses. SCCT was developed by Lent et al. (1994) in order to make connections between the construct of self-efficacy, interests, and career choice actions. Le and Robbins (2016) used SCCT to develop a model using longitudinal data which linked STEM abilities and interests in middle and high school to STEM abilities and interests in early adulthood. Sahin et al. (2017) applied the SCCT framework to their study of the relationship between personal and environmental factors and STEM career choice in young adults who have graduated from high school and are attending or have already graduated from college since SCCT allowed them to explore the three main aspects of career choice behaviors (i.e. individual, environmental, and behavioral) as a comprehensive model. SCCT is limited in that self-efficacy cannot explain all career choice actions and that it is domain-specific in application and does not allow researchers to explore the constructs of interests and self-efficacy as independent concepts. Another lens for evaluating these career choices is EVT, which was developed by Eccles et al. (1983) in order to explore how persistence and performance are impacted by student expectancy for success at a given task and how much that student places value on the task. Ball et al. (2017) used this framework to investigate how fourth and fifth graders would change their STEM affinities and academic expectations about their STEM abilities based on the importance that they placed on STEM careers. Maltese and Cooper (2017) used EVT to look at the reasons for STEM persistence in a group of adult participants from STEM and non-STEM career fields. Again, the weakness of EVT is that expectations and task value do not account for all career choice actions in this domain-specific decision-making model. SCCT and EVT are both grounded in the social cognitive theory of Bandura (1977) so they are very similar in their conceptual constructs though they each use slightly different terminology to discuss those ideas. The major difference between these models comes in how they package the different aspects of the career decision-making process into a predictive model. In SCCT, self-efficacy, task interest, and outcome expectations are located at the start of the model and high determinative value is placed on these constructs while in EVT, these same constructs are relegated to a later place in the model based on the student's short- and long-term goals and their expectations for subjective task value.

The STEM Pipeline as a Metaphor

The pathway between elementary school and STEM occupations is often envisioned by educators and policymakers as a metaphorical pipeline which starts out with many STEM-possible students and gradually narrows as those students make progress through several checkpoints or gateways until it at last ends in a small number of people entering STEM careers. This metaphor was first proposed by Berryman (1983) as a conceptual model for addressing the trends and causes behind the underrepresentation of certain subpopulations entering into advanced science and math degree programs at the post-secondary level. This pipeline metaphor has become the prevalent model for discussing issues like recruitment and retention of STEM-capable students along their educational pathway in the United States as well as internationally (Ball et al., 2017; Bergeron & Gordon, 2017; Cannady, Greenwald, & Harris, 2014; Doerschuk et al., 2016; Knipprath et al., 2018; Maltese & Tai, 2011; Mendick, Berge, & Danielsson, 2017; Redmond-Sanogo, Angle, & Davis, 2016; van den Hurk et al., 2019).

Along with the pipeline metaphor comes the concept of *leaks* at each of the checkpoint gateways. Alper and Gibbons (1993) coined the term "leaky" (1993, p. 1) after interviewing the director of women's studies from the University of South Carolina to address the idea that not all students who entered the pipeline were making it through to the other end and the ones who were dropping out of STEM career pathways were predominantly female. This concept of leaks in the pipeline has been expanded to include other subpopulations like ethnic/racial minorities, students from low SES households, and first-generation college students (Ball et al., 2017; Bennett Anderson, Moore, & Slate, 2017; Doerschuk et al., 2016). In a large scale, nationally representative, longitudinal study of elementary and middle school aged students, Morgan et al. (2016) collected quantitative data about child and family characteristics, school demographics and academic climate, general student knowledge of science content, science, reading, and mathematics achievement, self-regulation of learning-related behaviors, and parenting quality and the results indicated that these leaks in the career pipeline stem from achievement and opportunity gaps for underrepresented student populations. Strategies for dealing with these leaks come in the form of either pressurizing the pipeline by encouraging more students to participate in STEM career activities at the beginning of the pipeline or stopping the leaks as they occur at each of the crucial junctions along the pipeline (Ball et al., 2017; Redmond-Sanogo et al., 2016). While the leaks in the traditional STEM pipeline happen at various points along that pathways, there is also evidence to support the idea that many scientists and engineers advance through the pipeline along a consistent set of gateways. Cannady et al. (2014) conducted a longitudinal data analysis of using the National Educational Longitudinal Study of the eighth grade class of 1988 data set in order to determine how many currently practicing scientists and engineers followed a traditional STEM pipeline into their career and to determine where STEM career pathways deviated from that pipeline. Critical milestones include high school graduation, college entrance, the declaration of a STEM major in college, and graduating from college at the completion of that degree (Cannady et al., 2014). In many countries, the high school to college transition is a major site of student attrition from the pipeline (Knipprath et al., 2018). Many students who enter the STEM pipeline end up exiting at various sites along the traditional STEM educational pathway and do not end up transitioning into STEM occupations.

Entry into the STEM pipeline happens at an early age. Elementary school is often identified as the place at which students begin progressing towards possible STEM careers in the formal educational system (Ball et al., 2017); however there is some research which indicates that knowledge and opportunity gaps begin during this same time frame (Bennett Anderson et al., 2017; Morgan et al., 2016). In a multiyear, quantitative survey of 1155 fourth and fifth grade students regarding their science, math, technology affinity, as well as the importance that they assigned to math and technology, the results indicated that the intrinsic value of STEM was the strongest predictor of STEM-affinity in elementary school students (Ball et al., 2017). In addition to the idea that students may initially enter the STEM pipeline during elementary school, quantitative research suggests that their success at later points in STEM educational pathways can be predicted early in their pipeline progress. The large scale, longitudinal survey of elementary and middle school aged students performed by Morgan et al. (2016) over a ten-year period provided data to support the idea that general knowledge gaps that exist as young as kindergarten age are a strong predictors of science achievement in later grades. Although limited by archival data, the research of Bennett Anderson et al. helps support Morgan et al.'s findings that achievement gaps in the STEM pipeline start during elementary school. In an quantitative, multi-year analysis of STARR Mathematics and Sciences test results for grade 5 and grade 8 students in Texas, the results indicated that that students who came from economically disadvantaged backgrounds had lower average scores on both math and science tests across grade levels than their more advantaged peers which shows achievement gaps happening during the formative elementary school years (Bennett Anderson et al., 2017). Indicating an interest in pursuing a STEM degree as young as eighth grade positions a student to be more likely to earn a STEM degree at the other end of the pipeline and increasing student interest in STEM content areas at younger grade levels leads to higher persistence rates farther down the STEM career pathway (Ashford et al., 2016; Maltese & Tai, 2011). One of the most recognized and cited studies in STEM pipeline persistence involved a longitudinal survey of 4700 students in United States schools using the National Education Longitudinal Study of 1988 which provided a rich and representative sample to look at school experiences from middle school through the end of college and the impact that is had on mathematics and science outcomes (Maltese & Tai, 2011). The results of Maltese and Tai's (2011) research showed that increasing student interest in STEM at a young age led to a greater view of the utility of science and mathematics as the students progressed through the educational pipeline and eventually led to a higher likelihood of entering a STEM career. Determining student entry points into the STEM pipeline may allow for a better understanding of who persists in STEM occupational pathways and what obstacles might prevent those students from continuing into secondary and post-secondary STEM career and coursework opportunities.

Like many useful educational and policy metaphors, the STEM pipeline metaphor is not without its critics and its problems. Cannady et al. (2014) make the argument that viewing STEM career pathways using the pipeline metaphor leads to over-simplistic and inadequate attempts to solve the issue of underrepresentation of certain subpopulations and it creates a model of STEM career pathways as a linear progression towards a terminal goal of the attainment of a STEM career through a required set of academic gatekeepers with little room for deviation. Analysis of the pipeline model results in students being forced into “a career trajectory with one inlet, one outlet, and one direction of flow” (Cannady et al., 2014, p. 445). This narrow view of how students are inducted into STEM educational pathways sets up a dichotomy between the elitist view of training certain students to become scientists and engineers and the more democratic position of preparing every student to be scientifically literate (Mendick et al., 2017). The pipeline metaphor ignores important and complex nuances among the various subpopulations which are leaking out of the pipeline and fails to adequately distinguish what enables some people to progress towards a STEM career and what experiences might lead to alternate paths (Mendick et al., 2017). Cannady et al. (2014) have proposed an alternative model to the STEM pipeline metaphor in the form of a Sankey flow diagram showing all college graduates following various composite pathways towards the STEM workforce which allows for a range of experiences within this band of career goal actions. This alternative model opens discourse for addressing some critical questions about the relationship between STEM interest and SEM careers.

Gaps in a Leaky STEM Pipeline

Conceptualizing the pathway to STEM career occupations as a pipeline requires educators and policy makers to also be aware of subpopulations of students who are excluded from entering the pipeline or who leak out of the pipeline at each of the crucial gatekeeper junctions along the way. Researchers attribute the lack of pipeline pressure as well as the pipeline leaks to a combination of achievement, interest, and opportunity gaps for these subpopulations of students (Bennett Anderson et al., 2017; Jones et al., 2018; Morgan et al., 2016). The largest gaps in the STEM pipeline fall into four main categories: 1) between students from low socioeconomic households and their more affluent peers (Bennett Anderson et al., 2017; Connors-Kellgren et al., 2016; Doerschuk et al., 2016; Jones et al., 2018), 2) between male and female students (Bergeron & Gordon, 2017; Connors-Kellgren et al., 2016; Doerschuk et al., 2016; Guo, Eccles, Sortheix, & Salmela-Aro, 2018; Jones et al., 2018; Maltese & Cooper, 2017), 3) between ethnic/racial minority students and their white peers (Connors-Kellgren et al., 2016; Doerschuk et al., 2016; Jones et al., 2018), and 4) between students who are first-generation college attenders and their more traditionally college-bound peers (Doerschuk et al., 2016; Jones et al., 2018). The state of Idaho recognizes students who come from rural areas of the state as another category of underrepresented students in the STEM career pipeline (Hemmingway, 2015). The sociocultural, economic, and environmental challenges faced by these subpopulations of students increases their risk of not persisting in the STEM career pipeline to the terminal stage of successful occupancy of a STEM career (Doerschuk et al., 2016; Wang, Ye, & Degol, 2017). Recent data from ACT, Inc's research and policy division indicates that students who fall into more than one of these underserved categories are less likely to meet the STEM benchmark score on that national assessment; from 39 percent with no categories to 15 percent for a single category and only 3 percent achieving the STEM benchmark if the students fall into three of the categories (Hayes, 2017). Barriers which cause these populations of students to leak out of the STEM pipeline include fewer educational resources and opportunities in the home and at school (Bennett Anderson et al., 2017), slower language development (Bennett Anderson et al., 2017), lack of access to higher education (Jones et al., 2018), and the absence of role models (Doerschuk et al., 2016). Before the gaps in the leaky STEM career pipeline can be addressed with educational and public policy solutions, the gaps and their root causes must be identified and defined. The underrepresented populations of students in the STEM pipeline will be addressed in more depth later in this literature review.

An interesting phenomenon to note when looking at gaps in the leaky STEM career pipeline is that of gendered pathways within the STEM pipeline. While females are underrepresented in STEM careers from a holistic perspective, there are some fields of STEM where females are actually pursuing and completing degrees in higher percentages than their male counterparts (Bergeron & Gordon, 2017; Diekman & Benson-Greenwald, 2018; Guo et al., 2018; Maltese & Cooper, 2017). Male students tend to be overrepresented in math-heavy STEM majors like physics and engineering while females are overrepresented in the social and life sciences, including medical and health sciences (Bergeron & Gordon, 2017; Guo et al., 2018; Maltese & Cooper, 2017;

Valentino, Moller, Stearns, & Mickelson, 2015). Persistent leaks in the STEM pipeline related to gender gaps are not explained by a lack of ability or initial interest in STEM content on the part of female students (Diekman & Benson-Greenwald, 2018; Maltese & Cooper, 2017). Guo et al. (2018) conducted a longitudinal study with 1259 adult participants in Finland from their eleventh school year through eight years after their completion of postsecondary school. The results show that the imbalance in STEM occupational pathways is derived from gender differences in the following work-related values: social values (i.e. females prefer jobs that allow them to work with people and altruistically help society), material and status values (i.e. men tend to place higher value on jobs which provide a high salary and compensation), and work-life balance values (i.e. females are willing to work for lower pay rates in exchange for more flexibility in work hours). While Guo et al.'s work showed distinct gender divisions in work-related values, other studies have shown that both male and female students valued more work-life balance in their careers. Valentino et al. (2015) had conflicting findings in a study of college students from North Carolina who exhibited a gender-neutral, negative reaction towards choosing a STEM career field with a perceived lack of family flexibility indicating that the characteristic of work-life balance is a strong motivator for both males and females to choose non-STEM careers which are perceived as more family-friendly. Starting in late adolescence, females are more likely to place a higher value on finding a career which gives them the freedom to focus on their family lives and that is people-oriented with social benefit while men are more likely to value a career which allows them to work with and manipulate objects while earning power, prestige, and authority

(Guo et al., 2018). Females are less comfortable with risk-taking in competitive classroom and worksite environments and are less confident in their own math and science self-efficacy (Bergeron & Gordon, 2017; Redmond-Sanogo et al., 2016). Solutions which deal with this specific gender leak in the STEM pipeline need to be developed with conscious awareness of the fact that females experience STEM courses and careers differently than their male counterparts.

Closely tied to the differences in STEM experiences for male and female students is the stereotype that STEM careers are more agentic, or “self-oriented”, in goals than non-STEM careers which are seen as more communal, or “other-oriented” (Diekman & Benson-Greenwald, 2018, p. 11). People are more likely to choose careers which match their values, goals, and perceived social roles (Diekman & Benson-Greenwald, 2018; Fuesting & Diekman, 2017). Agentic careers are often associated with the traditional male characteristics of autonomy, status, and respect while communal careers are more often associated with traditional female characteristics of collaboration, altruism, and relationships (Clark, Fuesting, & Diekman, 2016; Fuesting & Diekman, 2017). Someone who strongly values a communal career experience might self-select out of STEM careers due to their perception that those careers are more agentic in nature (Clark et al., 2016). Society- and family-oriented people, overrepresented by women, are more likely to choose non-STEM-related careers while monetary- and prospect-oriented people, overrepresented by men, are more likely to choose professional-level, math-intensive STEM careers (Guo et al., 2018). These persistent gender-related stereotypes for career fields can impede progress is closing the achievement and opportunity gap for females who are in the STEM career pipeline.

A thorough understanding where the leaks in the STEM pipeline are occurring, and why they happen where they do, requires an exploration of the closely related ideas of academic preparedness and persistence in rigorous math and science course. Wang et al. (2017) performed a large-scale longitudinal study using two waves of data from 1762 participants over a 20-year period starting in ninth grade to look at the predictive ability of cognitive abilities when choosing a STEM career and found that high math and science abilities did provide an advantage in the pursuit and attainment of a STEM occupation though lower math and science abilities did not necessarily preclude students from entering STEM professions. Maltese and Tai (2011) completed a similar large-scale longitudinal study and found that taking science classes in high school was positively associated with earning a STEM degree which supports the idea that completing STEM courses in high school leads to a greater STEM-persistence. Redmond-Sanogo et al. (2016) used purposive sampling techniques to explore which high school courses predicted success in gatekeeper college STEM courses like calculus, chemistry, and physics and found that the type of course taken mattered more than the number of classes in which a student participated with calculus, trigonometry, chemistry, and physics serving as important indicators of academic preparedness. High school grade point averages were a more positive predictor of STEM success at the college level than STEM interest (Hayes, 2017). Math readiness shows a strong correlation to the successful completion of STEM majors in college and many college students who wish to major in

STEM fields find the need to take intensive math support courses and co-requisite remedial courses in order to begin their required STEM courses (Kezar & Holcombe, 2018). In a three-year, quantitative comparison of STEM-capable high school students, persistence in mathematics and science course taking was evaluated in rigorous programs of study (Ashford et al., 2016). Results showed that upon entrance into high school, male and female students have similar capabilities for excelling in math and science but that negative course experiences decreased their persistence over the term of their high school year (Ashford et al., 2016). Providing support structures in the form of curriculum and mentors can increase the persistence of STEM-capable students when taking rigorous math and science coursework (Ashford et al., 2016). Student interest in STEM topics and self-efficacy in science and mathematics can also serve as ways of increasing STEM persistence in advanced high school science and math classes (Maltese & Tai, 2011). Understanding the lack of STEM interest and academic preparation in students as they move through and leak out of the STEM pipeline entails focusing on the interdependent relationship between the preparedness and the persistence of those students.

Environmental Supports for STEM Pathways

Increasing the flow of students through the educational STEM pipeline is vitally important at both the macro-level for national innovative progress, as well as at the micro-level for the personal benefit of the students who end up in STEM careers, so it has become imperative that educators and policy makers develop environmental supports for the students who are participating in STEM pathways. The first theme from the literature shows that one of the most successful environmental supports for encouraging students, especially those from traditionally underrepresented populations, to persist in STEM pathways, is exposure to role models, sponsors, mentors, and advisors (Clark et al., 2016; Doerschuk et al., 2016; Fuesting & Diekman, 2017; Knowles et al., 2018; Rahm & Moore, 2016; Tenenbaum, Anderson, Ramadorai, & Yourick, 2017; Tootle et al., 2019). Of interest in Fuesting and Diekman's (2017) research is the emphasis on self-obtained role models as an environmental support in STEM career pathways. In a preliminary study of college students, the data showed that participants with a STEM major found that locating a role model in their area of study was more challenging than their non-STEM peers and both males and females found that STEM role models who were viewed at engaging in communal tasks within their STEM field were even more challenging to locate (Fuesting & Diekman, 2017). The co-authors of that study also found that the gender of the role model was less important to STEM-affiliated college students than finding one who exhibited communal behaviors and goals which encouraged a sense of belonging and involvement (Clark et al., 2016; Fuesting & Diekman, 2017). A best-practices model for STEM engagement developed by Lamar University used a combination of undergraduate research experiences, faculty and peer mentors, and outreach activities to help recruit and retain students in the post-secondary portion of the STEM pipeline (Doerschuk et al., 2016). Rahm and Moore (2016) performed a multi-sited ethnography study on at-risk ninth and tenth grade students from underserved student subgroups and found that the students who experienced mentorship opportunities had a better conceptual understanding of the nature of scientific career fields and were able to situate those job experiences in a more authentic and realistic view of STEM occupations. Students engaged at higher levels with their science coursework when they were provided with social supports from peers and practicing scientists as well as materials supports with hands-on projects and realistic scientific tools of the trade (Rahm & Moore, 2016). Taken together, these studies demonstrate how both faculty and peer mentoring can help create engagement and a sense of belonging in students during the secondary and post-secondary components of the STEM career pipeline. In addition to providing the benefits of traditional mentorship, there is additional value in utilizing mentors who are slightly older than the partnered mentee. Tenenbaum et al. (2017) used a mixed-methods study to evaluate a near-peer mentoring program for eleventh and twelfth grade high school students in which the high school students were partnered with college-level STEM students and assigned to hands-on laboratory-based research projects and found that the high school student participants reported that the shared experiences benefited both peers in the mentorship relationship and created interest and engagement that was not replicated with instructors or senior scientists as the mentor. Whether these STEM pipeline guides come in the form of practicing scientists serving as role models and sponsors, or if they come in the form of teacher mentors or even peer mentors, the depth that these collaborative and communal relationships bring to student perception of STEM careers and student engagement with STEM coursework is a valuable environmental support for ensuring persistence in the STEM pipeline.

Another environmental support for STEM pathways is the development and use of STEM-specific communities of practice (CoP) and partnerships in conjunction with traditional STEM educational pathways. These bring another layer of collaborative and communal relationships to the STEM-capable students who are part of the STEM career pipeline and for some students, these opportunities provide a reason to engage with the pipeline. Findings from a quasi-experimental research study of three cohorts of high school teachers who participated in a project designed to increase student interest in STEM careers show that while teachers have a large influence on the STEM interest and engagement levels of their students, many teachers do not have the training or the field experience to place STEM career pathways into authentic practice and situated contexts (Knowles et al., 2018). These findings were confirmed by the results from a three-year, mixed-methods study of 222 high school students aged 16-18 years old who participated in a near-peer mentoring program and reported that they had trouble engaging with some topics because of the lack of connections made by their teachers between the content material and the real world context of that information (Tenenbaum et al., 2017). Taken together, these studies confirm that teachers alone do not have the same influence on student STEM interest as teachers who are participating in a STEM-specific CoP. Engaged and networked CoPs were first proposed by Lave and Wenger (1991) as groups of people who share a passion and an interest in something that they do, often a profession, and according to the U.S. Department of Education STEM 2026 report, can help educators to locate STEM experiences in the context of local and relevant STEM issues and help reduce the biases that force some underrepresented populations of students to disengage with STEM career goals (Tanenbaum et al., 2016). In a case study of four first-generation, college-bound high school students participating in a residential STEM intervention program which partnered students, teachers, and practicing field scientists to create a STEM career CoP, the student interviews showed that those CoPs helped to broker relationships between students and the real world of STEM occupations (Rahm & Moore, 2016). Rahm and Moore (2016) noted that when students were provided with intensive, content-rich, instructional experiences and opportunities to engage with practicing scientists and engineers about STEM career practices, they gained a better understanding of the connections between STEM classroom instruction and real-world application. Providing those students with a view of the next steps in the STEM pipeline required teachers and STEM practitioners to align high school, college, and graduate level activities (Rahm & Moore, 2016). The practice of building community and partnerships provides another environmental support for developing and retaining highly capable STEM learners as they progress towards the attainment of a STEM-related career.

Environmental supports for STEM pathways also include the curricular and classroom experiences student have throughout their schooling. Building the STEM pipeline requires educators to deeply consider the intrinsic interests of their students and design explicit experiences which align to those interests. Both SCCT (Lent et al., 1994) and EVT (Eccles et al., 1983) model a relationship between interests, experiences, self-efficacy, and the inherent value of STEM when a student is considering a STEM-related career field. A quantitative research study was conducted on a cohort of fourth- and fifth-grade students from 12 large urban schools over the course of a school year before and after participation in a STEM intervention that was designed to integrate computer usage across the curriculum (Ball et al., 2017). The results showed that students who found the

STEM content to be useful and interesting were more likely to stay in the STEM pipeline and have a more positive attitude towards STEM (Ball et al., 2017). The NSF's Innovative Technology Experiences for Students and Teachers sponsored a similar series of five qualitative studies, with sample sizes ranging from four to 58 students, and 10 quantitative studies, with sample sizes ranging from 59 students to more than 600 students to look at student engagement and attitudes towards STEM curriculum projects (Connors-Kellgren et al., 2016). When taken as a group, the results of this series of studies showed that innovative, project-based curricula which promoted interest in STEM topics and explicitly integrate STEM career and content knowledge helped engage underrepresented student populations in STEM workforce development and to lease to a more culturally responsive and creative learning environment for all students (Connors-Kellgren et al., 2016). In a nine-year, longitudinal study of 270,954 students from the data-rich ACT, Inc database of standardized test scores and vocational interests, the results showed that abilities and interests are reciprocally related and develop over time in both male and female students so catering to a variety of academic abilities and career interests may be a crucial component of STEM classroom instruction (Le & Robbins, 2016). Other experiences that have seen increased use in STEM curriculum are makerspaces. Makerspace projects provide alternative pathways to STEM careers for potentially marginalized student populations by incorporating environmental justice, social activism, and community relevance into STEM experiences (Honma, 2017). An interpretative phenomenological analysis of a partnership between the Asian and Pacific Islander Obesity Prevention Alliance and Mark Keppel High School in California provided data to show that balancing the role of science in the community with the lived experiences of students helps provide access and opportunities for students to persist in STEM education and eventually, in STEM fields (Honma, 2017). Knowles et al. (2018) make the recommendation that teachers develop classroom experiences that are authentic to current STEM career practices and involve professional scientists and engineers in developing inquiry-based investigations, questioning practices, and classroom discussion forums for students. Providing environmental curricular supports which make STEM learning fun, interesting, and useful to students helps align skills with interests and may result in the choice of a STEM career for those individuals.

In addition to formal curricular experiences, the informal learning experiences can serve as a vital component of STEM career pathways and can function to provide educational opportunities, mentorship, and science identity for students who might not see a place for themselves in the STEM pipeline. Extracurricular activities like science fairs and competitions (Sahin et al., 2017), and STEM clubs (Ozis et al., 2018) can influence student outcomes in STEM learning and help prepare those students for professional STEM experiences (Ozis et al., 2018; Sahin et al., 2017). Libraries, museums, and after-school programs in community settings are helping students to develop confidence in their skills and abilities in STEM career fields through rich and extended exposure to STEM experiences (Honma, 2017; Ozis et al., 2018). Steenbergen-Hu and Olszewski-Kubilius (2017) surveyed students who were participating in supplementary STEM educational programs during high school and found that many students noted early extracurricular encounters with nature or astronomy as influential in cultivating their interest in STEM careers and that parents and family members, rather than school-based factors, helped encourage their initial STEM interest. Extending STEM learning beyond the traditional and formal educational experience provides environmental support for students who exhibit achievement and opportunity gaps in their STEM educational pathways and provides an alternative route for gaining STEM skills and applied knowledge.

Underrepresented Populations in STEM

In previous sections of this literature review I have explored the importance of STEM in allowing the United States to remain competitive on a global scale in both economic and social spheres (National Science Board, 2018a). Although the United States is a culturally-diverse nation, the current STEM workforce is predominantly male and White or Asian and does not reflect the demographics of a dynamic country with an increasing demand for diverse STEM workers (Jones et al., 2018). Educators and policymakers who are concerned about the underrepresentation of certain subgroups of people entering and persisting in the STEM pipeline have identified five major categories for concern: (1) females (Cheryan et al., 2016; Guo et al., 2018; Maltese & Cooper, 2017), (2) ethnic/racial minorities (Alhaddab & Alnatheer, 2015; Lent et al., 2018; Premraj, Thompson, Hughes, & Adams, 2019; Rainey, Dancy, Mickelson, Stearns, & Moller, 2018), (3) students from low socioeconomic family backgrounds (Bennett Anderson et al., 2017; Flores et al., 2017; Thompson & Dahling, 2012; Turner et al., 2017), (4) students from rural geographic locations (Assouline, Ihrig, & Mahatmya, 2017; Avery & Kassam, 2011; Eppley, 2017; Zimmerman & Weible, 2017), and (5) first-generation college-attenders (Garriott, Navarro, et al., 2017; Hayes, 2017; Jones et al., 2018; Smith, Jagesic, Wyatt, & Ewing, 2018). There are often cases where students fall into more than one of these categories and STEM-interested students are less likely to persist in STEM majors and career pathways as their number of underrepresented categories increases (Hayes, 2017). Based on the person inputs outlined by my SCCT framework (i.e. the innate characteristics of a person that influence their career decision-making processes), I centered this review of the current literature regarding underrepresented populations in STEM career pathways on the specific subgroups of gender and ethnic/racial minorities. In this section of the literature review I will examine the barriers of stereotyping and bias in the STEM pipeline which lead to discrepancies between STEM-capable female and ethnic/racial minority populations and the diversity of the current STEM workforce, as well as middle and high school STEM experiences that can act as supports in encouraging these underrepresented population to persist in the STEM pipeline. I end the section addressing research findings that indicate that ability and performance do not lead to the current gender and ethnic/racial gaps in the STEM pipeline.

Stereotyping and Bias in STEM

Stereotyping and bias in STEM career fields can take a variety of forms. STEM professionals are often perceived as having a variety of negative personality and character traits which can lead to an anchoring bias that selects against females and ethnic/racial minorities during the career decision-making process. A quantitative study of underserved high school students in federal Trio outreach programs identified negative

STEM stereotypes about interpersonal skills behaviors, and physical appearance as contextual barriers to self-efficacy and STEM interests (Garriott, Hultgren, & Frazier, 2017). While the work of Garriott, Hultgren et al. (2017) does not show strong correlations with any particular demographic variables, the overall STEM stereotypes structural model for the Math and Science Stigma Scale indicates there is a relationship between trait-based STEM stereotypes and STEM interest and self-efficacy for the at-risk student populations serviced by the TRIO program (i.e. low-income, first-generation college students, ethnic/racial minority). Bias and stereotyping in STEM fields can be trait-based or demographic-based according to the results of a study done on a racially-diverse sample of female college undergraduate students (Starr, 2018). Starr (2018) found that females who identified STEM careers with nerd/genius or implicit and/or explicit gender-biased stereotypes were less motivated to pursue those careers and those stereotypes negatively impacted their personal STEM identity and expectancy-value beliefs. While focused mostly on the impact of stereotypes on female students, this study did provide some exploratory results which indicated that European American participants held stronger implicit gender stereotypes about STEM than their Asian and Latina peers which correlated to a stronger STEM career motivation for the Asian and Latina students (Starr, 2018). A pair of pilot studies conducted on small groups of female college students to explore gender-related stereotypes in STEM showed a similar pattern of stereotype threats negatively impacting the STEM performance expectations of those females (Schuster & Martiny, 2017). For female and ethnic/minority underrepresented STEM populations, the stereotyping of and implicit or explicit bias towards personality and character traits can lead to a decrease in STEM career choice variables like self-efficacy, identity, interest, and performance expectations.

Competency-based stereotypes can also serve as a barrier to female and ethnic/racial minorities who are seeking to enter STEM fields. Latina and Black females were especially susceptible to the negative results of this type of implicit bias since their competency is stereotyped based on race and gender (Cheryan et al., 2016). Cheryan et al. (2016) indicated that the United States cultural perceived bias of having lower math and science abilities based on race and gender can limit a sense of belonging in STEM pathways. This negative effect on STEM career aspirations was confirmed by a pair of studies which were conducted on a group of mixed-gender high school and mixed-gender college students to assess the impact of negative competence-related stereotypes by gender (Schuster & Martiny, 2017). The activation of gender-based competency stereotypes about the success of female participants in STEM course and career scenarios had detrimental effects on the STEM motivations of those students (Schuster & Martiny, 2017). When taken together, these studies confirm that perceived math and science competency is a strong factor in STEM identity for female students who persist in STEM pathways. While many of the studies about STEM stereotypes are quantitative in nature and rely on large data sets to assess patterns about gender and ethnic/racial bias, there are also some studies which address this topic from a more qualitative narrative viewpoint. A purposive sampling of college seniors in STEM majors provided qualitative data to support the idea that a sense of competence based on the intersectionality of gender and race was the second highest cited factor for persisting in a STEM major behind interpersonal relationship (Rainey et al., 2018). Negative stereotypes about the math and science competency of female and ethnic/racial minorities who participate in STEM can impact their motivation and sense of belonging but using gender and ethnicity/race to locate themselves with other STEM-capable students who are like them can mediate those negative effects.

Work environment stereotypes play a role in deterring communally-oriented people from entering and persisting in STEM career fields. Diekman and Benson-Greenwald (2018) summarize their previous studies by acknowledging that females and ethnic/racial minorities place value on careers which have communal goals and seek to help others over more agentic or self-oriented work environments. This statement is supported by a meta-analysis of gender disparities in STEM participation that shows that females prefer working with people while males prefer working with things (Cheryan et al., 2016). Professional level and math-intensive STEM subjects are often associated with stereotypically male values like money, power, and social status (Guo et al., 2018). A quantitative analysis of the relationship between gender cueing and the perception of communal work environments in science performed on college psychology students indicated that when provided with examples of scientists acting towards communal goals, positive perception of science increased (Clark et al., 2016). Participant gender was less of a predictive factor for science positivity than communal behaviors were which indicates that both male and female students might have a more positive experience with STEM when they could see people-oriented tasks and goals (Clark et al., 2016). While supporting the idea that stereotypes about gender and STEM work environments can be mediated by communal goal affordances, Clark et al.'s (2016) work was based on a racially homogenous sample population so the impact of ethnicity and race on these STEM workplace and classroom environments was not explored. Encouraging females and ethnic/racial minorities to enter STEM career pathways will require workplace environment stereotypes to be addressed and for an emphasis to be placed on the communal nature of many STEM endeavors.

Insufficient Middle and High School STEM Experiences

Underrepresented populations in the STEM career pipeline often have insufficient middle and high school STEM experiences which result in the attrition of females and ethnic/racial minorities from STEM pathways. Institutional barriers in the form of inequity across academic and social supports is a contributing factor to these insufficient early experiences. A longitudinal analysis of students beginning in high school and then tracking them for a period of 10 years after graduation explored the pathways which led those students to STEM health occupations and found that Black and Hispanic students were not as prepared for the expectations of STEM post-secondary and workplace knowledge and skills as their white counterparts (Fletcher & Tyson, 2017). These results are related to the fact that the Black and Hispanic students were not exposed to the same quality of teaching and learning opportunities as their white peers which led to an institutionally created academic achievement gap in STEM career interests (Fletcher & Tyson, 2017). In addition to this institutional lack of academic supports, a phenomenological qualitative study of college scholarship recipients who came from large, urban high school with high poverty rates and high numbers of ethnic/racial minorities found that underrepresented minority students required strong social support services in order to succeed in post-secondary STEM programs (Eastman, Christman, Zion, & Yerrick, 2017). A second qualitative study of white and Hispanic high school students with the added at-risk characteristics of being first-generation college-bound and/or from a low socioeconomic family background indicated that the institutional compartmentalization of opportunities for access to academic supports prevented those students from progressing from high school to STEM undergraduate programs (Rahm & Moore, 2016). Taken together, these three studies show a pattern of inequity in academic and social supports for ethnic/racial minority students which has impacted their progress through the STEM educational pipeline. A similar quantitative study of female high school and college students who had been recognized for their interest and achievement in computer science indicated that social supports are crucial for females who persist in obtaining a computer science or technology degree and move into the STEM workforce (Weston, DuBow, & Kaminsky, 2018). When there are institutional barriers to participation in STEM courses and career pathways, female and ethnic/racial minorities do not persist in the STEM pipeline.

Opportunity barriers for underrepresented populations of students in STEM educational pathways can also take the form of resource gaps. A nationally-representative, longitudinal study of children from kindergarten through eighth grade found that students who demonstrated early gaps in math, science, and reading achievement were impacted by attending lower-resourced schools (Morgan et al., 2016). This macrosystem inequity was also apparent in a qualitative research study that interviewed Black high school students with an interest in STEM college majors and found that there were limited STEM courses available to them at both the high school and the community college levels due to a lack of funding and the availability of experienced teachers (Stipanovic & Woo, 2017). Many schools across the United States do not even provide computer programing/computer science or upper level math and science courses to their students and this trend is especially prominent in schools which service ethnic/racial minority students (Cheryan et al., 2016). These patterns of STEM resource gaps leading to STEM opportunity gaps are consistent for gender as well as ethnic/racial minorities. A quantitative study of metropolitan high school students attempted to understand the intersection of gender and socioeconomic status as it related to STEM career interests and actions and found that those students who attended high-poverty schools with a lack of STEM career counseling resources were less likely to develop STEM interests (Turner et al., 2017). Underrepresented STEM populations like females and minorities are more likely to be serviced by under resourced school systems (Stipanovic & Woo, 2017). Eastman et al. (2017) used a qualitative, interview-based research design to study access to a prominent, technical university for high-performing, urban students and found that female, Black engineering students in the program expressed a frustration with the lack of qualified STEM teachers, access to extracurricular STEM clubs, and individual tutoring opportunities available to them at the high school level when compared to more affluent schools in the area who sent mostly white, male students to the university engineering program. A lack of equitable resource availability in the form of qualified STEM teachers, STEM career counselors, advanced

STEM coursework, and STEM extracurricular opportunities becomes a contributing factor for the underrepresentation of female and ethnic/racial minorities in STEM educational and career pathways.

Classroom culture and positive experiences with STEM content and teachers have an impact on the persistence of female and ethnic/minority students in STEM educational pathways. A series of semi-structured interviews with K-12 STEM teachers of ethnically-diverse students in an urban school setting provided evidence that student engagement was highly depended on the types of experiences that the students were allowed to participate in (Icel, 2018). The teachers in this study stated that using hands-on, open-ended, and lab-based classroom activities allowed them to create a classroom culture where their ethnically/racially and socioeconomically diverse student population was allowed to apply their learning to authentic contexts (Icel, 2018). Weston et al. (2018) also explored the idea of classroom environments when they surveyed female computer science students to identify the characteristics of a STEM persister versus those of a non-persister in earning a computer science or information technology degree. The survey findings indicated that negative classroom environments, which lacked warm interactions with faculty and peers, negatively influenced the confidence of the female students in their STEM knowledge and skills and led to non-persistence in computer science degree completion (Weston et al., 2018). Negative classroom culture in STEM courses extends to the larger concept of programmatic cultural issues. Interviews with female and Black students entering college from urban high school settings provided insight into the fact that many college-level programs attempt to scaffold the entry of underrepresented

STEM populations into traditional programs rather than modifying those programs to be more inclusive and conducive of learning for all students (Eastman et al., 2017). Even though the sample size for these interviews was very small, the responses brought to light some disparities in how females and ethnic/racial minorities experience college STEM courses and instructors compared to students from the white and Asian, male dominant culture of engineering programs (Eastman et al., 2017). When STEM classrooms and programs operate under exclusionary practices create implicit barriers for female and ethnic/minority students who might seek to pursue STEM courses and careers.

Mentoring is an important component of middle and high school STEM experiences for female and ethnic/minority students. In a three-year qualitative study of ethnic/minority high school students who participated in a summer STEM intervention program, the data coding showed that students found a sense of camaraderie and increased their STEM self-efficacy by working with near-peer, college STEM major mentors (Tenenbaum et al., 2017). Providing mentors for ethnic/racial minority student participants also assisted them with their educational planning and gave them a clearer picture of their next steps on their STEM educational pathways (Tenenbaum et al., 2017). Mentorship experiences are valuable for female STEM students as well. A quantitative survey of undergraduates and post-graduates from a variety of majors and career placements indicated that providing teacher/staff and professional STEM mentors for female students increased their STEM interests and their representation in STEM majors and career fields (Maltese & Cooper, 2017). Fuesting and Diekman (2017) also explored the impact that mentors had on female STEM majors in a quantitative analysis of college students and found that females viewed advisor interactions as more fulfilling than their male counterparts and role models and mentors who demonstrated the communal nature of STEM fields, regardless of the gender of that role model or mentor. Both quantitative studies were conducted using a homogenously white ethnic/racial student population but when combined with the previous work of Tenenbaum et al. (2017), there is strong evidence for the need for early STEM mentorship at the intersection of gender and ethnicity/race in order to strength the STEM experiences of Hispanic and Black females. Mentors and role models can help students to explore their science identity and can help to locate STEM learning in contextually-relevant ways. Rahm and Moore (2016) conducted a case-study of underrepresented high school students who were participating in a summer intervention program and found that the students felt like mentorship opportunities helped them to be active participants and contributors to scientific practices instead of passively acquiring scientific knowledge. While some of the students talked about the tedious and repetitive nature of data collection in the field, they also were appreciative of the authentic presentation of science tasks by their mentors and felt like they were making a difference with their STEM projects (Rahm & Moore, 2016). Role models and mentors in STEM do not need to be gender or ethnic/racially matched to the STEM participant but both females and ethnic/racial minorities benefit from participating in early STEM mentorship experiences across a variety of contexts.

STEM Ability and Performance

There is some question about whether STEM ability and performance are contributing factors in the underrepresentation of females and ethnic/racial minorities in

STEM educational pathways and careers. Students across gender and ethnic/racial demographics consistently demonstrate similar science and math capabilities in advanced STEM coursework (Ashford et al., 2016; Le & Robbins, 2016; Wang et al., 2017). STEM ability and performance might be similar, regardless of person inputs like gender and ethnicity/race but other measurements of STEM-capability like interest in STEM or willingness to try STEM do not show the same parity.

Enrollment in courses across STEM disciplines and workforce demographics for STEM fields show some general trends and patterns when viewed through the lens of gender and ethnic/racial diversity. STEM fields like biology and chemistry have higher numbers of females pursing advanced degrees than more math-intensive fields like physics and engineering (Maltese & Cooper, 2017). In a quantitative analysis of college students and post-graduate employees in the workforce, the data showed that there was no difference in when males and females first became interested in STEM but females were more likely to report interactions with nature and the outdoors as a trigger for their interests while men were more likely to report building or making something as a trigger for their interest (Maltese & Cooper, 2017). These gendered pathways to STEM interest align with the gendered difference in STEM degree enrollment. A large-scale analysis of the International Baccalaureate internal data base shows similar trends in advanced STEM course enrollment for high school males and females (Bergeron & Gordon, 2017). Female students showed a significantly larger enrollment in standard level courses as opposed to higher level courses and had lower enrollment in higher level chemistry, all levels of design technology, higher level mathematics, all levels of physics, and all levels of computer science than their male peers (Bergeron & Gordon, 2017). Wiebe, Unfried, and Faber (2018) used a student attitude survey to explore the interaction of both gender and ethnicity/race with interest in various STEM disciplines across a large population of fourth through twelfth grade students in North Carolina. The results from this survey supported the previous gender-based trend of male student interest in core STEM courses like physics, math, computer science, and engineering and female student interest in biomedical STEM courses like biology, medicine, and zoology (Wiebe et al., 2018). Survey results did not show the same trends for overrepresented ethnicities/races like Caucasian when compared with the underrepresented ethnicities/races of Black and Hispanic since the data indicated that the underrepresented groups were more interested in the core STEM courses than their overrepresented peers while there was no indication of difference in the biomedical STEM courses based on ethnicity/race (Wiebe et al., 2018). Gender differences in STEM career and educational pathways are more pronounced than ethnic/racial differences and the ethnic/racial differences indicate a stronger career interest in STEM for underrepresented categories of students.

Self-efficacy and STEM perceptions are notably connected to STEM career goals and actions for underrepresented populations of STEM students. Much of the research that has been done around underrepresented STEM populations and the variables of self-efficacy and STEM perceptions has used the SCCT as a framework (Lent et al., 1994, 2018; Navarro et al., 2007; Sahin et al., 2017; Turner et al., 2017). A quantitative study of urban and suburban high school students showed a significant link between gender and self-efficacy in STEM with male students exhibiting a greater efficacy level than their female peers (Turner et al., 2017). Disaggregating the overrepresented populations from the data shows that self-efficacy plays a strong role in determining STEM educational pathways for underrepresented students. In a study of students who are attending or who have already graduated from college, the results indicated that female students with higher science efficacy scores were more likely to major in STEM in college while Black and Hispanic students with higher science efficacy showed the same trend (Sahin et al., 2017). These findings were supported by a meta-analysis of the impact of gender and ethnicity/race on STEM career pathways since both females and ethnic/racial minorities showed a stronger negative correlation to environmental barriers and a stronger positive correlation to environmental supports with self-efficacy and outcome expectations than did their overrepresented cohorts (Lent et al., 2018). For the specific ethnic subpopulation of Mexican American eighth graders, the background contextual affordance of Mexican cultural orientation interacted with gender and the data indicated that Mexican American girls were less confident in their science efficacy than their male peers (Navarro et al., 2007). Confidence and self-efficacy can be developed during high school STEM coursework. A longitudinal survey of U.S. students over the ten-year period between their tenth-grade year and their post-secondary experiences linked high school science and math preparation with increased math and science efficacy and increased representation in STEM fields for both females and ethnic/racial minorities (Alhaddab & Alnatheer, 2015). STEM perceptions can influence the self-efficacy and STEM enrollment for underrepresented STEM populations when they are involved with STEM activities. A survey of STEM perceptions was given to several K-12 STEM charter schools in northern Arizona and the data indicated that there was no difference in perceptions of STEM among gender and ethnic/racial subgroups and that participation in STEM extracurricular clubs was much more likely to influence STEM perceptions for all students (Ozis et al., 2018). Increasing self-efficacy and STEM perceptions for underrepresented populations of students, like females and ethnic/racial minorities, may lead to a more balanced representation of those subpopulations in STEM educational pathways and careers.

Persistence in STEM courses and career pathways shows sociodemographic trends that are relevant to understanding the underrepresentation of females and ethnic/racial minorities in the STEM pipeline. A cross-sectional and longitudinal analysis of a large, representative national data set of high school students shows that the gender divide in STEM career aspirations is widening over time while the ethnic/racial gap is getting smaller (Saw et al., 2018). Saw et al.'s (2018) data indicated that Black and Hispanic students have lower persistence in STEM coursework over their high school career than their white and Asian counterparts. Female students are showing less interest in enrolling in high school STEM courses as well as less persistence in maintaining that enrollment over a three-year period (Saw et al., 2018). This trend was supported by longitudinal data for a national cohort of ninth grade STEM-capable students who planned to enroll in advanced math and science coursework that indicated that Asian students had the highest levels of persistence in those advanced courses, followed in order by White, Hispanic, and the Black students (Ashford et al., 2016). Persistence in advanced, higher level STEM coursework is an indicator of persistence in college STEM majors. The College Board published data from their internal database of Advanced Placement (AP) exam results to show that female and ethnic/racial minority students who take an AP STEM exam after the completion of an AP course during high school are 10% more likely to complete a STEM major program in college, regardless of their scale score on that test, than their peers who do not participate in AP courses and testing (Smith et al., 2018). Persistence in advanced STEM coursework is an indicator of future success in STEM educational and career pathways for underrepresented STEM populations but, while ethnic/racial minorities are showing signs of closing the gap between themselves and their majority ethnic/racial contemporaries, the persistence gap between male and female STEM students is continuing to increase.

Effective STEM Intervention and Enrichment Programs

In the previous section of my literature review, I described barriers that prevent subgroups of people from entering and persisting in the STEM educational and career pipeline and I discussed findings that indicate that STEM experiences at the middle and high school level can positively impact underrepresented populations by providing contextual supports. STEM intervention and enrichment programs are those which seek to broaden participation in STEM pathways by providing opportunities and resources like career exposure, hands-on research experiences, mentoring and networking, and financial support to STEM-capable students at various points along the STEM pipeline (C. E. George et al., 2018; Rincon & George-Jackson, 2016b). In this section of the literature review, I will identify the major types of STEM intervention and enrichment programs based on their targeted participant populations and their temporal and spatial settings. I will discuss academic and nonacademic indicators of effectiveness for STEM intervention and enrichment programs and discuss problematic trends in program evaluation procedures. I end this section outlining common components of successful STEM intervention and enrichment programs like authentic STEM experiences, STEM community building experiences, and STEM-specific college experiences.

Types of Programs

STEM intervention and enrichment programs come in a variety of types depending on the outcome expectations of the program, each targeting different participants, time frames, and educational settings. Three main categories of STEM intervention and enrichment programs are STEM Intervention Programs (SIPs), Out-of-School-Time programs (OSTs), and school-based programs. SIPs, which are run by colleges and universities, are focused on helping high school students transition into college STEM programs and ensuring that undergraduate STEM students are able to successfully navigate their way through college coursework into a STEM career or a post-secondary degree program (Carpi et al., 2017; Dyer-Barr, 2014; C. E. George et al., 2018; Rincon & George-Jackson, 2016b). These college-level intervention programs can be summer bridge programs or they can happen during the school year (Windsor et al., 2015). OSTs, which are run by a variety of community, industry, and higher education partners, concentrate on students during their K-12 educational experience and often target students at the middle and high school levels when STEM interest, self-efficacy, and perceptions are becoming more defined (Baran, Bilici, Mesutoglu, & Ocak, 2016; Carrick, Miller, Hagedorn, Smith-Konter, & Velasco, 2016; Cohen, 2018; Young et al., 2017). The most common formats for OSTs are summertime enrichments programs and after school enrichment or intervention programs with the intent of increasing student interest in STEM content material and/or STEM career pathways (Young et al., 2017). The final category of STEM intervention and enrichment programs is a broad category that contains K-12, school-based programs that are developed by schools or school districts to influence student interest and outcomes in STEM subject areas during a traditional school year. These programs can take the form of single-sex schools (Park, Behrman, & Choi, 2018), enhanced STEM curricular programs in early childhood education (Tippett & Milford, 2017), or secondary STEM focused schools (Wiswall, Stiefel, Schwartz, & Boccardo, 2014). While the individual goals of each type of program are largely driven by the partnerships and external influences that led to the establishment of that program, all SIPs, OSTs, and school-based programs attempt to effectively create opportunities and/or provide resources to broaden student participation in STEM educational pathways.

Indicators of Effectiveness

One method of measuring the effectiveness of a STEM intervention or enrichment program is to look at academic indicators like course grades and grade point averages (GPAs). A longitudinal, quasi-experimental study that followed a cohort of Year Seven students over a five-year period using England's National Pupil Database provided data to show that student participation in a STEM initiative did not do better on their English and math General Certificate of Secondary Education exams than students who did not participate in a STEM enrichment activity (Banerjee, 2017). Success on the national exams, and therefore of the STEM enrichment program, was defined as the attainment of a 5+ A*-C grade with a C being the cutoff score for the accomplishment of acceptable results (Banerjee, 2017). This use of academic indicators to evaluate success in STEM programs is also prevalent in the United States. A mixed-methods program evaluation of an NSF S-STEM intervention program at a large, urban university collected data about the percentage of D and F grades of student participants in order to determine how communication strategies between instructors and students could be used to support student success in the intervention program (Windsor & Ivey, 2018). Taken together, these studies show that academic indicators like course and exam grades are useful gauges of student success in STEM intervention and enrichment programs at both high school and collegiate levels. The effectiveness of a secondary-level STEM intervention or enrichment program can be determined using academic indicators.

Many STEM intervention or enrichment programs rely on nonacademic indicators like science identity and self-efficacy as well as attitudes towards and interest in STEM to determine effectiveness. A quantitative analysis of the effectiveness of the Meyerhoff Scholars Program at the University of Maryland used increased sense of community and research self-efficacy as indicators that participation in this STEM intervention program benefitted their students (Maton et al., 2016). In a qualitative, case study analysis of the Comprehensive STEM Program at Jefferson State University in the Midwest United States, Lane (2016) determined that this STEM enrichment program was contributing to the success of underrepresented student populations by looking at participant interview data through the lens of STEM identity development and confidence building. Although different in methodology, the combined works of Maton et al. (2016) and Lane (2016) indicate that the effectiveness of a college-level STEM intervention or enrichment can be evaluated using the constructs of science identity and science self-efficacy. Other researchers have explored the conceptual ideas of attitudes and interest in STEM content and careers after participation in an intervention or enrichment program across a wide band of grade levels from middle school into college. For example, in a mixed methods evaluation of the Inquiry-Based Science and Technology Enrichment Program for middle school-aged female students, Kim (2016) used a substantial change in student attitudes towards science and an improved willingness to choose a career in a STEM field to determine that the enrichment program was effective. Success of a Geoscience summer enrichment program for high school students was determined by a quantitative analysis that indicated a significant increase in likelihood of studying STEM fields in college combined with a large increase in student who were considering the option of becoming a geoscientist at the close of the program to indicate that the program made a strong, positive impact on the participants' attitudes towards science and science careers (Carrick et al., 2016). In a mixed methods study of another precollege outreach intervention at a large midwestern university, Constan and Spicer (2015) found growth in the percentage of students who reported an increase in science interest and science educational goals and career plans after participation in the Physics of Atomic Nuclei program to determine program success. Although the students in this STEM intervention program had already expressed an interest in science careers and self-selected into this rigorous and competitive intervention, the interview results showed that student interest in STEM careers become more specific, active, and focused during their participation (Constan & Spicer, 2015). This trend of using nonacademic indicators like STEM attitudes and interests to determine the effectiveness of STEM interventions and enrichments continues into college and university programs. A concurrent triangulation, mixed methods study of the effectiveness of the science, engineering, and technology SETGO program for undergraduate STEM majors at a community college and a public, four-year college provided data that showed the positive impact of the intervention by measuring an increase in positive attitudes towards STEM and STEM careers as well as more positive attitudes towards doing scientific research as a career goal (Huziak-Clark, Sondergeld, van Staaden, Knaggs, & Bullerjahn, 2015). Increases in nonacademic indicators of STEM intervention or enrichment effectiveness like science identity and self-efficacy as well as STEM interest and attitudes have been used across many different types of programs to demonstrate positive participant outcomes.

The number of different measures of STEM intervention and enrichment program effectiveness have made it difficult for researchers to make any consistent conclusions about what truly constitutes an effective program. A meta-analysis of 918 STEM intervention program studies indicated that few thorough studies of successful interventions have been conducted so determining the causal effects of this type of STEM program is challenging (van den Hurk et al., 2019). The results showed most of the existing studies were focused on increasing STEM interest in high school and post-secondary programs and that evidence showed that STEM interest was already present for students in elementary grades (van den Hurk et al., 2019). A similar review of 53 existing experimental and quasi-experimental studies of student motivation in STEM subjects at the secondary level revealed that most STEM interventions show small to moderate effect sizes and it is difficult to determine which characteristics of the intervention or enrichment moderate success for different students so determining overall effectiveness is not possible (Rosenzweig & Wigfield, 2016). Another issue related to indicators of effectiveness is that program evaluations for STEM interventions and enrichment programs often do not use valid and reliable evaluation tools to report student outcomes, overall costs, and assessment techniques (Dillon, Reif, & Thomas, 2016). The lack of consistency in defining measures of effectiveness and the lack of robust research in this area of study serves as a barrier for setting guidelines for educators and policy makers around developing and implementing effective STEM intervention and enrichment programs.

STEM intervention and enrichment programs can be costly to implement in terms of time, money, and human resources and these costs can impact the long-term stability and sustainability of this type of educational program. In a quantitative study of the return on investment for two different STEM intervention program models, the data showed that both the single-day model and the multi-day model had a positive impact on student attitudes towards as well as their interest in STEM-related college and career pathways (Dillon et al., 2016). However, the study also found that the tangible costs (meals, stipends, housing costs, etc.) for the multi-day model were ten times greater than the single-day model and the intangible costs (staff contact hours, facilities space, STEM and college-prep experiences, etc.) were four times more for the multi-day model than for the single-day model (Dillon et al., 2016). Dillon et al. (2016) determined that student outcomes did not increase with increased investments in the program, bringing into question the value of offering more expensive multi-day experiences if outcomes are not also greatly increased. Similarly, a longitudinal study of high school students in England over a five-year period suggests that the large investment of resources in STEM intervention programs does not translate into improved school performances according to national assessment scores for students who have participated in STEM programs compared with their peers who have not participated in STEM interventions (Banerjee, 2017). However, qualitative data indicate that the leaders of programs believe these programs should continue to be funded. For example, in interviews, STEM program directors and administrators from public universities voice believe there is still a need for consistent and institutionally supported funding structures within colleges and departments to ensure the continuation of SIPs to meet the needs of underserved student populations in STEM programs (Rincon & George-Jackson, 2016b). Effective STEM interventions and enrichment programs that are supported by policies and practices that provide for the tangible and intangible costs of these investments provide for a higher return on investment for students and STEM programs.

Authentic STEM Experiences

Successful STEM intervention and enrichment programs often share an aspect of authentic and contextual learning within the confines of the STEM experience. One component of authenticity in a STEM program is that it provides an applicable and tangible field or lab work aspect. A naturalistic case study of fifth and sixth grade girls who participated in an informal engineering program found that when the students had the opportunity to feel like they were doing science rather than following someone else's instructions or relying on information that was provided to them, their engagement with the STEM content material increased (Hug & Eyerman, 2018). High student engagement, as well as increased self-efficacy in science and math, was also noted in the data of a mixed methods study conducted on a cohort of middle school girls who participated in a fashion-based, STEM intervention program when the learning practices included hands-on, experiential learning about the relationship between fashion and STEM (Ogle, Hyllegard, Rambo-Hernandez, & Park, 2017). Data from a mixed methods evaluation of a lab sciences outreach program for high school students at a Oklahoma State University indicated that when students were able to have a hands-on and interactive experience in a laboratory setting, they were able to understand science as practice rather than just a group of facts (Angle et al., 2016). Field work settings also provide opportunities for students to engage with STEM during an intervention or enrichment program. A quantitative study of high school students who participated in a geosciences summertime intervention program in partnership with the University of Texas that incorporated field-based, data collection practices and a field-work project showed an increase in positive attitudes towards science (Carrick et al., 2016).Induction and retention into the geoscience pipeline also increased for students following their participation in the program (Carrick et al., 2016). Research supports authentic and applicable lab and field work experiences as a component of a successful STEM intervention or enrichment program for middle and high school aged students.

Closely connected to the idea of hands-on and engaging field and lab work is the concept of inquiry in the authentic STEM experience. A mixed methods study of eighth grade female participants in a guided inquiry-based summer STEM intervention program indicated that the girls' attitudes towards science and science careers were significantly more positive after they were given the opportunity to engage in group work and hands-on technology activities to generate answers to their own questions (Kim, 2016). An important qualitative finding in this study was that being exposed to an inquiry experience helped to dispel the preconception that the students had about scientists being men who worked in labs and did chemistry experiments (Kim, 2016). Interview answers and post-intervention drawings from Kim's (2016) study showed that students began to explore the idea that they were scientists and that they saw the application of science and technology beyond the classroom. In a different study, qualitative interviews done with fifth- and sixth-grade female students following an engineering STEM intervention program that included inquiry as an instructional practice also showed an ownership of scientific and engineering practices as well as a deeper conceptual understanding of science content (Hug & Eyerman, 2018). An analytic sampling of middle school female students that participated in a summer STEM intervention camp which intentionally structured STEM experiences around inquiry and exploration of science concepts in relatable contexts showed higher post-intervention science efficacy, interest, identity, and attitude scores than students in the control group (Todd & Zvoch, 2018). Taken together, these studies indicate that inquiry is especially effective when used with middle school-aged, female STEM students. Meaningful interactions with STEM concepts in an inquiry-based format provides for authenticity in STEM intervention and enrichment programs and leads to positive, nonacademic student outcomes.

As inquiry and field-experiences are crucial components of authentic STEM experiences for middle and high school-aged students, research opportunities and professionalism are equally critical for college-aged students as they participate in STEM intervention and enrichment programs. A mixed methods study of participants in a pre-college, research intensive program indicated that the authentic research experience was highly valued by the students and that lab training sessions and experimental interactions with faculty members helped to challenge the stereotype that scientists work alone in isolation (Constan & Spicer, 2015). This framework of science identity and sense of belonging was echoed in the interview results from a case study of 50 undergraduate students at a midwestern university who participated in a Comprehensive Science Program which included an undergraduate research opportunity (Lane, 2016). Students said that they appreciated the chance to make connections between classroom learning and real-world applications and were able to use the research opportunity as a catalyst for the development of their STEM identity (Lane, 2016). A mixed methods study of participants in a STEM Summer Research program at a public, four-year university indicated that the students were more confident in their ability to persist in STEM fields and were better able to connect their undergraduate coursework with authentic STEM practices than before their authentic research experience (Huziak-Clark et al., 2015). Along with increased opportunities to participate in research experiences, STEM intervention and enrichment programs can also offer opportunities for other professional

STEM activities. A qualitative case study of 47 participants from the Program for Research Initiatives in Science and Math undergraduate STEM intervention program at John Jay College in New York provided data about the importance of professionalism experiences in the STEM educational pathways of underrepresented student populations (Carpi et al., 2017). Students expressed their appreciation for the ability to attend professional academic conferences, the empowerment of writing and submitting academic journal articles, and the excitement of being able to earn authorship credentials at such an early juncture in their STEM career pathway (Carpi et al., 2017). Learning the physical and social structures of a research lab setting and engaging with professional STEM experiences like writing and publishing STEM research papers as part of a STEM intervention or enrichment program provides authenticity at the post-secondary level for STEM students.

Teaching STEM content areas in isolation from each other is an issue mentioned earlier in this literature review that can be resolved by teaching STEM through an interdisciplinary and integrated lens in intervention and enrichment programs. A mixed methods study of sixth-grade students participating in a STEM intervention project in Turkey showed an increase in cognitive thinking skills, math and science skills, design skills, and engineering skills after engaging in a series of 13 interdisciplinary STEM modules (Baran et al., 2016). A mixed methods study of 184 undergraduate students at a public university that were involved with an intensive, summer research experience indicated that the participants were engaged and motivated by the real-world connections that the interdisciplinary nature of the project brought to their experience (Huziak-Clark et al., 2015). Taken together, these studies show the critical impact that integrating independent disciplines of STEM knowledge can have on students across a spectrum of age groups. STEM intervention and enrichment programs need the integration of many different skill sets to be effective. The results from a meta-analysis of 84 OST STEM programs provided evidence that enrichment and intervention programs that are strictly academic in nature are not as effective in increasing student interest in STEM educational and career pathways (Young et al., 2017). Young et al.'s (2017) analysis shows that the integration of social and emotional connections with academic rigor has a larger effect size on student STEM interest than less holistic programs that focus solely on academics for underrepresented populations of students. Building an authentic array of content disciplines and social-emotional skills into a STEM intervention or enrichment program increases the likelihood that the program will engage student interest in STEM educational and career pathways.

Community-Building Experiences

STEM intervention and enrichment programs which are holistic in nature and have a strong focus on community building experiences can be effective in recruiting and retaining STEM-capable students in STEM educational pathways. A series of interviews conducted with faculty and administrators that work with underrepresented college undergraduate students from 10 large, public universities provided qualitative data to support the theme of community building as a crucial component of intervention programs (Dyer-Barr, 2014). According to the administrators in this study, this sense of belonging and supportive community atmosphere extended from academic relationships into personal and social relationships and allowed faculty members to be more effective advocates for the needs of their STEM students (Dyer-Barr, 2014). Increasing positive relationships between STEM staff/instructors and STEM students, STEM students and STEM professionals, and STEM students and other STEM has shown to be successful in some STEM intervention and enrichment programs.

Providing mentorship support and diverse role models from the STEM community enhances the STEM intervention or enrichment program experience for underrepresented student populations. A case study of 47 underrepresented students participating in an undergraduate research experiential program at an east coast university cited mentorship as a key influence in the laboratory setting (Carpi et al., 2017). The students stated that they were able to gain a better understanding how to work within the professional scientific community after forming deep and long-term relationships with faculty members (Carpi et al., 2017). A mixed methods study of two similar research-based, college level intervention programs, a summer bridge program and a university level summer research experience, provided evidence that building working relationships with staff and faculty members increased student confidence in their ability to be successful at STEM tasks and increased the STEM persistence intentions of STEM majors (Huziak-Clark et al., 2015). Mentoring experiences like the ones provided in research-based intervention programs can lead to the formation of mentor networks for STEM students. A longitudinal study of 116 female STEM majors from seven universities in Colorado and Wyoming who all participated in the Promoting Geoscience Research, Education, and Success intervention program indicated that the STEM intervention program increased the number of mentors available to each participant and helped them to form large networks of faculty and peer mentors over the course of the program (Hernandez et al., 2017). The large mentoring networks that the students were able to develop by participating the STEM mentioning intervention program led to increased STEM interest and persistence intentions as well as an increased science identity (Hernandez et al., 2017). STEM students become more confident in their abilities and more likely to persist in STEM educational pathways when provided with opportunities to work with mentors and STEM professionals in authentic field work and laboratory settings.

Another community building experience that lays a foundation for favorable student outcomes in STEM intervention enrichment programs includes networking and social group membership. A quantitative evaluation of a STEM intervention program at the University of Memphis compared students who participated in networking events and learning communities during their STEM college experience with those who had a more traditional college experience and found that the social interactions in the networking significantly increased student retention and performance in STEM courses and the learning communities significantly increased student retention (Windsor et al., 2015). While this study focused on college-aged STEM students, other research shows that face-to-face social group membership is also important at the earliest stages of STEM education. A quantitative study of 150 preschool students from middle- or upper middle-class backgrounds showed that belonging to a social group increased the children's STEM engagement and task persistence when compared to performing the same STEM-related tasks as an individual (Master, Cheryan, & Meltzoff, 2017). Even though many STEM subjects are traditionally regarded as individualistic, participating in networking and socialized learning communities can provide environmental support for students participating in STEM intervention and enrichment programs.

Peer interactions and mentoring supports provide a benefit for students who are participating in STEM intervention and enrichment programs. A case study of undergraduate student outcomes after participating in a STEM intervention program at midwestern university showed that the use of peer-mentoring programs helped expose incoming students to more experiences students who could serve as role models in navigating a large STEM college program (Lane, 2016). Lane's (2016) study also indicated that peer-to-peer relationships within a cohort of STEM students increased comfort levels and sense of belonging for those students which led to persistence within STEM majors. Cohort models for cooperative learning and social support can lead to positive student outcomes in STEM intervention and enrichment programs. A quantitative analysis of the Student Retention Enhancement Across Mathematics and Science program, which encompassed five STEM departments at a large, public university, showed increases in student grades, course success rates, and retention rates for STEM majors who participated in peer cooperative learning (Salomone & Kling, 2017). While the study focused on peer interactions within the classroom with academic measures, other studies have shown that peer interactions outside of the classroom can positively impact nonacademic measures of STEM student success. A quantitative study of 381 female engineering students from nine, large public universities provided results which indicated that social support systems that included living-learning communities and peer mentorship opportunities positively impacted perception of departmental climate (Rincon & George-Jackson, 2016a). While this study did not find any significant impacts on female engineering student performance after participation in a STEM intervention program, there was increased self-efficacy due to the mitigating influence of perceived social supports (Rincon & George-Jackson, 2016a). STEM students that participate in STEM intervention and enrichment programs are positively influenced by interactions with their same-cohort and older-cohort peers.

STEM-Specific College Experiences

The transition from high school to college and beyond can be challenging for all students but STEM students benefit from STEM intervention programs that are specifically tailored to the unique needs presented by STEM educational and career pathways. Interview data from a mixed methods study of high school students and teachers that participated in a STEM college outreach program indicated that the STEM students were interested in exploring the lab and research classrooms of a college campus in order to make informed decisions about STEM college majors and STEM career possibilities (Angle et al., 2016). Once prospective STEM students enter college, further programmatic supports can lead to success for STEM majors. A quasi-experimental, longitudinal study of 424 high-achieving, underrepresented minority, science majors who participated in a research program that was designed to help strengthen student skills in the areas of academic preparation and research training provided data that showed supplementing student skills in STEM areas increased the likelihood that they would be engaged in a scientific career after graduation (Woodcock, Hernandez, & Schultz, 2016). Providing academic and persistence support helped to diffuse the effect of stereotype threat on underrepresented minority students entering an academic STEM environment by increasing a sense of belonging and science identity (Woodcock et al., 2016). Challenging gateway courses can be barriers for students as they enter STEM college programs. Salomone and Kling (2017) collected quantitative data from college students who participated in a peer cooperative learning STEM intervention program in five STEM-related departments at a public university and found that the cooperative learning support helped them to be more successful in learning the math and science content in those introductory courses. STEM intervention programs also focus on the post-baccalaureate planning stage of STEM educational pathways. Carpi et al. (2017) used case study data from college students who participated in a STEM intervention program that included monthly meetings with graduate program staff members and college alumni who were active in STEM careers to explore career choice behaviors. Participation in the STEM intervention program led to 68% of the students who had no prior interest in graduate school programs developing an interest in continuing their education beyond the undergraduate level due to their exposure to possible career options and potential degrees available in STEM fields (Carpi et al., 2017). Every stage in the STEM educational pipeline, from college entrance transitions to post-graduation opportunities, presents challenges and potential barriers that are specific to STEM programs and effective STEM interventions at the college level can mitigate the impact that these barriers can have on STEM students.

Citizen Science

In the previous section of my literature review, I described formal and informal types of STEM intervention and enrichment programs and I discussed components that are shared by effective programs, like authentic STEM building experiences, community building experiences, and STEM-specific college experiences. Citizen science programs are an innovative type of STEM program that enlists the support of professional scientists as it seeks to combine educational and participatory engagement with the creation of new scientific information through data collection and analysis for members of the public (Ballard, Robinson, et al., 2017; Bonney, Phillips, Ballard, & Enck, 2016; Kullenberg & Kasperowski, 2016). In this section of the literature review, I will define the practice of citizen science and discuss positive learning outcomes from participation is citizen science programs, especially as they relate to underrepresented STEM populations. I will outline some concerns that show up in the literature regarding citizen science and provide some background on citizen science programs that incorporate place-based learning to strengthen learning outcomes. I end this section by introducing a valid and reliable instrument for assessing SCCT variables in place-based, citizen science programs.

Defining Citizen Science

Citizen science has been practiced for centuries by amateur astronomers and natural history enthusiasts but has more recently been situated in the context of partnerships between formal science institutions, like colleges and museums, and community members with an interest in science (Wallace & Bodzin, 2017). Citizen science was first defined by Irwin (1995) through a sociological lens as a way to involve members of the public in decision-making processes that involved conservation and management of natural resources and increase their connection to scientific concepts. Bonney (1996) approached citizen science as a practicing ornithologist with Cornell University and added public participation in the processes of scientific research by means of data collection and analysis to the original definition. Combining aspects of scientific research with the stewardship of the environment led to the current definition of citizen science as a collaboration between professional scientists and nonprofessional citizens to collect and/or analyze scientific data to build scientific knowledge and practice active conservation of the natural world (Ballard, Robinson, et al., 2017; Merenlender, Crall, Drill, Prysby, & Ballard, 2016). Citizen science is a method of increasing public understanding of science and allows citizens to be stakeholders in scientific policies (Bonney et al., 2009, 2016).

As a concept, citizen science is becoming more recognizable to the general public and to members of the scientific community. In a quantitative study of 485 adult visitors to the Minnesota State Fair, survey data showed that only 25% were familiar with the term citizen science but when given a conceptual definition, 43% said that they had heard of citizen science (Lewandowski, Caldwell, Elmquist, & Oberhauser, 2017). Lewandowski et al. (2017) also found that when the fair-goers were provided with alternative terms for citizen science, like crowd-sourced science, community-based monitoring, and public participation in research, that percentage increased to 73% showing that the general public is familiar with citizen science programs. Defining and understanding the concept of citizen science requires researchers to be familiar with the variety of alternative terminology used to describe citizen science programs. A scientometric meta-analysis of two large data sets from the Web of Science based on the titles of citizen science projects as well as relevant search terms indicated that common synonyms for citizen science included community-based monitoring, volunteer monitoring, and participatory science (Kullenberg & Kasperowski, 2016). Bonney et al. (2009) pointed out that citizen science includes the processes of volunteer monitoring and participatory action research so these are often interchanged with the citizen science term. Citizens and scientists involved with citizen science use a wide range of terminology to refer to projects that allow for the active engagement of community members in scientific research and conservation decision-making processes.

Citizen science programs can be organized into different classification systems based on characteristics like the level of engagement by participants, the nature of activities engaged in by participants, the time and geographic scope, or projected goals and outcomes of the project. Bonney et al. (2009) originally suggested using level of citizen engagement to categorize citizen science projects as contributory, collaborative, or co-created. Contributory projects involve scientists as the designer while the public just helps to provide the data so engagement is limited; collaborative projects entail scientists designing the initial program with the public modifying the project with data analysis and/or the dissemination of relevant findings so engagement is increased; co-created projects require scientists and the public to identify a common interest and then to create a way of using scientific processes to address that issue so citizens are actively involved in this type of project (Bonney et al., 2009). Bonney et al. (2016) later suggested using the nature of citizen science activities as an alternative framework for categorizing citizen science projects as either data collection, data processing, curriculum-based, or community science. Data collection projects collect data for scientific research by following established scientific protocols; data processing projects focus on categorizing, transcribing, and interpreting data that was collected by someone else; curriculum-based projects are developed for K-12 audiences and are connected to either formal or informal educational settings; and community science projects might involve data collection but have policy- or decision-making as their intended outcome (Bonney et al., 2016). Citizen science programs develop to meet differing needs and interests in a community and can be specialized beyond engagement levels and nature of activities. Ballard, Robinson, et al. (2017) used program goals along with duration and geographic scope to categorize citizen science projects as bioblitzes and other citizen science events, ongoing monitoring programs, bounded field research and inventory projects, and data processing of digitized collections projects. BioBlitz and citizen science events are designed to take a snapshot of specific site over a very short period of time; ongoing monitoring programs are designed to monitor local and/or national changes in species over several years; bounded field research and inventory projects are driven by a single research question and can last for months or years at the local, regional, or national level; and data processing of digitized collections is a method of crowd-sourcing data entry for museum collections and can have any time duration and worldwide participation (Ballard, Robinson, et al., 2017). Evaluating participant engagement levels, project activity types, and the boundaries of intended goals, time, and geography allows for the development of different types of citizen science programs to fill a variety of niches in scientific and community spaces.

As citizen science becomes more common in scientific fields of study, some disciplines have been quicker to adopt citizen partnerships and collaborations than others. Ecological and conservation branches of study extensively utilize citizen science projects with astronomy, medical sciences, and meteorology beginning to find a place for both scientific research endeavors as well as policy- and decision-making citizen science (Lewandowski et al., 2017). With available information technology and the ability to make and record real-time data observations, global researchers of climate change are finding value in the data sets that are provided by citizen science (Wallace & Bodzin, 2017). A scientometric meta-analysis of citizen science using the Web of Science citation indexing service indicated that citizen science has three main areas of focus in scientific disciplines with the largest being biological, conservation, and ecological data collection and classification (Kullenberg & Kasperowski, 2016). Kullenberg and Kasperowski (2016) identified geographic informational research as a second focus area and the epidemiological branch of social science as a third strand of current implementation of citizen science projects. Some specialty content areas like ornithology, microbiology, and meteorology are creating large volumes of scientific output in terms of publishing the results of the citizen science partnerships in their respective areas (Kullenberg & Kasperowski, 2016). Citizen science has become prevalent in many disciplines of the natural sciences and is finding some crossover with social sciences as well as geographical information science.

Learning Outcomes of Citizen Science

As more scientific disciplines invest resources in citizen science programs and projects, measurable and achievable learning outcomes like scientific literacy, knowledge of science content material, and scientific inquiry process skills become accessible to a wide age range of citizen science participants (Bonney et al., 2016). In a mixed methods study of two regional citizen science programs in California and Virginia, data collected from 350 volunteer naturalists showed that ecological knowledge and skills increased after participating in the naturalist training course and those participants were more confident in their scientific inquiry skills (Merenlender et al., 2016). While most of the participants in Merenlender et al's (2016) study were older females, similar results were found in a population largely made up of adult male participants. A quantitative study done on 212 volunteers in a coral-reef biodiversity monitoring program in Egypt, Sudan, and Saudi Arabia showed a significant increase in biological and ecological knowledge (Branchini et al., 2015). This trend of increased scientific content knowledge for adult participants was evident in Evans et al.'s (2005) qualitative study of 45 interviewed volunteers in a Washington, D.C. area nestwatch program. Participants ranged from senior citizens to middle-aged couples and single adults as well as families with young children and 90% of the participants reported that they gained content knowledge from the project, especially on the topic of bird ecology (Evans et al., 2005). College-aged students also show an increase in science knowledge and skills after participating in citizen science programs. Although the sample size is small, a quantitative survey of 31 college student perspectives of their knowledge and skills related to the content area of forest ecology showed increases in all subcategories after participating in a series of volunteer field identification experiences in New Jersey forest areas (Tsipoira & Kelly, 2015). Similarly, in a qualitative study of 13 undergraduate education majors from the eastern United States provided data to show that participating in a turtle identification citizen science project as part of their elementary science methods coursework improved their science content knowledge (Scott, 2016). Studies on middle school and high school students have found similar results. Brannon et al. (2017) used quantitative data to support extended student learning beyond the classroom during a small-mammal identification citizen science project and found increased knowledge of dichotomous keys, small-mammal biogeography, and experimental design and field research skills for 44 sixth through eighth grade students in North Carolina. A qualitative study of nine high school students in Spain who participated in a neuroscience citizen science project about the impact of color on learning processes provided data that demonstrated an improved understanding of scientific research and presentation skills along with a deeper understanding of science topics that had been covered in traditional classroom settings (Ruiz-Mallen et al., 2016). Measurable increases in science content knowledge and scientific process skills are a positive learning outcome for participants in citizen science projects and programs.

Citizen science learning opportunities can facilitate a positive change in nonacademic learning outcomes like science self-efficacy, interest, and attitude for citizen participants (Phillips, Porticella, Constas, & Bonney, 2018). In a quantitative study of five citizen science events held at four midwestern museums, Hebets, Welch-

Lazoritz, Tisdale, and Wonch Hill (2018) noted high interest scores for the 350 adults and families that visited the arachnids informal learning exhibits. Informal citizen science projects were not the only ones to show positive nonacademic outcomes. In a mixed methods study of 102 college undergraduates in Florida who participated in one of two citizen science projects as part of their entomology course, researchers found large positive increases in student attitudes towards participatory science and entomology as well as higher interests in these areas (Vitone et al., 2016). Kelemen-Finan, Scheuch, and Winter (2018) tracked 428 students ranging in age from eight to 18 from 16 schools in Vienna and Austria over a two-year period as they participated in a citizen science project that focused on gardens and backyard biodiversity. Quantitative data collected for different learning outcome categories showed increased interest and self-efficacy in science for all students as well as a strong positive changes in attitude, motivation, and desire to help the animals in the garden after involvement with the citizen science project (Kelemen-Finan et al., 2018). While this study focused on an ecological citizen science project in Europe, similar results were found when studying a technological citizen science project in North America. Wallace and Bodzin (2017) investigated the relationship between science and technology-based citizen science projects and the development of science identity in a quantitative study of 78 ninth grade students in the eastern United States. Their findings indicate that students that participated in the Mobile Learning and Authentic Practice experience were more interested in STEM career paths and had developed a citizen science identity based on their authentic experiences (Wallace & Bodzin, 2017). Taken together, these studies demonstrate the development of positive, nonacademic learning outcomes after participating in formal citizen science programs. Science self-efficacy, motivation to pursue scientific career goals, and positive interest and attitudes towards science are relevant and measurable outcomes for both informal and formal citizen science learning experiences.

Personal engagement with and awareness of conservation issues are also important learning outcomes for citizen science program participation. Project leaders for citizen science programs list conservation awareness and action as an anticipated learning outcome for their participants. In a quantitative study of 22 butterfly citizen science projects in the United States, Lewandowski and Oberhauser (2016) found that conservation was a priority for the majority of the censused project leaders and that their programs engaged participants in conservation-based activities. Unfortunately, the promotion of less direct forms of conservation activities outside of the direct impact of the citizen science program were not as evident and most of the project websites did not include information about additional conservation opportunities beyond the project (Lewandowski & Oberhauser, 2016). This is particularly important knowing that conservation literacy can serve as a precursor to conservation action during and after citizen science experiences. A mixed methods study of 432 adult participants from a west coast citizen science program that monitored 450 beach sites provided data that showed higher levels of informed concern about anthropogenic impacts on beach ecosystems as well as an increase in conservation actions like communication of program goals to others and participation in beach monitoring and trash collection after involvement in the program (Haywood, Parrish, & Dolliver, 2016). Natural history museums utilize citizen science programs to increase conservation awareness and action outcomes for their visitors. In a qualitative analysis of 44 citizen science programs from three different museums in the United Kingdom and the United States, Ballard, Robinson, et al. (2017) found evidence that over half of those programs contributed to conservation activities over either short-term or ongoing time frames as well as local, national, and global geographic scopes. While conservation awareness and action are outcome of citizen science programs for adult volunteers, environmental engagement opportunities can be an important learning outcome of citizen science programs aimed at college-aged students. Mitchell et al. (2017) used a mixed methodology to study a six-year partnership between an Australian university and Earthwatch Australia in which almost 1500 college freshmen were provided an opportunity to collect phenological data on plants and animals and then write and publish peer-reviewed articles on climate change impacts on those species. Data from the student surveys showed that the majority of the participants increased their environmental engagement and their interest in interacting with biological issues in the future (Mitchell et al., 2017). Middle and high school students also show gains in conservation awareness and personal engagement with environmental issues after participation in citizen science projects. Over 1000 students aged nine to 14 from 28 schools in the United States, India, Mexico, and Kenya participated in a quantitative research study of a mammal data collection citizen science project and the researchers found that participation gave the students an opportunity to view themselves as stewards of their local ecosystems and to experience biodiversity through a community-outreach, conservation lens (Schuttler et al., 2018). A qualitative study of two citizen science programs at multiple in- and out-of-school sites in California provided data that indicated an increase in environmental science agency for the middle school, high school, and college participants who felt empowered to take on responsibility for human impacts in their local ecosystems (Ballard, Dixon, et al., 2017). Students in these citizen science programs reported seeing their work as a starting place for future college and career plans in ecology and environmental sciences (Ballard, Dixon, et al., 2017). Grouix, Brisbois, Lemieux, Winegardner, and Fishback (2017) performed a systematic review of 64 journal articles on citizen science themes and shared the finding that many of the published studies focused on using scientific data to answer scientific questions and did not report any learning outcomes for the participants. Lack of reported learning outcomes presents a missed opportunity for citizen science to engage community participants with transformative experiences rather than just participate in the scientific process and indicates that many research studies are focusing more on Bonney's (1996) definition of citizen science rather than a blended definition that includes the social and civic connections of Irwin's (1995) definition. Developing personal engagement with scientific issues and exerting influence on conservation and management themes are positive learning outcomes directly linked to citizen science programs through current research studies.

Identifying personal science expertise and experiencing a sense of community during participation in citizen science programs provides a positive learning outcome for students and community members. In a qualitative study of nine adolescent and young adult participants in two citizen science programs to monitor ecosystem health along

California waterways, students reported finding new roles and skills as practicing scientists in field experiences (Ballard, Dixon, et al., 2017). Adult volunteers finding a sense of community during participation in citizen science projects is a common theme in the work of Lewandowski and Oberhauser (2016) as well as Haywood et al. (2016). In the butterfly conservation citizen science project, project managers surveyed reported that the majority of their participants felt this sense of community as a direct result of participating in the citizen science experience due to newsletters, training sessions, the sharing of volunteer stories inn discussion forums, and group work (Lewandowski & Oberhauser, 2016). In another adult volunteer study, 432 participants in a west coast beach monitoring citizen science program shared that they felt like they were part of a bigger community of people that shared common interests in conservation and beach ecology, regardless of their geographical distribution (Haywood et al., 2016). Student participants in citizen science felt more included in a community of scientists and adult volunteers expressed their sense of belonging to a community of science as a positive learning outcome from their citizen science experiences.

Learning outcomes can be beneficial for underrepresented student populations who experience citizen science projects and their learning outcomes. Teachers and schools that adopt citizen science curriculum-based projects present mandatory science immersion opportunities for students that might not normally have those experiences (Bonney et al., 2016). These citizen science programs are innovative ways of embracing traditionally underserved student populations in the area of outdoor education and environmental science (Ballard, Robinson, et al., 2017). A mixed methods study of 49 fifth grade girls, who participated in the FrogWatch USA citizen science program in five different states, provided data that indicated that the ethnic/racial minority students exposed to a combination of multimedia citizen science experiences and field work expressed higher interest in future citizen science project participation and held a stronger belief in their ability to be good at doing citizen science projects than their ethnic/racial majority peers (Flagg, 2016). While that study focused on late elementary school students, increased positive learning outcomes were noted for high school aged students as well. In a quantitative study of 220 sophomore and junior high school students from 10 Maine schools that participated in a stormwater research citizen science project, Musavi, Friess, James, and Isherwood (2018) found that female and underrepresented minority students showed significant increases in STEM education and career interest after participation in citizen science research and were particularly appreciative of the mentors and role models provided by the program. Trends in positive outcomes for underrepresented populations continued to be present for teenagers and even adults who experienced citizen science programs. Winter et al. (2016) used a mixed methods study to explore the impact of an active-living, health-based citizen science program on low income Latino participants in California and found that the adolescent and adult participants had positive user experiences with the citizen science data collection tools to identify and document barriers to health and personal safety in their neighborhoods so that they could advocate for community-based solutions. Science self-efficacy, increased STEM career and educational interest, and ownership of community policy-making experiences are all positive learning outcomes which are directly connected to participation in citizen science programs and projects for underrepresented populations of STEM-capable students.

Concerns About Citizen Science

Concerns about the ability of citizen volunteers to accurately and reliably perform scientific data collection and analysis tasks show up in the literature. A quantitative study of 485 adults attending the Minnesota state fair provided data that indicated a lack of confidence in scientific findings that are based on data collected by citizen scientists when compared to findings produced solely by professional scientists, especially in younger and less educated survey participants (Lewandowski et al., 2017). The results of the Minnesota study are supported by a pair of studies done on citizen science participants to verify their reliability and accuracy in identifying various plant species. A quantitative study of 607 students in grades three through 10 that identified oak crown shapes in a Washington forest provided data that showed students were more likely to skew sample counts by focusing on larger trees, which inflated habitat quality estimates, than professional scientists, especially for students younger than sixth grade (Galloway, Tudor, & Vander Haegen, 2006). Another quantitative study of 59 professors, graduate students, and professional land managers at two locations in Wisconsin and California provided data that showed that the professionals were more accurate in their identification of invasive plant species than the volunteer students and professors, especially when dealing with species that shared physical similarities (Crall et al., 2011). Students that participate in citizen science projects can experience a decreased belief in the reliability of citizen science-generated data sets. In a mixed methods study, college freshmen from Australia who participated in an Earthwatch species monitoring program over the course of a six-year period expressed concerns about data reliability at the end of the project since they had first-hand experience with the challenges of collecting and recording data in a large-scale, scientific research project (Mitchell et al., 2017). Awareness of training volunteers to accurately and reliably collect data in citizen science programs is an important aspect of implementing any citizen science program.

Adult participation in citizen science programs is often a volunteer effort and there is concern that self-selection for participation skews participant outcomes. Crall et al. (2012) performed a quantitative research study on 166 participants from Wisconsin and Colorado to determine the impact of citizen science training programs on participant learning outcomes and found that attitudes, behavior, and science literacy scores did not improve after participation in the program. The participants entered the program with strong scores in each of the areas so it is possible that people who participate in volunteer citizen science opportunities already are pre-disposed towards positive science attitudes and behaviors (Crall et al., 2012). This finding of pre-disposition towards positive citizen science outcomes due to prior knowledge has been supported by a subsequent study which showed similar findings of existing science interest and affinity in self-selected citizen science participants. Lynch, Dauer, Babchuk, Heng-Moss, and Golick (2018) conducted a mixed methods research study on 28 adult participants from six different entomology citizen science projects across the United States and found that test scores showed that the program did not have a statistically significant impact on the self-efficacy, action, or attitude of the participants. Participants in the projects had test scores that were significantly higher than the control group members which led the researchers to the conclusion that the participants entered the program with stronger background knowledge due to existing entomological interest than nonparticipants (Lynch et al., 2018). There is some indication that a lack of these pre-existing attitudes and behaviors serve as an impediment to self-selection into citizen science participation. A mixed methods study of over 1200 volunteers, agency staff members, and naturalists from two regional citizen science programs in California and Virginia allowed Merenlender et al. (2016) to identify a lack of science education and skills as well as low science self-efficacy as barriers to participation in citizen science programs for adult participants. Adults that participate in citizen science are often self-selected into those programs and may have a higher, pre-existing affinity for science content knowledge and skills than most members of the public.

Place-Based Citizen Science

Place-based citizen science programs offer the opportunity to interact with local issues through environmental and outdoor educational experiences (Brannon et al., 2017). In a qualitative analysis of 134 case studies from the citizen science project databases of CitSci.org, The Stewardship Network: New England, and Earthwatch, Newman et al. (2017) found that projects that used more dimensions of place like socioecological, symbolic narratives, knowledge-based, aesthetic/emotional, and performance were more likely to influence decision-making processes in relation to their local environment. While including the dimensions of place in a citizen science project can lead to advocacy and action, a sense of place can also increase awareness of relationships within those environments. In interviews with 45 suburban adults who participated in the Neighborhood Nestwatch Program in Washington, D.C. showed that participants were more aware of how the birds in their neighborhood interacted with components of the available habitat after their experience in the program (Evans et al., 2005). Heightened awareness was an emerging theme in a mixed methods study of 432 adult participants in a west coast beach monitoring citizen science program as well (Haywood et al., 2016). Haywood et al. (2016) noted that participants felt more ownership for the places in which they worked during their citizen science experience and that their sense of place increased their perception of the worth of citizen science. While the work of Evans et al. (2005) and Haywood et al. (2016) focused on adult volunteers, the impact of sense of place on citizen science participants can also affect student participants. A qualitative study of nine student participants from three different citizen science sites provided evidence that youth experiences with citizen science programs positively impacted their perception of the creek and beaches that they studied as well as the neighborhoods that surround them and increased their place identity and attachment (Ballard, Dixon, et al., 2017). Leveraging the power of place through citizen science experiences can create positive long-term outcomes in advocacy, awareness, and perceptions of local environments for both adult volunteers and student participants.

Citizen Science Self Efficacy Scale

Some work has been done in the area of citizen science programs and STEM career motivation. In a mixed methods dissertation study, Hiller (2012) developed a Citizen Science Self Efficacy Scale (CSSES) to explore the relationship between the

SCCT constructs of self-efficacy, task interest, outcome expectations, career choice goals, and science achievement and participation in a citizen science program for 86 eighth grade students. The results of the study showed that career choice goals were impacted by the other constructs after experiencing the citizen science intervention though there were no gender differences in any of the construct-based subtests except for science achievement, where males outperformed females (Hiller, 2012). Hiller also published the study, without including the CSSES instrument, in a scientific journal after earning her PhD. Her recommendations for further studies in this area were to explore the impact of prolonged citizen science experiences with the middle school-aged population since her program of study was a one-day program, to use a larger sample size for establishing construct relationships, and to delve deeper into gender differences among the SCCT constructs (Hiller & Kitsantas, 2014). In follow-up research, Hiller and Kitsantas (2016) validated the CSSES instrument using a series of three studies involving 248 eighth grade students and 15 field experts. Results from the validation study indicated that the instrument had high internal reliability and was a useful measure of self-efficacy in place-based, outdoor citizen science settings (Hiller & Kitsantas, 2016). When taken together, the dissertation and the two resulting published studies demonstrate the applicability of the CSSES instrument to my study of SCCT variables based on the gender and ethnicity of STEM students that participated in a middle school, place-based, citizen science enrichment program.

Summary and Conclusions

An overview of the SCCT model at the beginning of Chapter 2 provided a framework for exploring the possible interactions between person input variables like gender and ethnicity and career choice variables like self-efficacy, outcome expectations, and task interest in the study population of middle school students. In my review of the literature related to STEM career choice variables and underrepresented STEM populations, the themes that emerged were a working definition of the STEM acronym, the outlining of STEM educational and career pathways, a delineation of underrepresented STEM populations, descriptions of effective STEM intervention and enrichment programs, and a conceptual understanding of citizen science. An integrated STEM definition, like the ones used by the Pennsylvania STEM workgroup and the Idaho STEM Action Center anchored the current research study (Hemmingway, 2015; Nathan & Nilsen, 2009).

One of the major themes to emerge during a comprehensive search of the literature was that student decision-making about STEM career pathways begins to happen at very young ages so increasing student knowledge at those early stages of the STEM educational pathway must happen as well (Ball et al., 2017; Blotnicky et al., 2018; Morgan et al., 2016). Much of the current research focused on recruiting and retaining students in the STEM pipeline during high school and early college so the gap that remained was to determine effective strategies for encouraging STEM ability in middle school aged students.

A second theme to become apparent in the literature review was that contextual barriers and supports have an impact on some demographics of the population based on person inputs like gender and ethnicity/race and lead to an underrepresentation of those subgroups in STEM educational and career pathways (Cheryan et al., 2016; Fouad & Santana, 2017; Lent et al., 2018; Saw et al., 2018). Common methodologies for this research are large, longitudinal quantitative studies and small, qualitative case studies. More research was needed to quantitatively explore smaller cross-sectional populations of students from both demographics as they experience STEM learning experiences.

A third theme that was evident in current STEM education research was the effectiveness of STEM intervention programs at the college level and the contextual supports that help STEM-capable students to transfer from high school into STEM college programs and STEM careers (Carpi et al., 2017; C. E. George et al., 2018; Rincon & George-Jackson, 2016b). Research showed that OST STEM intervention programs exist at the middle and high school levels across the United States but their learning outcomes have not been evaluated for effectiveness (Young et al., 2017). There was a gap in the literature surrounding the use of formal and informal STEM intervention programs at the middle school level as an effective method for engaging underrepresented student populations.

A final theme to appear in this literature search was the positive impact of citizen science programs on academic and nonacademic learning outcomes for adult and student participants (Haywood et al., 2016; Kelemen-Finan et al., 2018; Merenlender et al., 2016; Mitchell et al., 2017; Ruiz-Mallen et al., 2016). Published research on the topic of citizen science programs and their impact on self-efficacy, content knowledge, and task interest and engagement focuses on adults and college-aged youth. A significant gap remained about the impact that these programs might have on the learning outcomes for middle and high school students. My study expanded on current research about how SCCT career choice variables like self-efficacy, interests, and outcome expectations encouraged students to enter and persist in the STEM career pipeline and added understanding to the gap by providing quantitative data about how citizen science intervention programs served as environmental supports at early entry points into that pipeline which lead to differences in STEM career pathways for underrepresented subpopulations of students.

Chapter 3: Research Method

Introduction

The purpose of this quantitative study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender and their ethnicity after participating in a citizen science STEM intervention program. To accomplish this purpose, I collected survey data from students who had participated in a water quality citizen science program. The data were then analyzed for relationships between the major variables in this study.

In Chapter 3, I will outline my research methodology for this study. I will begin by describing my research design and rationale for implementing that design. Then, I will review how I recruited and sampled my research population. Next, I will discuss my chosen instrumentation and data analysis plan. I will end the chapter with an overview of threats to validity for the data and ethical considerations that are relevant to this study.

Research Design and Rationale

In this nonexperimental comparative study, I examined differences in the dependent career choice variables of science self-efficacy, task choice, and outcome expectations for the independent variables of gender and ethnicity. The use of a nonexperimental comparative research design was well suited to my RQs because the students were not randomly assigned to control and treatment groups, but instead had been participants in the same STEM intervention program before my study was conducted; thus, there was no researcher influence on that experience. Use of this study design provided correlational data for the major study variables.

Participants in this research study had already completed the citizen science intervention program when they took the CSSES so there was a time-associated constraint on remembering their levels of the dependent career choice variables. Because student participants from the citizen science intervention program had completed a posttest version of the CSSES survey, a posttest-only design best fit this study. Trochim (2006) indicated that this research design provides protection from selection-testing and selection-instrumentation issues as repeated measures are not required . Due to the shortened time frame required by use of this research design, any potential resource constraints regarding the cost of administering multiple surveys were also mitigated.

Nonexperimental comparative research designs have been used in the study of career choice variables for underrepresented STEM populations in order to determine differences in dependent variables following participation in STEM activities for genetically and socially determined independent variables which cannot be randomized by the researchers (Fouad & Santana, 2017; Lent et al., 2018). My study explored the variables of gender and ethnicity and compared self-efficacy, task interest, and outcome expectations for a group of students who had participated in a STEM intervention. The use of this design was therefore consistent with my research intended to advance knowledge in the area of underrepresented populations in STEM educational and career pipelines.

Methodology

In the methodology section of Chapter 3, I provide information about the population for this study. I will share my sampling procedures for obtaining a reasonable sample including inclusion and exclusion criteria and recruitment procedures. I will give an overview of the instrument that was used in collecting the data, how the variables in this study were operationalized, and how the data were analyzed.

Population

The target population for this study included students who had completed the eighth-grade water quality citizen science component of the Water and Soil Stewards Summer Program (WASSSP) partnership (pseudonym) between a public-school district and a private college in a northwestern U.S. state. The target population size was 96 students over a 3-year period including the years 2017, 2018, and 2019.

Sampling and Sampling Procedures

I selected research subjects using a purposive sampling method in which only former participants from the eighth-grade component of the WASSSP program were sampled. This sampling method was justified because nonexperimental comparative designs involve the use of nonprobability sampling strategies that cannot rely on randomization to obtain a sample that is representative of the target population (Daniel, 2012). The procedures for how the sample were drawn included obtaining an attendance list from the WASSSP program for the 2017-2019 programs and then working with the affiliated public-school district to obtain contact information for the parents of the students on the attendance list. An a priori power analysis using G*Power (Faul, Erfelder, Lang, & Buchner, 2007) with an alpha level of .05, a power of 0.80, and a medium effect size of 0.40 was used to determine a sample size of 28. This sample size allowed for the detection of differences for the two levels of each independent variable and the three dependent variables.

The procedures included both inclusion and exclusion criteria. To be included, participants (a) must have been former participants in the eighth-grade citizen science water quality component of the WASSSP program, (b) must have participated in WASSSP during the 2017-2019 time frame of interest, and (c) must have been able to take a computerized version of the data collection survey instrument using an e-mail account. Participants could not have been currently enrolled in a course taught by me. Otherwise, students who participated between the years 2017-2019 were invited to participate.

Procedures for Recruitment, Participation, and Data Collection

The recruiting procedures for the study included several steps. First, I obtained a letter of cooperation from the partnering school district indicating that the superintendent supported and approved of my plan to conduct research in the school district. As part of that agreement, the district released to me the names of student participants in the program between the years 2017-2019 and the student school e-mail addresses, as well as parental content information, which was either an e-mail address or a postal mail address. Then, I began the process for obtaining parental consent. My recruitment procedures were a two-phase process. The first phase included an e-mail and postal mail attempt at contacting parents. For the parents for whom I had e-mail addresses, I sent an e-mail to each in which I invited their student to participate in my study. Due to a high percentage of families in this school district who speak a second language at home, I followed common school district practice and sent all communications with families in both English and Spanish. The English text appeared first in the e-mail with a message that encouraged Spanish-speaking families to scroll to the end of the e-mail for the Spanish translation. I provided information about the purpose of the study and let parents know that their student would be asked to take a short online survey, using the Qualtrics survey platform, about their experience with the WASSSP program. Qualtrics is an online survey platform with security features such as data encryption and accredited data storage centers (Qualtrics, 2019). A password-protected user login was required to access the data collected from this study. Qualtrics is compliant with a range of data security mandates including being ISO 27001 certified and FedRAMP authorized (Qualtrics, 2019).

I included a couple of sample questions in my e-mail to the parents and shared with them that the study was voluntary in nature and would not have any impact on the student's standing in the school district. In my e-mail, I briefly mentioned the minor risks of discomfort associated with taking an online survey, explained the benefits of study participation to both the STEM programs in the school district, and noted the thank you gift that I would give the students for their time. The e-mail concluded with some information about the privacy of their student's identity and survey responses and gave some contact information for me if they had any additional questions. Parents were provided with the option of hitting "reply" and typing the phrase "I consent" if they were willing to allow their student to participate in my study. If the parent did not have an e-mail contact, I mailed a letter to the physical address that was on file with the school district that contained the same information as the e-mail (purpose of study, Qualtrics procedures, sample questions, voluntary nature of survey, minor risks and benefits, privacy issues, and contact information for questions). Like the e-mail, the letter was written in both English and Spanish. A self-addressed, stamped envelope was included for parents to return the form to my home address. There was a note at the bottom that parents were able to make a copy of the form for their own records if they wished before returning it to me. I sent out follow-up e-mails and mailings, 7 days and 14 days after the first contact.

After 14 days, I needed additional responses, so I moved to Phase 2 of the recruitment process. I arranged to have a table at the high school's registration day to obtain consent from the parents of students who participated in the WASSSP program during the 2017-2019 cohorts using the letter that was mailed out during Phase 1.

Once consent was obtained from the parents, I created a list of those students who have been given parental permission to participate and matched the student names to their school e-mail addresses. Each student was then assigned a random code to protect their privacy. For these students, I sent an e-mail to their school e-mail address that contained the assent form. The assent form was similar to the parental consent form in content. I started by inviting them to join my project and then share with them the purpose of my study and making sure they understand that the survey is in no way associated with any project for school. Participation means agreeing to take a Qualtrics survey. I provided student participants with a couple of sample questions and then made sure that they knew that it is their choice to take the survey and that they could stop at any time. I mentioned the $5 gift card to a local coffee shop as a thank you gift for their time and let them know that their personal information and their survey answers would be kept private and secure unless they disclosed something that I would be legally required to share with a person in authority. My contact information was in the e-mail in case they had any questions. If they wanted to participate after reading the assent text in the e-mail, they were directed to click on the Qualtrics survey link at the bottom of the body of the e-mail. Students who clicked on the link from the e-mail were providing their implied assent. The link within the e-mail took them to the confidential online survey where they provided demographic information, including gender, ethnicity, and race, school e-mail address, and year of participation in the STEM intervention program. Requesting the school e-mail address was necessary for several reasons. The first was so that I could track student participation for the purpose of providing any student who attempted to complete the survey with a thank you gift card from a local coffee shop. The second was so that I could confirm that their parents consented to them taking the survey. The rest of the survey consisted of the CSSES survey questions.

Upon competition of the survey, students submitted their Qualtrics form by hitting the “done” button on the survey. A data report from Qualtrics was pulled daily following the issuance of the first set of assent e-mails to student participants until there were enough responses in the data set to meet the requirements of the MANOVA data analysis method. I sent a follow-up e-mail with a short reminder note about the invitation to participate in the study still being open and reminding them about the gift card for attempting to complete the survey 7 days, and 14 days after the initial e-mail was sent. Exiting procedures for this study were minimal in nature since student participation was limited to an electronic survey form. I cross-referenced the student e-mails provided in the survey data with the student e-mail file to confirm participation was attempted and then I mailed a thank you note and their gift card to the home address that was on file for that student. No additional exiting procedures were required after the survey had been attempted and the thank you gift had been delivered.

Instrumentation and Operationalization of Constructs

The instrumentation I used for this study was the CSSES (Hiller, 2012). I gained permission to modify and use this instrument from the author, Suanne Hiller (see Appendix A). This instrument was appropriate for this study because it was specifically designed and used as a method of collecting data on career choice variables in underrepresented student populations who have participated in citizen science STEM intervention programs. The CSSES instrument was previously used on eighth grade students from two suburban, public middle schools located in the northeastern United States (Hiller, 2012; Hiller & Kitsantas, 2014, 2016). The students had participated in a two-day citizen science program with horseshoe crabs. The students were 40% male and 60% female. The racial background of these students was approximately 60% white with 30% black, and the remaining 10% selecting other categories. Hiller and Kitsantas (2016) have performed reliability and validity research done on this instrument using a three-part study. The first part of the study used a small group of trained field experts (n = 15) and a small group of eight grade students (n = 12) to develop the instrument using their perceptions of effective outdoor educational practices. The second part of the study was an exploratory factor analysis which used a cohort of eight grade students (n = 113) to look at construct validity and internal consistency of the CSSES tool. The third part of the study was a confirmatory factor analysis that relied on another group of eight grade students (n = 123) to complete the final construction and validation of the instrument. The published reliability value for the CSSES is a Cronbach's alpha of .89. The CSSES had a high construct and predictive validity since it showed significant correlations with other established measures of career choice variables like the Sources of Science Self-Efficacy (Britner & Pajares, 2006) and the Career Goal Scale (Mu, 1998). A factor analysis showed a unidimensional factor structure.

Minor changes were made to the instrument based on the curriculum content (see Appendix B). This curriculum content of the current study was water quality while the original curriculum content assessed by the instrument was horseshoe crabs. The change in curriculum required changes to the terminology in the original instrument to align with the specific content topics covered by the WASSSP program. Another change was that the original instrument included a content knowledge section. Content knowledge was not a variable in my study, so I removed that portion of the instrument. The final change was to the demographics section of the instrument which was modified slightly to make the survey anonymous and to remove some unnecessary references to the dates and participation experiences from the original horseshoe crab program. Ethnicity categories were included alongside the CSSES's racial categories to align with the variables in my study.

Operationalization of variables. The independent variables were gender and ethnicity. These variables were measured/collected using part A of the modified CSSES. Gender was a categorical variable and was coded into two naturally occurring categories of male or female based on how participants self-identified on the survey (Babbie, 2017). Ethnicity was also a categorical variable and was coded into Hispanic or non-Hispanic based on participant self-identification (Babbie, 2017).

The dependent variables included the career choice variables of science self-efficacy, task interest, and outcome expectations. All three of the dependent variables were at the categorical ratio/interval level (Babbie, 2017). Science self-efficacy was defined as the belief that one is capable of performing scientific tasks (Lent et al., 1994). Science self-efficacy was measured using a Likert scale in part C of the modified CSSES. Scores were on a scale of 1 to 5 with 1 being "not sure at all" and 5 being "very sure". An example item from the survey was: *Use data (absorption curves) to determine a conclusion*. Task interest was defined as a liking for scientific activities (Lent et al., 1994) and was measured using a Likert scale in part B of the modified CSSES. Scores were on a scale of 1 to 5 with 1 being "strongly disinterested" and 5 being "strongly interested". An example item from the survey was: *Working in a science lab*. Outcome expectations were defined as one's beliefs about the consequences of performing scientific activities (Lent et al., 2002). Outcome expectations were measured using a Likert scale in part D of the modified CSSES. Scores were on a scale of 1 to 5 with 1 being "strongly disagree" and 5 being "strongly agree". An example item from the survey was: *Studying water quality will help me decide if I want to be a scientist*.

Table 1 shows an alignment of the dependent variables to the research questions.

Table 1

Alignment of Dependent Variables with Research Questions

Dependent Variables	RQ1	RQ2	RQ3
Science Self-efficacy	X		
Task Interest		X	
Outcome Expectations			X

Data analysis plan. For this quantitative study, I conducted a two-way MANOVA test. I used IBM SPSS version 24.0 software for analysis. Before data analysis, I cleaned and screened the data by running a frequency analysis to look for missing data and then replacing those missing values with a series mean. I looked at the skewness and kurtosis data using histograms and Q-Q plots. I used the Shapiro-Wilk test of normality to ensure that the assumption of normality was met for the dependent variables in the data. The Box's M test of Equality of Covariance Matrices was used to test the assumption of homogeneity for the results of the survey and a matrix of scatterplots satisfied the assumption of linearity. The data was also screened for multicollinearity by looking at correlations between the dependent variables.

1. Do self-efficacy scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0$1: There is no statistically significant difference in self-efficacy scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

$H_1$1: There is a statistically significant difference in self-efficacy scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

2. Do task interest scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

   $H_0$2: There is no statistically significant difference in task interest scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

   $H_1$2: There is a statistically significant difference in task interest scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

3. Do outcome expectation scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

   $H_0$3: There is no statistically significant difference in outcome expectation scores by gender or ethnicity for middle school students participating gin a citizen science intervention program.

   $H_1$3: There is a statistically significant difference in outcome expectation scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

The data analysis plan included several steps. The two-way MANOVA (multivariate analysis of variance) was the most appropriate statistical test for testing the hypotheses of this study since I analyzed the difference between the means of two independent variables, each with two independent levels, across a combination of three dependent variables (Warner, 2013). For the purposes of this study, there were no potential covariates or confounding variables. I calculated descriptive statistics for the data set, including mean scores and standard deviations. Results were interpreted using a series of multivariate tests including Wilk's λ for gender, for ethnicity, and for the interaction between gender and ethnicity. A partial η^2 was used to determine the percentage of variance that was explained by variations in my independent variables. The tests of between-subjects effect sizes also used a partial η^2 value. No post hoc testing was necessary since there were fewer than three groups for both independent variables. I set the p-value at the traditional .05 level for the purposes of assessing the significance of each statistic and confidence intervals were be set at 95%.

Threats to Validity

Addressing threats to validity refers to anything that might prevent a researcher from making trustworthy inferences about their study from the data that were collected (Babbie, 2017). Threats are important to discuss in quantitative research because experimental designs must meet rigorous standards for both external and internal validity in order to be recognized by the academic community as having a high level of trustworthiness (Campbell & Stanley, 1963). External threats to validity are those that make it difficult to generalize the findings of a study to the larger population that the study was meant to represent (Babbie, 2017). Internal threats to validity are factors that prevent the researcher from using the results from the experiment due to the fact that those results may have been caused by something other than the variables that were being tested (Babbie, 2017). Both external and internal threats to validity were addressed during my study.

It is possible that there were also threats to construct or statistical conclusion validity. The Cronbach's alpha for the data was analyzed to ensure that the measurements were reliable. The published instrumentation has a Cronbach's alpha of .89. A power size of .80 was chosen to make sure that the data analysis had the power to detect a medium effect size.

External Validity

There were several threats to external validity. In relation to my study, two important threats to external validity were the effect of testing and multiple treatment interference. Since student participants were surveyed after their participation in the citizen science STEM intervention program, there was no pretest administered, which created an effect of testing threat (Campbell & Stanley, 1963). To address this threat, the research design followed a posttest only design and relied on the assumption that the independent variable groups were equal before their exposure to the STEM intervention program (Campbell & Stanley, 1963). Students participating in this study were from a school district that offers several different STEM intervention and enrichment programs to interested students. The effects of those multiple STEM experiences could not be totally controlled for in the design of this experiment (Campbell & Stanley, 1963). There was a chance that some of the influence of those other programs affected the way in which those students responded to survey questions about STEM educational and career interests. To address this threat, the survey instrument was written with sentence stems to reference the current program as frequently as possible so that the student was considering that context as they answered each question.

Internal Validity

There were also issues of internal validity. For this study, the threats of maturation and instrumentation were especially important. Maturation becomes an issue in experimental studies when the subjects of the study grow or change during a long-term data collection period (Babbie, 2017). The citizen science STEM intervention program had three cohorts of student participants that were surveyed during this study and there was a chance that the participants from the 2017 and 2018 cohorts had been exposed to additional STEM experiences and activities that have influenced their answers on the survey for this study. To address this threat, the data was analyzed to look for statistical differences between the 2019 cohort and the previous two cohorts. No significant differences were detected so all three cohorts of data were included in the study. Changes in the instrumentation tool to meet the context of the citizen science program for this study may have affected the validity of the instrument (Campbell & Stanley, 1963). To address this threat, the changes made to the data collection tool were minor and applied only to the science content of the question rather than the sentence stem so that the sentences were still aligned to the career choice variable that they were measuring. As an additional precaution, the modified instrument was vetted by instructors from the citizen science program to ensure that the changes were only to the portions of the question that referenced the science content of this specific STEM intervention.

Ethical Procedures

For this study, I followed ethical procedures by applying to the Institutional Review Board (IRB) at Walden University. Institutional permissions, including IRB approvals were obtained for this study. The IRB approval number for this study was 06-12-19-0025761. There was some chance for a conflict of interest since I was employed by the cooperating school district, but this was minimized by the quantitative nature of the data collection and the fact that none of the participants were currently in or might in the future be in my classroom. The cooperating school district provided a letter of cooperation that gave me access to contact information for the study participants and their parents during the duration of the study. I obtained the appropriate permissions from the author to modify and use the CSSES instrument in my research.

The first ethical procedures I had in place were related to the treatment of human participants. I addressed ethical concerns about participant recruitment by using both a parental consent form as well as a participant assent form. These forms outlined the voluntary nature of this study and ensured both privacy and confidentiality of the data that was collected. No coercive methods were used to obtain these permissions, and it was made clear, that the school was not associated with the study, and that participating would not have any impact on the participants' school status or standing. The risks associated with this study were minimal and were described in the consent and assent documents. Contact information for myself and my university was included to make sure that anyone with questions about the study could get answers before agreeing to participate. Exclusion criteria for this study was very minimal and any student who met the inclusion criteria and wished to participate had that opportunity.

Other ethical procedures I had in place were related to the treatment of data. The data collected during the study was confidential. Once I confirmed the participants' demographic information and verified both consent and assent had been obtained, identifying information like names and e-mail addresses were stripped from the data file and stored in a separate file. A coding system was used to connect the two files and I was the only one with access to that system. My research procedures ensured privacy for the participants and their data and that data will be stored securely for at least five years on a password protected, home computer. Any hard copy data that was generated during this study will be kept in a file cabinet at my home, locked and secured for at least five years. Results can be shared with participants and other stakeholders from the cooperating school district after the study is completed but no one beyond myself, as the researcher, and the authorized representatives from the cooperating school district will have access to the data.

Summary

In Chapter 3 I explained my research design and my rationale for using that design. This chapter also consists of an overview of my methodology, including my research population, my sampling procedures, and my procedures for recruitment, participation, and data collection. I provided details about the instrumentation that I used for the study and how each of my variables was operationalized. My data analysis plan is provided along with a discussion of the anticipated threats to the validity of my study. The chapter concluded with the procedures that I followed to alleviate any ethical concerns or issues raised by this study.

In Chapter 4 I will discuss my data collection procedures in more depth. I will provide descriptive statistics for my data set and I will give an overview of participant demographics for my study. My overall statistical model will be presented along with the appropriate statistical data for each independent variable. I will end Chapter 4 by providing an overall summary of the data that I collected during my study.

Chapter 4: Results

Introduction

The purpose of this quantitative study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender and ethnicity after participating in a citizen science STEM intervention program. To accomplish this purpose, I conducted a MANOVA to examine the differences in means of science self-efficacy, outcome expectations, and task interest scores on the CSSES by gender and ethnicity for a population of students who had participated in a citizen science STEM intervention program while they were in middle school. The RQs and hypotheses for this study were

RQ1. Do self-efficacy scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0$1: There is no statistically significant difference in self-efficacy scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

$H_1$1: There is a statistically significant difference in self-efficacy scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

RQ2. Do task interest scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0$2: There is no statistically significant difference in task interest scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

$H_1$2: There is a statistically significant difference in task interest scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

RQ3. Do outcome expectation scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

$H_0$3: There is no statistically significant difference in outcome expectation scores by gender or ethnicity for middle school students participating gin a citizen science intervention program.

$H_1$3: There is a statistically significant difference in outcome expectation scores by gender or ethnicity for middle school students participating in a citizen science intervention program.

Chapter 4 includes the results of this quantitative, nonexperimental, comparative study. I will begin with a description of my data collection process, including participant recruitment and the demographics of my study population. Then, I will outline the results of my data collection with descriptive statistics and statistical findings for each of my research hypotheses. I will end the chapter with a summary of my findings.

Data Collection

I recruited participants throughout a 9-week period during the summer of 2019. The timing of this data collection period allowed the 2019 cohort of the STEM intervention program to complete their STEM experience and be eligible to participate in this study. Students and parents do not frequently check their school e-mails over the summer time. Opening data collection after the completion of the final cohort of STEM students had participated in the intervention program and closing it at the start of the new school year therefore provided ample time for contacting participants and their parents or guardians to obtain the necessary consent and assent. By August 10, 2019, I had 52 survey responses. I sent the initial invitation to participate and consent paperwork via e-mail and postal mail to parents on June 14th. Parents with working e-mails received a follow-up invitation on the 21st of June and the 1st of July. Parents without a working e-mail address received a follow-up hard copy mailing on the 1st of July. Due to the low response rate to the invitations that were sent by postal mail, only a single follow-up attempt was made to contact these parents. The culture of the cooperating district made it more likely that those parents would respond to a face-to-face contact at the August 7th high school registration activity. I decided to close the survey the weekend after the high school registration event and complete data collection at that point. All the students in the applicable cohorts had multiple opportunities to participate by that date. There were no discrepancies from the data collection plan that was outlined in Chapter 3. The response rate for this study was 54.2%. I attempted to contact 96 students who had participated in the citizen science STEM intervention, and I was able to obtain parental consent, student assent, and survey results from 52 of those participants.

Students participating in this study were public school students who had completed the eighth-grade component of the WASSSP STEM intervention program partnership in a northwestern U.S. state. Participants were currently entering their ninth-, tenth-, and eleventh-grade years when they completed the CSSES questionnaire. As reported in Table 2, the demographic characteristics show that the percentage of students in the study sample was about 40% male and 60% female in terms of gender and about 63% non-Hispanic and 37% Hispanic in terms of ethnicity.

Table 2

Participant Demographics of Students That Took the Modified CSSES

	2017 cohort *n* = 17	2018 cohort *n* = 18	2019 cohort *n* = 17	Combined *n* = 52
Gender				
Male	5	7	9	21
Female	12	11	8	31
Ethnicity				
non-Hispanic	10	10	13	33
Hispanic	7	8	4	19

I selected the sample for this study using a purposive sampling method. Only former participants of the eighth-grade component of the citizen science STEM intervention program were considered for the study. Participation was voluntary and not coerced. Both the parent and the student had to give consent/assent in order to be able to take the CSSES. Each sample of student participants varied slightly in how representative they were of their cohort in the population but the overall sample of the three combined cohorts was proportional to the larger population of STEM intervention participants with regard to the independent variables of gender and ethnicity (see Table 3); thus, external validity can be assumed.

Table 3

Participant Demographics of Students (Sample vs Population)

	2017 cohort		2018 cohort		2019 cohort		All cohorts combined	
	Population	Sample	Population	Sample	Population	Sample	Population	Sample
Gender								
Male	40%	30%	31%	39%	47%	53%	40%	40%
Female	60%	70%	69%	61%	53%	47%	60%	60%
Ethnicity								
non-Hispanic	49%	59%	48%	56%	66%	76%	54%	63%
Hispanic	51%	41%	52%	44%	34%	24%	46%	37%

Results of a series of one-way ANOVAs performed on each of the CSSES questions by year of cohort (see Tables 4, 5, and 6) showed that there were no significant differences among the three cohorts of students who participated in this study for 18 of the 19 CSSES questions. Question 7a showed significant differences among the cohorts. Levene’s test of homogeneity of variances based on the means yielded p values that ranged from .087 to .984 and showed no significance for 18 of the 19 CSSES questions so the assumption of homogeneity was not violated. Question 6c showed some significance with a *p* value of .023. The lack of significant differences among the three cohorts allowed me to include all three groups of students in the MANOVA model that explored differences in self-efficacy, outcome expectations, and task interest for the independent variables of gender and ethnicity. No covariates were included in either the preliminary one-way ANOVA models or the final MANOVA model.

Table 4

Descriptive Statistics for One-Way ANOVAs of Task Interest CSSES Questions by Cohort Year

	M	SD	*n*	Sig.
Q5a				.935
2017	4.00	1.0	17	
2018	4.06	.802	18	
2019	3.94	.966	17	
Q5b				.277
2017	4.18	.951	17	
2018	4.22	.808	18	
2019	3.76	.970	17	
Q5c				.764
2017	4.71	.470	17	
2018	4.61	.850	18	
2019	4.53	.717	17	
Q5d				.083
2017	4.35	.931	17	
2018	3.94	.873	18	
2019	4.59	.712	17	
Q5e				.474
2017	4.59	.618	17	
2018	4.72	.575	18	
2019	4.47	.624	17	

Note. $*p > .05$

Table 5

Descriptive Statistics for One-Way ANOVAs of Self-Efficacy CSSES Questions by Cohort Year

	M	SD	*n*	Sig.
Q6a				.220
2017	4.53	.514	17	
2018	4.17	.857	18	
2019	4.47	.514	17	
Q6b				.745
2017	4.24	.664	17	
2018	4.06	.639	18	
2019	4.18	.809	17	

(*table continues*)

	M	SD	*n*	Sig.
Q6c				.175
2017	4.65	.493	17	
2018	4.78	.428	18	
2019	4.47	.514	17	
Q6d				.928
2017	4.41	.712	17	
2018	4.44	.784	18	
2019	4.35	.606	17	
Q6e				.979
2017	4.12	.781	17	
2018	4.17	.786	18	
2019	4.12	.857	17	
Q6f				.868
2017	4.47	.624	17	
2018	4.44	.784	18	
2019	4.35	.606	17	
Q6g				.950
2017	4.65	.493	17	
2018	4.61	.608	18	
2019	4.59	.507	17	
Q6h				.200
2017	4.53	.624	17	
2018	4.11	.900	18	
2019	4.41	.507	17	

Note. *p > .05

Table 6

Descriptive Statistics for One-Way ANOVAs of Outcome Expectations CSSES Questions by Cohort Year

	M	SD	*n*	Sig.
Q7a				.044*
2017	4.47	.514	17	
2018	3.94	.639	18	
2019	4.00	.791	17	
Q7b				.908
2017	3.76	.664	17	
2018	3.72	.752	18	
2019	3.65	.931	17	

(*table continues*)

	M	SD	*n*	Sig.
Q7c				.293
2017	4.53	.514	17	
2018	4.33	.686	18	
2019	4.18	.728	17	
Q7d				.411
2017	4.12	.485	17	
2018	3.89	.758	18	
2019	3.82	.728	17	
Q7e				.953
2017	4.65	.606	17	
2018	4.67	.594	18	
2019	4.71	.470	17	
Q7f				.412
2017	4.47	.624	17	
2018	4.39	.608	18	
2019	4.65	.493	17	

Note. *p > .05

Results

Descriptive statistics that characterize the sample are shown in Tables 7, 8, and 9 and include the mean and standard deviation for each of the 19 modified CSSES questions. For the task interest questions on the CSSES (see Table 7), female, Hispanic students often had the highest mean, ranging from a 4.5 on question 5a and 5d to a 4.75 on question 5b. The lowest means scores for task interest were from male, Hispanic students and female, non-Hispanic students. The lowest task interest mean score of 3.57 was from male, non-Hispanic students on question 5b.

For the self-efficacy questions on the CSSES (see Table 8), female, Hispanic students again often had the highest mean for each individual question with a range from 4.42 on question 6b to a 4.83 on questions 6c and 6g. Male, Hispanic students continued to score the lowest means for almost every question. The lowest self-efficacy mean score was 3.74 from female, non-Hispanic students on question 6e.

For the outcome expectations questions on the CSSES (see Table 9), the means were lower overall that for the other two types of questions though this is the only section where one of the questions showed a 5.00 with female, Hispanic students on 7e. The female, Hispanic scores were again usually the highest for each question and ranged from a mean of 3.83 on question 7b to the 5.00 on question 7e. The lowest mean score for outcome expectations was a 3.29 for male, Hispanic students on question 7b.

Table 7

Descriptive Statistics for Two-Way MANOVA of Task Interest CSSES Questions

	M	SD	*n*
Q5a			
Male			
non-Hispanic	3.79	1.122	14
Hispanic	3.71	.488	7
Female			
non-Hispanic	3.95	.911	19
Hispanic	4.50	.674	12
Q5b			
Male			
non-Hispanic	3.57	1.016	14
Hispanic	3.86	.900	7
Female			
non-Hispanic	4.05	.780	19
Hispanic	4.75	.622	12
Q5c			
Male			
non-Hispanic	4.71	.825	14
Hispanic	4.14	.900	7
Female			
non-Hispanic	4.68	.478	19
Hispanic	4.67	.651	12

(*table continues*)

	M	SD	*n*
Q5d			
Male			
non-Hispanic	4.57	.938	14
Hispanic	3.71	.756	7
Female			
non-Hispanic	4.16	.834	19
Hispanic	4.50	.798	12
Q5e			
Male			
non-Hispanic	4.64	.633	14
Hispanic	4.71	.488	7
Female			
non-Hispanic	4.47	.612	19
Hispanic	4.67	.651	12

Table 8

Descriptive Statistics for Two-Way MANOVA of Self-Efficacy CSSES Questions

	M	SD	*n*
Q6a			
Male			
non-Hispanic	4.36	.633	14
Hispanic	4.29	.488	7
Female			
non-Hispanic	4.37	.496	19
Hispanic	4.50	1.00	12
Q6b			
Male			
non-Hispanic	4.14	.864	14
Hispanic	4.00	.816	7
Female			
non-Hispanic	4.05	.524	19
Hispanic	4.42	.669	12
Q6c			
Male			
non-Hispanic	4.57	.514	14
Hispanic	4.71	.488	7
Female			
non-Hispanic	4.53	.513	19
Hispanic	4.83	.389	12

(*table continues*)

	M	SD	*n*
Q6d			
Male			
non-Hispanic	4.64	.633	14
Hispanic	4.14	.690	7
Female			
non-Hispanic	4.16	.688	19
Hispanic	4.67	.651	12
Q6e			
Male			
non-Hispanic	4.50	.519	14
Hispanic	3.86	.900	7
Female			
non-Hispanic	3.74	.806	19
Hispanic	4.50	.674	12
Q6f			
Male			
non-Hispanic	4.50	.519	14
Hispanic	4.14	.900	7
Female			
non-Hispanic	4.37	.597	19
Hispanic	4.58	.793	12
Q6g			
Male			
non-Hispanic	4.64	.633	14
Hispanic	4.57	.535	7
Female			
non-Hispanic	4.47	.513	19
Hispanic	4.83	.389	12
Q6h			
Male			
non-Hispanic	4.50	.650	14
Hispanic	4.43	.535	7
Female			
non-Hispanic	4.05	.621	19
Hispanic	4.58	.900	12

Table 9

Descriptive Statistics for Two-Way MANOVA of Outcome Expectations CSSES Questions

	M	SD	*n*
Q7a			
Male			
non-Hispanic	4.07	.829	14
Hispanic	3.57	.535	7
Female			
non-Hispanic	4.16	.602	19
Hispanic	4.50	.522	12
Q7b			
Male			
non-Hispanic	3.86	.770	14
Hispanic	3.29	.756	7
Female			
non-Hispanic	3.68	.749	19
Hispanic	3.83	.835	12
Q7c			
Male			
non-Hispanic	4.29	.825	14
Hispanic	4.00	.577	7
Female			
non-Hispanic	4.37	.597	19
Hispanic	4.58	.515	12
Q7d			
Male			
non-Hispanic	3.86	.770	14
Hispanic	3.57	.535	7
Female			
non-Hispanic	4.00	.577	19
Hispanic	4.17	.718	12
Q7e			
Male			
non-Hispanic	4.64	.633	14
Hispanic	4.29	.756	7
Female			
non-Hispanic	4.63	.496	19
Hispanic	5.00	.000	12

(*table continues*)

	M	SD	*n*
Q7f			
Male			
non-Hispanic	4.71	.469	14
Hispanic	4.29	.488	7
Female			
non-Hispanic	4.32	.582	19
Hispanic	4.67	.651	12

There were several statistical assumptions appropriate for this study. The first assumption was that the data observations for each question on the CSSES were random and independently sampled from each other and this data set met that assumption (Warner, 2013). I attempted to run a Box's Test of Equality of Covariance Matrices to test the assumption that the covariance matrices were equal for the groups. SPSS was not able to compute this assumption because there were fewer than two, nonsingular cell covariance matrices. Since the sample sizes were fairly equal and the covariance matrices were not too different, the MANOVA test was robust enough to tolerate some violations of this assumption (Warner, 2013). Levene's Test of Equality of Error Variances was used to determine that the assumption of homogeneity of variances has been satisfied for this data set (Warner, 2013). The results from that test indicated that only 2 of the mean errors of variance were significant when p was set at .01 due to the sample size (see Table 10).

Table 10

Levene's Test of Equality of Error Variances Based on Mean

	Levene Statistic	d*f*	Sig.
Q5a	1.332	(3, 48)	.275
Q5b	1.516	(3, 48)	.222

(*table continues*)

	Levene Statistic	d*f*	Sig.
Q5c	.861	(3, 48)	.468
Q5d	.045	(3, 48)	.987
Q5e	.402	(3, 48)	.752
Q6a	2.093	(3, 48)	.114
Q6b	3.297	(3, 48)	.028
Q6c	6.193	(3, 48)	.001*
Q6d	.027	(3, 48)	.994
Q6e	.880	(3, 48)	.458
Q6f	1.184	(3, 48)	.326
Q6g	3.138	(3, 48)	.034
Q6h	.788	(3, 48)	.507
Q7a	1.173	(3, 48)	.330
Q7b	.126	(3, 48)	.944
Q7c	3.423	(3, 48)	.024
Q7d	1.540	(3, 48)	.216
Q7e	14.809	(3, 48)	.001*
Q7f	.479	(3, 48)	.698

Note. *p > .01

Overall MANOVA Model

Wilks' λ was calculated for the variables of gender and ethnicity and for the interaction between these variables using .05 as the alpha value. Only one of the multivariate tests was significant in the overall MANOVA model for all three combined dependent variables. For gender, Wilks' λ = .441, F (19, 30) = 2.004, p = .043. Ethnicity was not significant with a Wilks' λ = .643, F (19, 30) = .876, p = .611 and the interaction was also not significant with a Wilks' λ = .529, F (19, 30) = 1.416, p = .193. No post-hoc testing was performed because both gender and ethnicity had fewer than three groups of subcategories.

Science Self-Efficacy

Data related to hypothesis 1 about the differences in self-efficacy scores for middle school students that participated in a citizen science STEM intervention program includes between-subjects effects for questions 6a-h for the MANOVA model (see Table 11). Based on the results of the CSSES, I failed to reject my null hypothesis for a statistically significant difference in self-efficacy based on gender or ethnicity for these middle school students. However, there were significant interactions between gender and ethnicity for questions 6d and 6e. The effects for the self-efficacy portion of the CSSES were weak and ranged from .001 to .184. Self-efficacy had the strongest effect sizes out of all the dependent variables in this study.

Table 11

Between-Subjects Effects for Self-Efficacy CSSES Questions

	F	Sig.	Partial η^2
Gender			
Q6a	.316	.577	.007
Q6b	.619	.435	.013
Q6c	.067	.798	.001
Q6d	.010	.922	.001
Q6e	.079	.780	.002
Q6f	.603	.441	.012
Q6g	.088	.768	.002
Q6h	.508	.479	.010
Ethnicity			
Q6a	.022	.881	.001
Q6b	.284	.596	.006
Q6c	2.463	.123	.049
Q6d	.001	.982	.001
Q6e	.079	.780	.002
Q6f	.128	.722	.003
Q6g	.854	.360	.017
Q6h	1.253	.269	.025
Gender*Ethnicity			
Q6a	.256	.615	.005
Q6b	1.493	.228	.030
Q6c	.328	.570	.007
Q6d	6.558	.014*	.120
Q6e	10.819	.002*	.184

(*table continues*)

	F	Sig.	Partial η^2
Q6f	2.067	.157	.041
Q6g	1.910	.173	.038
Q6h	2.153	.149	.043

Note. *p > .05

Task Interest

Data related to hypothesis 2 about the differences in task interest scores for middle school students that participated in a citizen science STEM intervention program includes between-subjects effects for questions 5a-e for the MANOVA model (see Table 12). Based on the results of the CSSES, I failed to reject my null hypothesis for a statistically significant difference in task interest based on gender or ethnicity for these middle school students. There were, however, significant interactions for gender and for ethnicity for question 5b and between gender and ethnicity for question 5d. The effects for the task interest portion of the CSSES were weak and ranged from .002 to .139.

Table 12

Between-Subjects Effects for Task Interest CSSES Questions

	F	Sig.	Partial η^2
Gender			
Q5a	3.260	.077	.064
Q5b	7.728	.008*	.139
Q5c	1.486	.229	.030
Q5d	.552	.461	.011
Q5e	.357	.553	.007
Ethnicity			
Q5a	.841	.364	.017
Q5b	3.956	.052*	.076
Q5c	2.114	.152	.042
Q5d	1.057	.309	.022
Q5e	.531	.470	.011
Gender*Ethnicity			
Q5a	1.414	.240	.029

(*table continues*)

	F	Sig.	Partial η^2
Q5b	.694	.409	.014
Q5c	1.870	.178	.037
Q5d	5.732	.021*	.107
Q5e	.112	.739	.002

Note. *p > .05

Outcome Expectations

Data related to hypothesis 3 about the differences in outcome expectations scores for middle school students that participated in a citizen science STEM intervention program includes between-subjects effects for questions 7a-f for the MANOVA model (see Table 13). Based on the results of the CSSES, I failed to reject my null hypothesis for a statistically significant difference in outcome expectations based on gender or ethnicity for these middle school students. However, there were significant interactions for gender for questions 7a and 7e, and between gender and ethnicity for questions 7a, 7e, and 7f. Outcome expectations was the dependent variable that had the most statistically significant questions, even though the null hypothesis itself was not rejected. The effects for the outcome expectations portion of the CSSES were weak and ranged from .001 to .127. Outcome expectations had the weakest effect sizes out of all the dependent variables in this study.

Table 13

Between-Subjects Effects for Outcome Expectations CSSES Questions

	F	Sig.	Partial η^2
Gender			
Q7a	7.001	.011*	.127
Q7b	.665	.419	.014
Q7c	3.010	.089	.059
Q7d	3.539	.066	.069

(*table continues*)

	F	Sig.	Partial η^2
Q7e	5.185	.027*	.097
Q7f	.003	.958	.001
Ethnicity			
Q7a	.169	.682	.004
Q7b	.845	.362	.017
Q7c	.034	.854	.001
Q7d	.092	.763	.002
Q7e	.001	.971	.001
Q7f	.055	.816	.001
Gender*Ethnicity			
Q7a	4.818	.033*	.091
Q7b	2.461	.123	.049
Q7c	1.701	.198	.034
Q7d	1.329	.255	.027
Q7e	5.523	.023*	.103
Q7f	5.529	.023*	.103

Note. *p > .05

Summary

The data showed that while there was an overall significant difference between male and female students that participated in a citizen science intervention program for the three combined dependent variables of self-efficacy, task interest, and outcome expectations, self-efficacy by itself did not show any significance based on gender and task interest, and outcome expectations only showed significance for a few questions on the survey. The data also showed that there was no overall significance based on ethnicity or for the interaction between gender and ethnicity for the three combined dependent variables.

I was not able to reject any of my null hypotheses for this study and found no statistically significant differences in each individual dependent variable based on gender, ethnicity, or the interaction between gender and ethnicity. There were, however, some interesting statistically significant results for individual questions in each dependent variable. For self-efficacy, questions about using testing equipment, and choosing sampling locations showed differences based on the interaction between gender and ethnicity. Female, Hispanic students and male, non-Hispanic students showed a similarly high self-efficacy for completing these two activities. A task interest question about collecting water samples at field locations showed differences by both gender and ethnicity. Female and Hispanic students were more interested in that task than their male or non-Hispanic peers. Analyzing soil samples for aluminum showed differences based in the interaction between gender and ethnicity. Female, Hispanic students and male, non-Hispanic students indicated stronger task interest in that question than their fellow participants. Outcome expectations had several questions that showed significance. Studying water quality to understand the work of scientists and studying water quality to understand human impacts on the environment showed differences by gender and in the interaction between gender and ethnicity. Female students, and more specifically, female Hispanic students saw connections between those two activities during the citizen science intervention program and the potential outcomes of those activities. Studying water quality as a way of helping scientists with their work as a citizen scientist was significant based on the interaction between gender and ethnicity with female, Hispanic students, and male, non-Hispanic students being most likely to see that as an outcome of their own water quality work.

In Chapter 5 I will reiterate the purpose and nature of my study. I will describe the methodology that I used to conduct the study and explain why the study was conducted. I will concisely summarize key findings from Chapter 4 and relate them to current themes in the literature of my discipline. I will give an overview of some of the limitations of my study and make recommendations for future study in the area of underrepresented student populations in STEM education. I will end Chapter 5 by discussing the social change implications of my research and the contributions that this work will provide to professional practice and educational stakeholders in the future.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative study was to explore the extent to which differences in science self-efficacy, outcome expectations, and task interest were present in middle school students based on their gender and ethnicity after participating in a citizen science STEM intervention program. To accomplish this purpose, I sought to answer a series of RQs concerning the differences in the dependent variables of science self-efficacy, outcome expectations, and task interest by gender and ethnic/racial minorities (the independent variables) after participation in a citizen science STEM intervention program. This study featured a quantitative, nonexperimental comparative design. I analyzed survey responses from students who had participated in a citizen science STEM intervention from 2017-2019. The data were analyzed using a two-way MANOVA test as I was looking for differences in two independent variables across three dependent variables. I conducted this study to understand differences that may exist in career choice variables for traditionally underrepresented groups in the STEM career pipeline as they develop their career goals and choices.

Key findings showed that, while there was an overall significant difference between male and female students who participated in a citizen science intervention program for the three combined dependent variables of self-efficacy, task interest, and outcome expectations, self-efficacy by itself did not show any significance based on gender and task interest, and outcome expectations only showed significance for a few questions on the survey. The data analysis also showed that there was no overall significance based on ethnicity or for the interaction between gender and ethnicity for the three combined dependent variables. I was not able to reject any of the three null hypotheses for this study and did not find any statistically significant differences in any of the individual dependent variables based on gender, ethnicity, or the interaction between gender and ethnicity. There were, however, some interesting significant differences for specific survey questions for each dependent variable that I will discuss in the next section.

Interpretation of the Findings

I viewed the survey results of the middle school students who participated in the citizen science intervention program through the lens of SCCT (Lent et al., 1994). The SCCT framework provides a model of STEM career choice variables, like science self-efficacy, task interest, and outcome expectations, which might guide career goals and actions for career development for underrepresented populations of students (see Lent et al., 1994; Lent et al., 2018). It is important to avoid the generalization of this model to explain all STEM career decisions in these subpopulations of students, but it has been found to be a useful starting point for defining potential decision-making variables for females and ethnic/racial minorities (Fouad & Santana, 2017; Turner et al., 2017). Some of the findings from the current study extend the findings from the literature while others disconfirm current literature. In the following sections, I interpret these results in relation to the SCCT career choice variables of science self-efficacy, task interest, and outcome expectations. I have organized my interpretation of the findings by research question.

Science Self-Efficacy

RQ1 was, Do self-efficacy scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

The data related to this RQ indicated that there were no significant differences in science self-efficacy based on gender, ethnicity, or the interaction between gender and ethnicity for students who had participated in the WASSSP STEM intervention program. The findings of this study disconfirm the current literature because many researchers have found female and ethnic minority student populations to express a significantly lower self-efficacy in both math and science than their male and ethnic majority peers (Alhaddab & Alnatheer, 2015; Blotnicky et al., 2018; Fouad & Santana, 2017). This lack of difference in science self-efficacy between the male and female students and the Hispanic and non-Hispanic students in this study may indicate that previous STEM intervention and enrichment experiences offered to the participating students by their school district may already affect the way in which they view their ability to perform science-related tasks prior to their participation in the citizen science intervention program. A review of current literature on effective STEM programs indicates that providing hands-on experiences, mentoring, and career exposure to students across a wide range of entry points during their STEM educational pathway increases their science and math self-efficacy (Carrick et al., 2016; Lane, 2016; Maton et al., 2016). My findings that the person inputs of gender and ethnicity did not lead to significant differences in science self-efficacy can be explained through the lens of my theoretical framework of SCCT (Lent et al., 1994; Lent, Ireland, Penn, Morris, & Sappington, 2017) because the existence of multiple STEM learning experiences in the educational space of the participating students could have moderated the impact that belonging to an underrepresented student population had on the career choice variables of those students.

An interesting finding from the data related to student science self-efficacy was that the survey questions about using scientific testing equipment and choosing sampling locations for a scientific investigation showed similarly high levels of self-efficacy for male, non-Hispanic students and for female, Hispanic students. In a review of the literature, there is an intersectionality of the interconnected nature of overlapping systems of disadvantage for the social categories of gender and ethnicity (Saw et al., 2018). There is evidence to indicate that actively recruiting students who fall into two or more underrepresented STEM categories, building community for these students, and creating learning experiences that are geared towards the needs and experiences of female students of color can increase their outcomes in STEM pathways (Falco & Summers, 2019; Leyva, 2016). Controlling for personal experiences and environmental and behavioral factors diminishes the gap in STEM confidence and self-efficacy for students who fall in the intersection of underrepresented gender and ethnicity groups (Litzler, Samuelson, & Lorah, 2014). In the context of these studies, my findings extend the current research on the self-efficacy of female, Hispanic students in STEM educational pathways. School district culture and local community attitudes towards inclusive STEM practices may have led to the increased science self-efficacy of these students with multiple minority statuses for some of the activities that they participated in during the citizen science intervention program.

Task Interest

RQ2 was, Do task interest scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

The key finding from the data related to this RQ was there were no significant differences in task interest based on gender, ethnicity, or the interaction between gender and ethnicity for students who had participated in the WASSSP STEM intervention program. The findings of this study disconfirm the current literature because a review of the literature on STEM task interest using the SCCT framework indicated that students from underrepresented populations such as females and ethnic/racial minorities did not show the same levels of personal liking for the tasks and processes associated with science and engineering activities as their peers (Fouad & Santana, 2017; Lent et al., 2018). Stereotyping and bias play a strong role in discouraging females students overall and Latina students from enjoying and choosing to participate in STEM activities during their K-12 education and often prevent them from selecting STEM majors during their college years (Garriott, Hultgren, et al., 2017; Starr, 2018). Much like my study findings for science self-efficacy, the finding that there were no significant differences in task interest between males and females and between Hispanic and non-Hispanic students may mean that prior STEM learning experiences in their educational setting have created more equitable interest in STEM tasks for all the participants from the citizen science intervention program.

A secondary finding from the data related to STEM task interest was that the survey questions about collecting water samples at field locations and analyzing soil samples for aluminum levels showed similarly high levels of task interest for male, non-Hispanic students and for female, Hispanic students. Recent research into the intersectionality of gender and ethnicity as it relates to participating in the tasks of science and engineering indicates that Hispanic women do not show the same double-bind gaps as some women of color, especially in the area of engineering (Tao & McNeely, 2019). My findings extend the current research on the task interest of female, Hispanic students in STEM educational pathways. The student participants from my study live in an area that is majority-minority and can see teachers, other students, and even community members who share their demographics doing science and engineering tasks on a regular basis. This normalization of Hispanic STEM task participation, combined with a lower gap in task interest for Hispanic females could explain the finding from my study that the intersectionality of female gender and Hispanic ethnicity led to the same levels of task interest for some portions of the citizen science program as their male, non-Hispanic peers.

Outcome Expectations

RQ3 was, do outcome expectation scores significantly differ by gender or ethnicity for middle school students participating in a citizen science intervention program?

The key finding related to this RQ was there were no significant differences in STEM outcome expectations based on gender, ethnicity, or the interaction between gender and ethnicity for students that had participated in the WASSSP STEM intervention program. The findings of this study disconfirm the current literature because previous literature indicates that white and Asian, male students are more likely than their female and ethnic/racial minority peers to connect participating in STEM activities during their middle and high school years with the eventual outcome of a career pathway that culminates in a STEM field (Blotnicky et al., 2018; Guo et al., 2018; Mau & Li, 2018; Turner et al., 2017). Once again, my findings of no significant differences in outcome expectations between males and females, and between Hispanic and non-Hispanic students may mean that all the student participants in the STEM intervention program have been immersed in a positive, district-wide culture that includes exposure to STEM career pathways and have benefitted from the presence of strong community and industry partnerships which have created many difference STEM learning experiences for students to participate in during the course of their educational journey. My SCCT theoretical framework shows that these types of STEM learning experiences mediate the influence of gender and ethnicity on the outcome expectations of students so students who have been exposed to multiple STEM learning experiences over a long period of time are less likely to suffer from the same STEM achievement gaps as underrepresented student populations as a whole (Lent et al., 1994, 2017).

Another conclusion of significance from the data related to outcome expectations was that the survey questions about how studying water quality helped students to understand the work of scientists and how studying water quality helped students to understand the impact that humans have on the environment showed similarly high levels of outcome expectations for male, non-Hispanic students and for female, Hispanic students. Having an awareness of the intersectionality for students of being both Hispanic and female in STEM educational pathways can lead to better student achievement and career outcome expectations for those students (Falco & Summers, 2019). My findings extend the current research on the outcome expectations of female, Hispanic students in STEM educational pathways. As mentioned previously, school district culture and local community attitudes towards inclusive STEM practices may have led to the development of educational settings which have placed emphasis on equitable opportunities for students from multiple minority statuses to internalize positive STEM outcomes for themselves over a period of time leading up to their participation in the citizen science intervention program.

Limitations of the Study

One of the limitations of this study is related to research design. My study was quantitative in nature and consisted of participants taking a Likert scale survey that self-assessed their science self-efficacy, task interest, and outcome expectations after participating in a citizen science intervention program. The survey allowed students to quantify their experiences in the intervention program but there was no way for them to provide their observations and perspectives about those experiences using just a Likert scale. A mixed-methods research design could have provided depth and breadth to the data that was collected on the survey by the addition of some open-ended questions that could have been coded by theme, thereby increasing the richness of the final analysis of the results.

Another limitation of this study is related to the limitations of time. I conducted the data collection portion of this study over the course of a summer. My data collection procedures required parents to give consent using either email, which many parents in the community that the study was conducted in do not check frequently due to a lack of access to technology, or using postal mail addresses, which had a very low rate of return. These factors limited the number of potential study participants to approximately half of the total population of eligible students. The fact that the students were on summer break from school also meant that many of them were not checking their school emails so of the students who had verified parental consent to participate, there were some who never opened the participation invitation and assent email during the data collection window, as required by my data collection procedures. These time-related issues limited the number of students who participated in the survey.

The third limitation is related to the participants. Many quantitative statistical tests rely on the assumption of normality and increasing the size of the sample helps the distribution of the data collected to approximate a normal distribution (Frankfort-Nachmias & Leon-Guerrero, 2015). My survey return rate was higher than expected for this study but the final sample size for this population was still just above the general rule of thumb of $n \geq 50$ so my number of study participants was a limitation to performing quantitative statistical testing on my survey results. While MANOVA testing is not especially sensitive to violations of the assumption of normality, having a larger number of students from the three cohorts of the citizen science intervention program contribute to the survey data might have changed some of the significance values for variables or individual questions that were close to meeting the $p > .05$ threshold that I set for interpretation of the results.

Recommendations

Recommendations for further research are based on study results and limitations of the study. The first recommendation is related to the finding that female, Hispanic students had higher science self-efficacy, task interest, and outcome expectations following their participation in a citizen science STEM intervention program than their same gendered, non-Hispanic peers and their male, Hispanic peers. I suggest qualitative research needs to be done to explore perceptions that these young women, who fall into two different underrepresented STEM populations, have about their STEM educational and career pathways so that deeper understanding may be gained into the lived experiences of students who come into STEM programs at a double disadvantage but are still showing successful outcomes.

The second recommendation is related to the study finding of significance for certain activities and tasks from the citizen science STEM program. Therefore, qualitative research needs to be done to explore why underrepresented students rated their science self-efficacy, task interest, and outcome expectations higher on some components of their STEM intervention program than others so that deeper understanding can be gained about developing effective STEM intervention and enrichment programs that can target STEM career goal development for female and Hispanic student populations. A series of follow up interviews with the 2017, 2018, and 2019 student cohorts from the WASSSP program could provide valuable insights into specific programmatic components for future STEM learning experiences for underrepresented student groups to support STEM educational pathways. The current literature could also be enriched by a different type of quantitative study that uses another data collection instrument to measure the variables of self-efficacy, task interest, and outcome expectations to see if the results are similar.

The last recommendation is related to the limitations of this study. This study was done with 96 students from a rural, Northwestern public school who participated in a citizen science intervention program in partnership with a private college. Therefore, this study should be replicated in other rural, public school districts and in other public school, private college STEM intervention partnership programs to determine if results are similar. In addition, longitudinal data should be collected on the student cohorts from the citizen science intervention partnership in this study to determine how gender and ethnicity impact additional components on the right-hand side of the SCCT model that occur during high school and at the post-secondary level, like the influence of career choice goals on career choice actions for this student population, as well as performance attainment outcomes.

Implications

This study may contribute to positive social change in several ways. First, at the individual level, this study has the potential to help students from underrepresented populations to envision success in their STEM educational and career pathways by seeing other students experience success and equity in those areas. There is also potential for change at the organizational level. Exploring how students from underrepresented STEM populations, especially those who come from more than one minority groups, experience the career choice goals of science self-efficacy, task interest, and outcome expectations can have a positive impact on how STEM intervention and enrichment programs are developed by schools and community partners. Designing programs that are explicitly aware of the specific needs of underrepresented student populations can lead to better student outcomes for those groups. This study also advances knowledge in the field of STEM education because it presents an example of student career choice variables in the context of district and community culture and encourages awareness of holistic K-12 and postsecondary STEM educational pathways consisting of multiple STEM learning experiences for underrepresented student populations.

The second contribution that this study makes to positive social change is in relation to improved professional practice concerning the development of effective STEM intervention and enrichment programs which encourage more equitable representation of all demographic groups in the Unites States' STEM career pipeline. Programs that incorporate environmental supports like role models and mentors, hands-on and engaging authentic STEM activities, and emphasis communal and collaborative work can increase the positive student outcomes for students from traditionally underrepresented STEM populations (Fuesting & Diekman, 2017; Knowles et al., 2018; Rahm & Moore, 2016). The results of this study may inform STEM educators in designing and choosing innovative curricular programs which provide ways for nontraditional students to engage with STEM content material.

The last contribution and implications of this study is that it may provide educational stakeholders, like community members and industry partners, with a deeper understanding of the interactions between the variables that contribute to student career decision making in STEM. Parents can use these findings to better advocate for STEM learning opportunities with their local school boards. Providing insight for policy makers at the local, state, and national levels into how to arrange support for the development and implementation of high quality, and impactful STEM programs for K-12 and postsecondary settings that lead to increased STEM literacy and help to enrich the diversity of the STEM career pipeline will lead to positive social change for individual students as well as the entire U.S. workforce.

Conclusion

The key finding for this quantitative, nonexperimental comparative design study was that a rich and intentional series of STEM opportunities decreased the gap in self-efficacy, task interest, and outcome expectations between underrepresented student populations and their more overrepresented peers in STEM educational and career pathways. In a school district where there was a history of multiple and systemic STEM learning experiences, there were no statistically significant differences in those career choice variables between male and female students and between non-Hispanic and Hispanic students after participating in a citizen science intervention program. In some areas, students with multiple minority statuses even had scores that were very close to their peers who did not have any minority statuses. This lack of significant differences by gender and ethnicity for self-efficacy, task interest, and outcome expectations is significant because it forces educational stakeholders to look at SCCT in a more holistic manner and determine what types of STEM learning experiences mediated the influence of those person inputs on the career choice variables in the center of the SCCT model.

The United States is currently undergoing a dynamic shift in response to global competitiveness that demands a creative and innovative STEM workforce. The current STEM workforce does not adequately represent the diversity of the U.S. population and many of the skills and talents of those underrepresented populations are missing from STEM career pools (Jones et al., 2018; National Science Board, 2018b). Increasing pressure at every point along the STEM career pipeline requires educators and policymakers in the United States to rethink and redesign the STEM education pathways which lead to a strong and diverse workforce (Bennett Anderson et al., 2017; Maltese & Tai, 2011). Developing a culture of well-designed STEM opportunities that focus on underrepresented student populations will decrease barriers to their entry into STEM pipelines. Increasing science self-efficacy, task interest, and outcome expectations for those underrepresented populations, like the female and Hispanic students in my study, can help them to see themselves as scientists and engineers in U.S. STEM jobs.

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Appendix A: Permission to Reproduce Social Cognitive Career Theory Figure

Social Cognitive Career Theory Model Request

Melyssa Ferro
Sun 9/9/2018 1:41 PM
Robert W. Lent <[redacted]>; Darci J. Harland

Thank you so much Dr. Lent. I will ensure that proper citations are used!

Have a great week!
Melyssa

Robert W. Lent <[redacted]>
Sun 9/9/2018 6:16 AM
Melyssa Ferro; Darci J. Harland

Permission to reproduce the figure in your dissertation is granted as long as you properly cite the original source.

Thanks for your kind words.

Best wishes with your research,
Dr. Lent

Melyssa Ferro
Sat 9/8/2018 4:52 PM
[redacted]

Good evening Dr. Lent-

I am a doctoral student from Walden University. I am currently working on my dissertation proposal which focuses on citizen science STEM intervention programs and their effect on the self-efficacy, task interest, and outcome expectations of female and ethnic/racial minority students. I plan to use the Social Career Cognitive Theory as my study framework. I have cc'd my dissertation chair, Dr. Darci Harland, on this email so that she is part of this conversation.

As I was looking for potential theoretical frameworks for my research study, I came across your work and fell in love with your SCCT model. Your theory is perfect for my study topic. I would like to respectfully ask your permission to incorporate a diagram of your SCCT in chapter 1 and chapter 2 of my dissertation when I complete my own research later this year. The diagram that I will most likely be using is Figure 2 on page 93 of your seminal 1994 publication with Dr. Brown and Dr. Hackett.

Thank you for your work in the field of career theory, especially as it applies to underrepresented populations like women and ethnic/racial minorities. I look forward to hearing from you soon.

Sincerely,
Melyssa Ferro

Appendix B: Permission to Use, Modify, and Republish the Citizen Science Self-Efficacy Scale Instrument

Citizen Science Self Efficacy Survey Use Request

Melyssa Ferro
Wed 6/13/2018, 7:52 PM

Dr. Hiller (and Dr. Kitsantas)--

Thank you so much. I really appreciate your help. One of my favorite quotes is by Sir Isaac Newton and talks about seeing further by standing on the shoulders of giants. Thank you for letting me stand on your shoulders to complete my project. I would love to let you read my finished work.

Have a great evening,
Melyssa

Suzanne E Hiller [redacted]
Wed 6/13/2018, 6:25 PM

csses_hiller_kitsantas.pdf 1 MB
10.1111_ssm.12081_hill... 139 KB
2 attachments (1 MB) Download all Save all to OneDrive - Laureate Education - ACAD

Hello Melyssa,

Thank you so much for your email. Your dissertations sounds like a wonderful research study. Please feel free to modify the scale I developed with my coauthor, Dr. Anastasia Kitsantas. I am attaching several articles we did related to the scale as well as some other motivational factors for your information. Please keep me posted on your progress. I would very much like to read your dissertation.

Best wishes, Suzanne

Melyssa Ferro
Wed 6/13/2018, 6:17 PM
[redacted]

Good evening Dr. Hiller-

I am a doctoral student from Walden University. I am currently working on my dissertation prospectus which focuses on citizen science STEM intervention programs and their effect on female and ethnic/racial minority students. I plan to use the Social Career Cognitive Theory as my study framework. I have cc'd my dissertation chair, Dr. Darci Harland, on this email so that she is part of this conversation.

As I was looking for potential survey instruments for my quantitative research study, I came across your work and fell in love with your CSSES tool. Your research tool would be perfect for my study. I would like to respectfully ask your permission to use a modified version of your instrument when I complete my own research later this year. Since your tool is specifically designed to be used with a horseshoe crab citizen science context and my work will be water quality citizen science, I would like to insert water quality specific tasks in place of your horseshoe crab tasks but keep your sentence stems intact. I would also like to replace your horseshoe crab content measure with one geared towards water quality indicators.

Thank you for your work in the field of citizen science and student self-efficacy. I look forward to hearing from you soon.

Sincerely,
Melyssa Ferro

Citizen Science Self-Efficacy Scale

Melyssa Ferro
Wed 10/9/2019 8:20 PM
[redacted]

That is great news about your recent publication! I will definitely be looking at that book. I think that citizen science is a great way to engage students in STEM.

Thank you for your support. I spent several paragraphs of my Chapter 3 and 4 discussing the modifications due to the difference in content of our two citizen science programs. Have a great Thursday!

Melyssa

Suzanne Hiller <s.hiller@wingate.edu>
Wed 10/9/2019 7:27 PM
[redacted]

Hello Melissa,

Thank you for your email and congratulations! I have a new position with [redacted] which may be why you had difficulty reaching me.

Yes, we give you permission to use the scale for your dissertation and future publications. We ask that you mention that the original scale was modified for the context of water quality. Please do send your dissertation. I will be very interested to read it.

I wanted to mention that we published a book on citizen science and STEM motivation which was released last July. I thought you might be interested. Here is the link for your information:

https://novapublishers.com/shop/enhancing-stem-motivation-through-citizen-science-programs/

Best wishes,

Dr. Suzanne E. Hiller

Appendix C: Modified Citizen Science Self-Efficacy Scale Instrument

Welcome to the Citizen Science Self Efficacy Survey.

Thank you for your participation.

Your input will help me to understand how to effectively teach science to middle school students.

Part A: Demographics

I am a

- ○ Male
- ○ Female

My race is

- ○ Asian
- ○ Black/African American
- ○ White
- ○ other

My ethnicity is

- ○ Hispanic
- ○ non-Hispanic

During which year did you participate in the 8th grade Water and Soil Quality Math and Science Summer Institute (MASSI)?

- ○ 2017
- ○ 2018
- ○ 2019

My student ID# is

[ ]

Part B: Task Interest Scale (Hiller, 2012c)

Rate how interested you are in the following activities listed below AFTER you attended MASSI.

	Strongly disinterested	Somewhat disinterested	Neither disinterested or interested	Somewhat interested	Strongly interested
a. Analyzing water samples for phosphates	○	○	○	○	○
b. Collecting water samples at field locations	○	○	○	○	○
c. Using color absorption detector or flame spectroscopy equipment	○	○	○	○	○
d. Analyzing soil samples for aluminum	○	○	○	○	○
e. Working in a science lab	○	○	○	○	○

Part C: Citizen Science Self Efficacy Scale (Hiller, 2012b)

Rate how well you believe you can conduct the activities listed below AFTER you attended MASSI.

	Not sure at all	Not sure	Neither unsure or sure	Sure	Very Sure
a. Build a hypothesis to test	○	○	○	○	○
b. Use data (absorption curves) to determine a conclusion	○	○	○	○	○
c. Write down the things that I see when testing water	○	○	○	○	○
d. Use the testing equipment correctly	○	○	○	○	○
e. Choose sampling locations	○	○	○	○	○
f. Communicate findings to others	○	○	○	○	○
g. Use data to form a conclusion	○	○	○	○	○
h. Collect data for a scientist's research study	○	○	○	○	○

Part D: Citizen Science Outcome Expectations (Hiller, 2012c)

Rate how strongly you agree with the following statements below AFTER you attended MASSI.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
a. Studying water quality will help me understand the work of scientists	○	○	○	○	○
b. Studying water quality will help me decide if I want to be a scientist	○	○	○	○	○
c. Studying water quality will help me improve my science skills	○	○	○	○	○
d. Studying water quality will help me improve my science grades	○	○	○	○	○
e. Studying water quality will help me understand human impacts on the environment	○	○	○	○	○
f. Studying water quality helps scientists with their work	○	○	○	○	○