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Creating Citizen Science Identity: Growing Conservation And Environmentally-Minded Stem Interest Through Mobile Learning And Authentic Practice

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CREATING CITIZEN SCIENCE IDENTITY: GROWING CONSERVATION AND ENVIRONMENTALLY-MINDED STEM INTEREST THROUGH MOBILE LEARNING AND AUTHENTIC PRACTICE

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CERTIFICATE OF APPROVAL

Dedication

This work is dedicated to my wife MaryAnn who makes me laugh every day and is quite possibly the best thing that has happened to me on this earth

and

to my team of all-star parents: Esther, Aunt Lanny, Uncle Jer and Billy.

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Disce quasi semper victurus vive quasi cras moriturus.

Dilly Dilly

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"Educating the mind without educating the heart is no education at all."

— Aristotle

Abstract

STEM education reform and climate change awareness are two of the United States' most challenging educational issues. When integrated into curricula, citizen science projects have shown the ability to increase STEM interest and enhance climate change understandings in high school students. This quasi-experimental study investigated the approach of mobile learning and the authentic practice (MobiLAP) of a citizen science project and how it relates to forming STEM interest, citizen science identity, conservation and environmentally-minded STEM perceptions (CEmSTEM), mobile learning perceptions, climate change awareness and environmental stewardship in participants. The study made use of a control group (n = 44) and two treatment groups. One treatment group took part in the citizen science project with the use of mobile technologies (n = 48), while the other group used paper-based materials to take part in the project (n = 45). Utilizing a 66 item instrument and group-specific, open-ended questionnaires, this study determined that participants in both groups significantly increased interest in STEM, perceptions of CEmSTEM and citizen science identity when compared to the control group. The Non-mobile Technology (NMT) group also had a significant increase in environmental stewardship. Additional findings indicate that citizen science can create a pro-environmental ethos in participants and increase climate change understandings and that mobile technologies afford learners a personalized, accessible, engaging and efficient way to learn science and scientific principles. These findings illustrate some of the many benefits of employing citizen science projects in high school science classes.

CHAPTER 1: INTRODUCTION

STEM Education and Climate Change

Two of the major educational challenges in the United States are science, technology, engineering and mathematics (STEM) education reform and climate change awareness and acceptance. These issues are interconnected with many parallels and may be solved through a combined focus. STEM innovations could lead to a better understanding of and solution toward climate change, specifically human-caused climate change (Kriegler et al., 2014). Reciprocally, creating interest in STEM subjects may also lead high school students to a greater interest in climate change. Teaching climate change science requires an interdisciplinary approach and promotes important science pedagogical practice that includes hands-on learning and authentic practice which can attract students to STEM (McCright, O'Shea, Sweeder, Urquhart, & Zeleke, 2013). The synergy between STEM education and climate issues should be leveraged to redound to the benefit of future generations and prepare learners for 21st Century careers.

The National Science Board (2007) noted that the current educational system is failing to meet the STEM education needs for U.S. students. As a result, our nation's inability to produce STEM workers will negatively impact our economic growth and national security. Likewise, The President's Council of Advisors on Science and Technology (PCAST, 2010) acknowledged that the U.S. is no longer a leader in STEM education and is, in fact, ranked in the "middle of the pack" or lower. Further exacerbating the problem is the lack of traditionally underrepresented groups (such as women, Black Amercians and Hispanic Americans) in STEM educational programs and careers (Anderson, 2014). With a predicted 80% of new jobs requiring math, science and engineering (Wolfram, 2017), the challenge of adequately preparing the future workforce has been clearly set forth.

The U.S. educational system has fallen behind that of other industrialized nations. The Organisation for Economic Co-operation and Development (OECD) conducted the Programme for International Student Assessment (2010) and found that the United States scored below average and ranks 27th in math scores and 20th in science scores compared to the remaining 33 OECD countries. When compared to non-member countries, the U.S. ranks 36th overall. Shanghai-China tops the list with mean math scores of 613 and science scores of 580, while the U.S. scored 481 in math and 497 in science respectively. Scores from Massachusetts, a strong-performing U.S. state, indicate the equivalence of being more than two years of formal education behind Shanghai-China. This poor performance cannot be attributed to lack of funding as the United States ranks 5th in terms of average educational spending per student between the ages of six and 15. Countries that spend much less, score much better.

The United Stated Bureau of Labor Statistics projects that STEM related employment will grow by 13 percent between 2012 and 2022 (Vilorio, 2014). Without enough STEM educators and workers, we will not be able to meet this need. In 2011, President Obama called for the training of 100,000 STEM teachers over the next decade (The White House, Office of the Press Secretary, 2011). Likewise, President Trump signed bills H.R. 255 and H.R. 321 into law (The White House, Office of the Press Secretary, 2017) in order to inspire and protect women in STEM fields. The need for quality STEM workers and educators receives overwhelming bipartisan support and is clearly a national priority for the United States.

Creating the next generation of highly-skilled STEM workers and educators is of vital importance because it will help United States combat national issues such as the health care needs for an aging generation of baby-boomers and global issues such as climate change. The challenge of climate change needs to be fought on two fronts: educating the public on the existence of anthropogenic climate change and creating solutions to aid in reversing the impact humans make on the planet. Agencies such as the National Science Foundation and the National Oceanic and Atmospheric Administration have called for an increase in climate literacy in an effort to inform citizens about the dangers of global warming (Cooper, 2011). Changing minds on this topic is a challenge, however, as many individuals see this issue in a political or ideological manner (Dickinson, Crain, Yalowitz, & Cherry, 2013). Liberals and Democrats tend to side with science in their acknowledgement of anthropogenic climate change, while conservatives and Republicans are more apt to deny its existence (McCright & Dunlap, 2011). Even though there is vast amounts of evidence and data from climate science experts on the rise in global temperatures due to human activity, there are many that still challenge this unequivocal truth (Lewandowsky, Oreskes, Risbey, Newell, & Smithson, 2015).

Despite one's political affiliation, there is a great need to instill a pro-conservation ethos into all of the U.S. population. Conservation efforts tie directly into educating the public and aiding important issues such as human-caused climate change. This environmental stewardship is already prevalent in one segment of the population. Hunters, anglers, outdoorsmen and outdoorswomen traditionally lean heavily toward the conservative end of the spectrum politically, but acknowledge the problems associated with human-caused climate change and contend that we have a moral obligation to confront it. This faction has an up close look at nature and many are, at their core, conservationists. In fact, conservation is just as important as gun rights for this population (The National Wildlife Federation, 2012). Hunters use personal experiences from the outdoors to validate climate phenomena. For instance, observations may include noticing a sharp decline in moose populations caused by the predation of a thriving winter tick population due to warmer temperatures and thus shorter winters (Bergeron and

Pekins, 2014). This change in climate results in an imbalance in nature and ultimately a decline in moose populations with as many as 70% of moose calves falling prey the parasite.

Consistently spending time in nature seems to impact perceptions on climate change despite political affiliation. The sportsmen and women surveyed for the National Survey of Hunters and Anglers (Carpenter, 2012) overwhelmingly agree that children do not spend enough time outdoors and are concerned with the resultant lack of connection with nature. Just 10% of American youth spend time in nature each day and less than 40% participate in outdoor recreation on even a weekly basis (Nature Conservancy, 2011). There seems to be little hope of instilling environmental stewardship in children if they aren't even willing to be in nature. Louv (2005), boldly stated that society is teaching our youth to avoid experiences in nature and that these lessons come directly from schools, media, institutions and families. With children today spending 7.5 hours per day playing video games, watching television or on the computer (Carpenter, B., 2012), there seems to be sufficient time for outdoor activities and experiences in nature. The National Research Council's Next Generation Science Standards (NGSS Lead States, 2013) call for strategies in outdoor learning activities to connect students with their respective communities and environment. In order to change the hearts and minds of those not in agreement with anthropogenic climate change, a significant effort should be made to increase the public's exposure to nature.

A large majority of individuals in the United States do not hunt, fish, hike, birdwatch or take part in any recurring activities involving nature and must be presented with solid scientific evidence, relevant information and more outdoor experiences. The fact is, global temperatures have increased steadily with 10 of the warmest years on record taking place over the last two decades (NASA's Jet Propulsion Laboratory, 2016). This trend is continuing as the winter of

2016-2017 is on record as being the warmest winter in several parts of the United States (Southeast Regional Climate Center, 2017). This abnormal weather can have adverse effects of plant and animal species as it may signal the start of spring earlier than expected. For example, the world-renowned cherry blossoms in Washington D.C. bloomed too early in 2017 due to unseasonably warm weather which caused half of the blossoms to perish once colder temperatures resumed (Mele, 2017). The significance of warmer temperatures disrupting nature is not a new phenomenon. Over the past 30-80 years, the spring season has been extended by 2-3 days and the fall season has been extended by 0.3-1.6 days per decade (Sherry et al., 2007). This artificially extends the growing season, disrupts regular phenological events and alters the balance in ecosystems.

This issue is not limited to the United States as climate change and its acceptance is a worldwide problem that spans the globe in countries ranging from Australia (Hughes, 2003) to Zimbabwe (Thierfelder & Wall, 2010). Climate change causes significant threats to our planet such as ocean acidification, rising sea levels, disease, death, species extinction and loss of plant and animal life (Pachauri & Reisinger, 2007). There are a number of organizations dedicated to solving this dilemma, but we must do better in terms of building consensus within the United States and around the world. The first step to solving any issue is recognizing there is a problem. If a large segment of the population fails to recognize anthropogenic climate change as the urgent matter it is, steps must be taken to convince them.

In order to safeguard the future of human civilization, a conservation ethos and sense of environmental stewardship need to be instilled within each member of the global community. Changing attitudes and perceptions in this area, may lead to changes in behavior in consumptive practices. Perhaps embracing this ethos will help our world avoid another environmental catastrophe such as the Chernobyl nuclear explosion, the "electronic graveyard" in Guiyu, China or the BP oil spill in the Gulf of Mexico. Currently, we still operate in a way that threatens more disasters such as the recent Fukushima Daiichi nuclear meltdown. Because of this, there should be a concentration on STEM innovations that reduce fossil fuel consumption, oil spills, greenhouse gas emissions, methane gas released from livestock and limiting the need for nuclear energy. It is evident that a conservation and environmental-mindedness needs to be engendered into the next generation of STEM workers and educators.

Conceptual Underpinnings for the Study

STEM education has undergone massive changes in the United States over the last two decades, yet educators still lack a cohesive grasp on integrating STEM into their curricula (Kelley & Knowles, 2016). There are even misconceptions with the STEM acronym as it is often used to describe only science related subjects in STEM education (English, 2016). If science is the intended focus, the science currently being taught in schools has been criticized for neglecting climate change as a primary focus (Sharma, 2012), for a lack of creating problem-solving skills and for not applying real-world problems and solutions (Trueman, 2014). More troubling is students' disinterest in STEM education and careers (Blue et al., 2005). For STEM education to be effective, it must be multidisciplinary, use project-based learning to address real-world problems (Asghar, Ellington, Rice, Johnson, & Prime, 2012) and become accessible for students of all racial, ethnic, gender and socioeconomic (SES) classes.

Utilizing Citizen Science to Create STEM Interest and Climate Change Awareness

One of the ways in which educators may help facilitate STEM interest in students is through citizen science projects. Citizen science projects make use of a network of amateur scientists (often students) to make, record and submit observations on environmental occurrences in an effort to better understand our world. Citizen science projects address real-world problems, create authentic learning experiences (Meyer, Scott, Strauss, Nippolt, Oberhauser, & Blair, 2014) and help students understand the importance of STEM education as it relates to their schooling and everyday lives (Lamb, 2016). In addition to providing students opportunities to learn STEM content and becoming familiar with the scientific process (Ruiz-Mallén, Riboli-Sasco, Ribrault, Heras, Laguna, & Perié, 2016), citizen science has shown promise in creating motivation toward STEM careers (Hiller & Kitsantas, 2014). Many citizen science projects offer experiences with nature which have shown to create initial interest in STEM, while hands-on projects help to sustain that interest (VanMeter-Adams, Frankenfeld, Bases, Espina, & Liotta, 2014). This falls in line with the Next Generation Science Standards recommendation of preparing students for college, career and citizenship by educating in an authentic manner, with real-world problems and using outdoor learning experiences (NGSS Lead States, 2013). Likewise, the *2016 Horizon Report* asserts that students should have community-connected, real-world, authentic learning experiences (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016).

In addition to the prospect of fostering STEM interest, a large number of citizen science projects are based upon the observations of climate change phenomena and have shown the capacity of creating climate change awareness and environmental activism in participants (Johnson et al., 2014; Toomey & Domroese, 2013). Research literature has also shown an increase in subject matter knowledge and a greater understanding of the scientific process after taking part in scientific citizenship (Jordan et al., 2011). Moreover, citizen science, when paired with community awareness and scientific rigor, could produce societal intervention to correct environmental challenges (Couvet, Jiguet, Julliard, Levrel, & Teyssèdre, 2008). STEM interest and conservation and environmental-mindedness may be two outcomes directly associated with taking part in citizen science. Little is known however, about these interwoven characteristics and how they may be formed.

Conservation and Environmentally-minded STEM: Defining a Concept

Developing a mindset of conservation in one's person may require a transformational learning experience or a change in identity. Transformative learning is an experience that alters the learners' perceptions (Illeris, 2013; Mezirow, 1978), while social identity theory contends that individuals identify through an internalization of beliefs, values and attitudes of self as compared to a group (Ashforth & Mael, 1989). Authentic scientific inquiry can be a transformational learning experience, initiate a change in identity (Farnsworth, 2010) and ultimately reshape students' education and career interest (Walker & Molnar, 2014). While several studies investigate STEM identity (Hughes, Nzekwe, & Molyneaux, 2013; Stout, Dasgupta, Hunsinger, & McManus, 2011; Yoon, Dyehouse, Lucietto, Diefes-Dux, & Capobianco, 2014), there is a significant gap in the literature when it comes to understanding conservation and environmentally-minded STEM (CEmSTEM) interest. In this study, we consider a new concept regarding STEM which brands and focuses on individuals that may have a conservation and environmentally-minded approach to education and careers within STEM fields. Individuals that have this deep-seated conviction may be more likely to put conservation and the environment at the forefront of decision-making in regard to innovation and problem solving. This definition of CEmSTEM and the resultant pursuit of education and careers in this arena may lead to further advances in major issues such as climate change.

There are several recent studies which may lightly touch on the conservation and environmentally-minded aspects of STEM alongside citizen science identity, but none delve deep into the topic. The work of Gaydos and Squire (2012) showed promise in terms of students forming citizen science identity and developing environmental stewardship after playing an educational game based on citizen science. The technological and science related components of this study fit firmly into the STEM world, but little is known about the study's impact relating to CEmSTEM interest and perceptions. The researchers focused on citizen science identity formation which highlights the conservation and environmentally-mindedness of participants, but did not examine the STEM identity and interest components in students after intervention.

Mobile learning has also been found to contribute to STEM interest (Gilliam, Bouris, Hill, & Jagoda, 2016; Metcalf, Milrad, Cheek, Raasch, & Hamilton, 2008; Terkowsky, Haertel, Bielski, & May, 2013). When used to learn about climate change, mobile learning technologies afford learners with opportunities to grasp content knowledge in alternative methods such as using social media, personalized learning an authentic practice (Pettit, & Kukulska-Hulme, 2011). Many citizen science projects make use of the ubiquity and accessibility of mobile devices in terms of conducting research. Utilizing a holistic approach that includes mobile learning and the authentic practice of a citizen science project may lead to STEM workers and educators that are conservation and environmentally-minded. It is these individuals that may provide the next breakthrough in sustainable and renewable energies or may influence others to develop a pro-environmental ethos and change daily consumptive behaviors.

Wallace and Bodzin (2017) contended that the approach of using mobile learning and the authentic practice of contributing to a citizen science project creates citizen science identity as well as interest in STEM. The intent of this study, however, was limited in scope as several potentially related aspects of citizen science identity (such as climate change awareness and environmental stewardship) had yet to be connected. A brief implementation, paired with a limited scope left a gap where not enough is known about the impact of creating citizen science identity through mobile learning and authentic practice and how it relates to STEM interest, climate change awareness and environmental stewardship. The individual components of this approach have proven to be effective in regard to creating STEM interest and citizen science identity. Citizen science projects can aid in creating STEM interest (Hiller & Kitsantas, 2014), climate change awareness (Groulx, Brisbois, Lemieux, Winegardner, & Fishback, 2017) and environmental activism (Cooper, Dickinson, Phillips, & Bonney, 2007; Devictor, Whittaker, & Beltrame, 2010), but these projects have not been organized in a way that examines and measures CEmSTEM interest.

Citizen Science Identity

The interwoven facets of STEM interest, climate change, environmental stewardship and CEmSTEM may be adhered by one key construct: citizen science identity. Wallace and Bodzin (2017) found that participants that formed identities as citizen scientists had a significant increase in STEM interest. Gaydos and Squire (2012) observed that the formation of citizen science identity lead to increased understanding of climate change and attitudes toward environmental stewardship. Individuals that take part in authentic citizen science projects may have experiences which can aid in fostering citizen science identity.

In attempting to understand the topic of citizen science identity, one should look no further than the attributes that comprise a citizen scientist. A citizen scientist is a common individual that seeks to observe, record and report a natural occurrence for the betterment of a species, environment or science as a whole or who is merely interested in the world around them. Often these individuals use technology to take part in research and learn about their local environments as they help solve real-world issues. Since citizen scientists use technology and are learning about science and the scientific process, it seems there is a natural inclination to associate these practices with STEM interest. A great number of citizen science projects are related to climate change and, ultimately, learning how to be a steward for the earth. It is these experiences which may correlate to shaping climate change perceptions, environmental stewardship and CEmSTEM perceptions.

Statement of the Problem

The United States is falling behind other countries in terms of developing STEM workers to meet the challenges of the 21st Century such as climate change. The U.S. needs highly-skilled workers in the areas of science, technology, engineering and mathematics, but the demand greatly outweighs the supply. In order to fill the void for these high-paying jobs, foreign-born workers are utilized (Hossain & Robinson, 2012). Additionally, China and South Korea are the two primary sources for graduate students in science and technology fields at American universities (Mullich, 2013). This trend should be a "red flag" to the U.S. and should create an urgent response to address the problem.

Creating interest in STEM during an individual's formative years results in learners seeking out STEM education and careers (Manson, Martinez, Buchwald, Rubio, & Moss, 2015). More importantly, however, is sparking interest in STEM during high school years and before a college major is chosen (Maltese, Melki, & Wiebke, 2014). Sadler, Sonnert, Hazari, and Tai (2012) contend that career interest in STEM at the beginning of high school is the best predictor of maintaining STEM interest upon leaving high school. High school experiences are, in fact, the most crucial in terms of creating STEM interest in students (Riegle-Crumb, Moore, & Ramos-Wada, 2011). In order to meet the deficit in STEM workers and to conquer challenges such as anthropogenic climate change, the U.S. educational system needs to find ways to generate STEM interest in high school students.

While there is a great deal of research on climate change, STEM education reform and studies on creating interest in STEM, there is a significant gap in the literature when it comes to developing conservation and environmentally-minded STEM (CEmSTEM) interest and perceptions. Not enough is known about what types of learning activities help to create STEM interest while building climate change awareness and imparting a sense of conservation and environmental stewardship. Environmental science falls under the STEM umbrella, but it is unclear how this may impact CEmSTEM perceptions. It is not enough to solely create STEM workers, there is a greater need to develop the next generation of conservation and environmentally-minded STEM workers and educators in order to solve challenges facing our world. Greater still, is the need to foster a citizenry in which individuals take action to reverse humankind's negative impact on earth. The goal is not to educate an engineer that will build a better engine, but to educate an engineer that will build a better engine with renewable and environmentally-friendly energy. Innovation should be intertwined with conservation.

Purpose of the Study

This quasi-experimental, quantitative study utilized an open-ended, qualitative component to support findings and seeks to fill an important void in the literature by understanding how mobile learning and the authentic practice of a citizen science project may lead to citizen science identity and CEmSTEM interest in high school students. This research seeks to formalize and brand several interconnected outcomes associated with taking part in citizen science projects including: STEM interest, CEmSTEM perceptions, citizen science identity, climate change awareness and environmental stewardship. It is hypothesized that taking part in a mobile learning and authentic practice (MobiLAP) citizen science project will create within participants a STEM interest that is permeated with conservation and environmental-mindedness. Environmental stewardship may be a potential positive side effect of creating STEM interest and climate change awareness through mobile learning and the authentic practice of taking part in citizen science. This study seeks to highlight that the MobiLAP approach to citizen science projects is important and relevant and may be a vehicle to propel CEmSTEM workers and educators.

Research Questions

1. How does high school student interest in STEM education and careers change after taking part in the MobiLAP approach?
2. How does the MobiLAP approach affect CEmSTEM perceptions in high school students?
3. How do high school students perceive their identity in regard to citizen science after taking part in the MobiLAP approach?
4. How does the MobiLAP approach impact high school student perceptions of mobile learning?
5. How does the MobiLAP approach impact climate change perceptions in high school students?
6. How might the MobiLAP approach change high school students' perceptions of conservation and environmental stewardship?

Definition of Key Terms

Anthropogenic Climate Change. The gradual warming of the earth caused by greenhouse gas emissions caused by humankind's dependence on burning fossil fuels.

Authentic Practice. A method of learning that allows students to learn from hands-on, real-world experiences.

Citizen Science. A process in which common citizens can contribute to the scientific knowledge of a large-scale scientific study.

Climate Change. An alteration of global average temperature, precipitation and atmospheric circulation caused by humankind's use of fossil fuels, with an additional contribution from land use for agriculture.

CEmSTEM. An acronym that represents conservation and environmentally-minded thinking in connection with STEM subject areas.

Environmental Stewardship. A sense of responsibility toward caring for the environment.

MobiLAP. An educational approach that uses mobile learning and the authentic practice of a citizen science project to foster scientific citizenship.

Mobile Learning. The utilization of mobile tools to enhance the learning process.

Phenology. The observation of seasonal changes in plants and animals related to environmental cues such as seasonal variations in temperature, precipitation and length of days.

Summary

This study sought to examine how mobile learning and the authentic practice of a citizen science project may create citizen science identity, STEM interest, shape conservation and environmentally-minded STEM perceptions, affect climate change awareness and environmental stewardship in high school students. Creating STEM workers and educators is an important goal of the United States educational system. Creating CEmSTEM workers and educators is important as they may be the catalyst to enact change in major challenges such as climate change. The remaining chapters of this dissertation include a thorough review of the literature in chapter two. Main topics discussed in chapter two include STEM education, climate change, citizen science, mobile learning and authentic practice. Chapter three outlines the methodology that was used to conduct the study. Chapter four contains the results from the data analysis. Chapter five discusses the findings from the previous chapter and chapter six provides insights for implications.

CHAPTER 2: REVIEW OF THE LITERATURE

Introduction

Two of the major issues facing education in the United States today are the lack of STEM workers and educators and climate change awareness. Both of these issues are complex yet have interconnecting facets. STEM workers have the ability to positively impact climate change, while climate change science can create STEM interest in participants (McCright, O'Shea, Sweeder, Urquhart, & Zeleke, 2013). The goal of this research is to find a point of intersection within educational learning activities that may provide opportunities to address both issues.

This chapter delves into the current literature in the following areas: STEM interest in education and careers, climate change, environmental stewardship, citizen science, mobile learning, authentic practice and an approach to foster CEmSTEM interest. Information and statistics will be derived from national and international organizations related to the topics. Alternate and opposing views are included in order to gain a holistic understanding of disputed topics such as climate change. Special attention is paid in finding gaps in the literature so that this study may contribute to the knowledge base.

STEM Education in the United States

In the United States, STEM education reform has highlighted ways in which to implement and expand STEM education in K-12 schools and institutions of higher education. Researchers have focused on advancing educational (Bastedo & Jaquette, 2011) and career-based opportunities (Grodsky & Pager, 2001; Weis et al., 2015) for all students regardless of race, social class, and other demographic factors. Several educational reforms have been proposed over the last few decades, however, STEM education reform is the most expansive nation-wide approach to increase student engagement, student learning, and academic student performance in STEM fields of study (Bastedo & Jacquette, 2011; Weis et al., 2015). According to the President's Council of Advisors on Science and Technology (2010), Congress and President Barack Obama denoted the importance of increasing the preparedness of students to ensure that all students develop and sustain a strong foundation and underpinnings in STEM-related subjects in schools. By increasing a student's active involvement and participation in STEM, students will be inspired to pursue STEM majors in higher education and careers in the STEM workforce.

The efficacy and success of STEM reform is dependent on good leadership. Goldey (2010) and the National Research Council (2011) proclaimed that STEM reform involves effective leadership to develop a shared vision and enhance the provision of partnerships and support networks within and outside of educational institutions. Schools play a prominent role in STEM education reform and are continuously challenged to utilize a multidisciplinary and integrative approach to advancing STEM. However, the opportunities to obtain STEM-focused learning are few as there are a limited number of STEM-focused high schools nationwide (Rogers-Chapman, 2014). As a multidisciplinary educational approach, STEM underscores the demands of implementing new content-based standards in mathematics and science (Weis et al., 2015). However, the lack of a one-size-fits-all model has resulted in schools utilizing varying approaches to improve STEM education throughout the United States. Some schools focused on offering additional classes in mathematics and science while other schools raised graduation requirements in mathematics and science or created 'STEM schools' (Weis et al., 2015). STEM schools stress STEM pedagogy and curriculum that strengthens learning and allocates more time to STEM instruction (National Research Council, 2011; Weis et al., 2015). Increased accessibility and availability of resources will better prepare teachers in mathematics and science thereby improving STEM instructional practices.

In order to be successful, STEM education needs to provide students with opportunities to solve real-world problems (LaForce et al., 2016). Teachers should aim to transition from the traditional transmitter of information to a facilitator role where they use a multidisciplinary approach to guide students through authentic practices and problem-solving activities (Asghar, Ellington, Rice, Johnson, & Prime, 2012). The work of Cox, Reynolds, Schunn, and Schuchardt (2016) showed the potential of using math and engineering principles to successful teach biology at the secondary level. A multidisciplinary approach to teaching STEM is not always possible, however, as STEM educators typically work in silos within their own area of expertise and aren't comfortable collaborating with educators in other STEM fields (Zhang, Mclnerney, & Frechtling, 2010). Teachers that are willing to work with other educators often lack the support necessary to collaborate and form concepts related to multidisciplinary STEM education (Slavit, Nelson & Lesseig, 2016). When STEM teachers take part in integrated professional development, their subject matter knowledge and perception toward STEM has been shown to increase, while their discontentment toward teaching STEM subjects decreases (Nadelson, Seifert, Moll, & Coats, 2012). Additionally, schools may wish to look to school libraries and librarians as they are underutilized resources in terms of creating valuable STEM learning spaces (Subramaniam, Ahn, Fleischmann, & Druin, 2012)

Despite the resources currently available, the majority of high school students are ill-prepared for college-level math and science courses (Raines, 2012). In an effort to remedy this, many colleges across the U.S. offer summer bridge programs to help incoming freshmen transition to higher-level math and science courses. The goal of these programs is to foster, encourage, and motivate high school students to pursue STEM majors in college and STEM careers after college (Auburn University College of Sciences and Mathematics, 2017; Kapi'olani Community College, 2012; University of Washington College of Engineering, 2017). Findings from a study of 33 high school students in 10^{th} – 12^{th} grades revealed that after completing a summer bridge program, 100% of students decided to attend college, of which approximately 86% of students selected a STEM major (Zhe, Doverspike, Zhao, Lam, & Menzemer, 2010). This research demonstrated that bridge programs are an effective way to create and retain STEM interest in high school students and that there is an obvious need to increase and diversify STEM career awareness in school curricula for students ages 7 to 16 (Archer & Tomei, 2014).

The Gap in STEM Education

Despite the initiatives supporting STEM education reform in schools and institutions of higher education throughout the U.S., there still exists gaps in STEM education and in the workforce. The disparities in STEM education are mainly observed in accordance to gaps in gender, race, and socioeconomic status (SES). A number of research studies (Anderson, 2014; Casey, Nuttall, Pezaris & Benbow, 1995; Forgione, 1998; Hyde, Linberg, Linn, Ellis, & Williams, 2008; Neuhauser, 2015; Reardon & Bischoff, 2011; Thoman, Arizaga, Smith, Story, & Soncuya, 2014; Xie & Shauman, 2003) investigated the role of gender, race, and SES in fostering, developing, and widening the current gaps in STEM education. A report by the National Science Board summarized these findings and posits that females and minorities (Ing & Nylund-Gibson, 2013; Halpern et al., 2007) as well as students from low-income families (Archer et al., 2012; Miller & Kimmer, 2012) comprise an underrepresentation of students in STEM education.

Gender. Historically, gender disparities played a quintessential role in education, specifically STEM education. From a historical perspective, males have readily outperformed their female counterparts in STEM subject areas, both mathematics and science, at the grade school level (4^{th} – 8^{th} grade) (Forgione, 1998; Stumpf & Stanley, 1998), high school level (Forgione, 1998; Stumpf & Stanley, 1998; Thoman et al., 2014), and upon entrance into college or a university (Casey, Nuttall, Pezaris & Benbow, 1995). As time transpired, high schools throughout the U.S. experienced a shift in trends as female students soon began to be recognized for performing at the same level as males in high school mathematics and readily performing significantly higher than male students in other high school classes, both STEM and non-STEM classes (Hyde et al., 2008; Thoman et al., 2014).

In today's educational sector, a large proportion of high school females are considered high achievers in mathematics when compared to high school female academic performance in previous decades. Although current high school females have enhanced their preparedness for success upon entry into colleges and universities (Forgione, 1998; Stumpf & Stanley, 1998), these females are reportedly known to withdraw from their respective STEM major in college at a significantly faster rate than their male counterparts (Thoman et al., 2014). This gap in education relative to gender widens as students continue their educational pursuit, from undergraduate to graduate level studies (Settles, Cortina, Buchanan, & Miner, 2013; Thoman et al., 2014).

Women surpass men in terms of college completion (DiPrete & Buchmann, 2013), but are underrepresented when it comes to earning science and engineering degrees and are therefore less likely to become scientists or engineers. Likewise, women are not as likely to obtain STEM positions in academia or to hold corporate positions in traditional STEM industries (Adams &

Kirchmaier, 2016). While this imbalance has tightened over the last few decades, certain fields such as engineering are still male-dominated, with only 18% of degrees going to females (U.S. Department of Education National Center for Education Statistics, 2015). This persisting gender gap may be attributed to perceptions of traditional gender roles, work-family balance, math performance and preference toward liberal arts education (Mann & DiPrete, 2013).

Evidence suggests that undergraduate female students often withdraw from STEM due to negative experiences that push females away from STEM activities, STEM classes, and STEM-related majors. An amalgamation of gender stereotypes as well as emphasis on a cultural and social climate of masculinity diminishes a female's overall sense of belonging in science fields (Carli, Alawa, Lee, Zhao, & Kim, 2006; Thoman et al., 2014). Females who take STEM courses, are continuously exposed to negative stereotypes (Thoman et al., 2014) and social norms (Koch, D'Mello, & Sacket, 2015; Powell, 2011) that form barriers and obstacles that hampers their ability to develop and maintain an unwavering, optimistic sense of belonging. Discrimination, gender prejudice, and sexism manifests in STEM education and still persists in assessing the academic work and professional experience of females (Carli et al., 2006; Settles, Cortina, Malley, & Stewart, 2006; Thoman et al., 2014).

The bias that ensues due to gender discrimination alongside the presence of environmental and social cues perpetuates the threats of social identity issues among females (Thoman et al., 2014). Settles et al. (2006), Seymour and Hewitt (1997), and Thoman et al. (2014) further posits that females feel as though they do not belong in such areas which diminishes their level of interest in STEM and weakens the prospect of females pursuing STEM in higher education and the workforce. Seymour and Hewitt (1997) conducted a series of interviews on women who decided to leave their current course study in STEM. Findings identified the primary reason for leaving STEM was attributed to a lack of interest in STEM topics and themes covered in STEM-based classes (Settles et al., 2006; Seymour & Hewitt, 1997). The females interviewed also reported the increased likelihood of social challenges and the inability to develop strong social relationships which further decreased females' interest in STEM (Seymour & Hewitt, 1997). This exacerbates the widening gap in STEM education due to gender norms and disparities.

Many of the aforementioned barriers regarding women in STEM fields may be attributed to a concept know as stereotype threat. Over two decades of research illustrate the phenomenon of individuals underperforming in environments where they are expected to do poorly (Schmader, 2010). Girls performance and interest in STEM fields can be hampered by the negative stereotypes, anxieties and attitudes of their teachers and even their parents (Gunderson, Ramirez, Levine & Beilock, 2012). Normative influences related to STEM may act as self-fulfilling prophecies in which girls and women do poorly in STEM due to their awareness of expectations. A recent study by Schuster and Martiny (2017) found that as a result of stereotype threat, women had a lower positive outlook and increased negative affect toward STEM performance. Additionally, females reported lower aspirations toward STEM careers and were discouraged by the lack of women in STEM fields.

Race. According to recent reports (Neuhauser, 2015; Xie, Fang, & Shauman, 2015), gender and racial gaps in STEM education are widening in the United States. Black Americans, particularly those of lower socioeconomic status, are at an academic disadvantage in the U.S. (Massey, 1993; Xie, Fang & Shauman, 2015). Differences in levels of achievement based on race is strongly correlated with limitations of underrepresented racial minority groups in STEM education (Museus, Palmer, Davis & Maramba, 2011; Xie & Killewald, 2012). Achievement disparities among Black and White students in mathematics doubled at a faster rate than other racial groups in elementary school (Reardon & Bischoff, 2011). Even the most academically inclined racial minority students fall behind faster than other racial groups. Underrepresented minorities (K-12) are placed in remedial mathematics and science classes compared to their Asian and Caucasian peers (Hsin & Xie, 2014; Xie, Fang & Shauman, 2015). Hence, underrepresented minorities inclusive of Black Americans and Hispanic Americans are overrepresented in remedial courses, which reinforces the racial gap and alters the mindset that such groups will not perform well in STEM education (Museus, Palmer, Davis & Maramba, 2011; Xie & Killewald, 2012). Adolescents perceive barriers such as discrimination and stereotypes toward pursuing STEM education and careers in terms of microaggressions across racial/ethnic and gender groups. To further compound this issue, research has shown that STEM teachers require training in language and culture-infused pedagogy in order to better serve culturally and linguistically diverse student populations (Mallinson & Hudley, 2014). Despite these issues and perceptions, high school students remain positive about overcoming barriers (Grossman & Porche, 2014).

STEM education and employment in STEM fields throughout the U.S. has increased since 2014; however, there still remains a racial gap between Caucasians and other minorities that continues to widen (Anderson, 2014; Xie, Fang & Shauman, 2015). In computer science higher education programs, the disparity is significant for Black women as they note the difficulty in being accepted by their White, male counterparts (Charleston, George, Jackson, Berhanu, & Amechi, 2014). Black women in the United States, however, are more educated, academically successful and more likely to be employed than Black men (Mocombe, 2016).

Statistical findings showed that Caucasian college students earned approximately 10%

more bachelor STEM degrees than other races (Anderson, 2014). From 2000 to the latter part of 2014, the number of bachelor degrees attained by Black students in STEM increased astronomically by sixty percent, yet the overall proportion of bachelor degrees earned by Black college students decreased (Anderson, 2014). In 2011, Caucasians, Hispanic Americans, and Black Americans received engineering and science degrees at a rate equivalent to 63%, 10%, and 9%, respectively (Anderson, 2014).

The research literature highlights the disparity in STEM careers where both Asians and Caucasians are overly represented (Anderson, 2014; Chang, Sharkness, Hurtado & Newman, 2014; Min & Jang, 2015; Moakler & Kim, 2014). Additional findings demonstrated that Caucasians comprise roughly 57% of the entire workforce; however, make up approximately 71% of STEM careers (Anderson, 2014). Similar findings were revealed amongst Asians with a greater difference of Asian STEM workers (15%) and the workforce at large (6%) (Anderson, 2014). This gap is wider amongst other minorities, primarily Black and Hispanic Americans. In 2011, the total workforce consisted of about 11% of Black Americans, yet this demographic only accounted for a mere 6% of the STEM workforce (Anderson, 2014). A comparable trend was observed among Hispanic Americans who made up approximately 15% of the total workforce; however, only contributed to 7% of STEM-related careers (Anderson, 2014).

Socio-economic Status. Research studies have revealed an inherent association between socioeconomic status and a student's level of academic achievement and success in STEM education. Poverty amongst students has proven to adversely affect academic performance in mathematics and science (Sastry & Pebly, 2010), cognitive ability (Sharkey & Elwert, 2011), and graduation rates (Sastry & Pebley, 2010; Xie, Fang & Shauman, 2015). Income levels have segregated families and placed such families in poor communities, which has revealed educational disadvantages (Reardon & Bischoff, 2011; Xie, Fang & Shauman, 2015). Other studies by Archer et al. (2012), Harackiewicz, Rosek, Hulleman, & Hyde (2012), and Miller and Kimmer (2012) demonstrated that participation and achievement in STEM varies among students from lower socioeconomic backgrounds and those from a higher socioeconomic status. Findings showed that individuals from middle-income and higher-income levels have the financial resources necessary to encourage and expose their children to STEM education (Archer et al., 2012; Miller & Kimmer, 2012). This has proven to increase accessibility and support of STEM activities and classes thus developing interest in STEM education and confidence that science is a realistic career option (Archer et al. 2012; Harackiewicz et al., 2012).

Although socioeconomic status impacts students in primary school as well as those in secondary school, Chen (2009) further claims that a disproportionate number of students from families with a higher socioeconomic status obtain degrees in STEM and tend to pursue STEM careers. STEM-focused high schools have a disproportionately small number of disadvantaged students when compared to their school districts (Rogers-Chapman, 2014). This disparity exists even when reform efforts and resources are earmarked for students of this at-risk population. A study on STEM reform (Weis et al., 2015) in two separate schools serving urban, low income, racial minority students highlights the challenges associated with providing quality STEM education. In both instances, the STEM programs were eroded to the point where they were no longer high quality programs and were considered unsuccessful.

Need for STEM Workers with 21st Century Skills

Careers in STEM areas have grown by 770% between 1950 and 2000 (Lowell & Regets, 2006) yet the gap in STEM education relative to gender, race, and SES disparities remains significant. The exponential increase in technological innovation and demand for STEM workers highlight the need for STEM professionals with 21st century skills. A report conducted by Change the Equation, a STEM advocacy group, revealed that the STEM workforce is not any more diverse today than it was more than a decade ago (Neuhauser, 2015). Companies and organizations specializing in STEM-related fields proclaim that a workforce without a diverse skill set is based on a shortage of highly qualified, skilled professionals with the adequate abilities, competencies, knowledge, and skills needed for a 21st century STEM workforce (Jones, 2014; Neuhauser, 2015).

This 21st century STEM workforce must possess a skill set that encompasses the four major C's including collaboration, communication, creativity, and critical thinking (Jones, 2014; Neuhauser, 2015; Partnership for 21st Century Skills, 2007). Moreover, skills such as emotional intelligence, problem solving capabilities, social intelligence, and technological literacy sets STEM professionals apart from individuals who only excelled in engineering, mathematics, technology, or science simply due to their ability to memorize and perform well on assessments (Jones, 2014; Partnership for 21st Century Skills, 2007). STEM professionals who are technology savvy possess the competencies and wherewithal to create charts and graphs which display a visual representation of the data collected from research (Jones, 2014; Liao, Motter, & Patton, 2016). STEM workers with 21st century skills must be fully capable of applying their knowledge to the STEM field since practical experience is sought after and at times mandatory in today's workforce.

Due to the importance of enriching the skills of individuals interested in pursuing a career in a STEM subject area, teachers must begin to hone in on developing these 21st century skills in elementary school and that same emphasis must transcend throughout middle school, high school, undergraduate studies, and graduate level studies (Jones, 2014; Liao, Motter, & Patton, 2016; Partnership for 21st Century Skills, 2007). Through education and hands-on experience over the years, students from all ethnicities, races, and socioeconomic levels become lifelong learners (Lareau, 2011; Xie & Shauman, 2003). This will enhance their preparedness for STEM careers in the real-world, all of which requires 21st century skills.

Equity in STEM

Equity in STEM fields is an important goal as there is currently a need for STEM workers in the United States. One simple reason for creating equity is that adding STEM workers from traditionally underrepresented groups will bolster the overall number of STEM workers. Doing so, would greatly decrease the number of foreign-born individuals that currently fill these positions. The need for equity is pressing as global economies continue to strengthen and the United States may no longer be able to rely on obtaining enough foreign-born workers (Mcdermott & Mack, 2014). According to the National Alliance for Partnerships in Equity (2018), preparing women, underrepresented racial minorities and persons with disabilities for STEM careers at a rate similar to their fulfillment of non-STEM jobs would meet the demand for highly-skilled workers, enhance the United States' position in the global market, have a greater impact on global challenges and would lead to stronger families and communities.

Traditionally underrepresented groups in STEM fields that identify as Black, Hispanic, Native American or Alaskan Native often live in underserved communities (Harkavy, Cantor & Burnett, 2015). These individuals and communities would benefit greatly from increased representation in STEM fields and access to resources related to solving science-related and engineering issues. A powerful example of this can be found in the recent Flint, Michigan water contamination scandal. A Black-majority city with over 40% of residents living below the poverty line was subjected to drinking water with toxic levels of lead and corrosive materials

(Martinez, 2016). This resulted in serious health problems and even the deaths of several Flint residents. Communities such as this may benefit from equity in STEM education, careers and resources. It is possible that enhanced equity in STEM education could have identified this issue sooner or prevented it altogether.

Creating Interest in STEM Education and Careers

STEM innovations specializing in climate change alongside new innovations in various STEM-related fields of study will create a paradigm shift in STEM education and STEM careers. Interest in STEM education must be fostered and created at a rather young age to influence an individual's choice of STEM majors and future career options in related fields of study. Clements and Sarama (2016) contended that interest in mathematics and science in early education, as early as preschool and kindergarten, is predictive of future achievements in STEM. Likewise, van Tuijl and van der Molen (2016) contend that students aged between 8-16 should have STEM experiences and education in order to influence education and career choices in STEM fields. Additionally, several studies contend that career interest in STEM areas are directly tied to creating and maintaining STEM interest during high school years (Maltese, Melki, & Wiebke, 2014; Sadler, Sonnert, Hazari & Tai 2012). These correlations are supported by a meta-analysis of six research studies, which suggests that knowledge of mathematics during ones formative years is indicative of later accomplishments and success (Duncan et al., 2007).

The cultural framework relating to STEM education and careers has to continue to become inherently more appealing to all populations, however, the gaps in gender, race, and SES revealed that STEM must be capable of influencing underrepresented populations, primarily females, minorities, and low-income families (National Action Council for Minorities in Engineering, 2013; U.S. Department of Energy, 2017). Closing the gap in academic achievement in STEM education between Caucasian and Black students should begin in pre-school (Williams, 2014). The limited number of females and minorities in STEM education and careers makes the STEM field inhospitable to individuals that decide to remain in STEM (Neuhauser, 2015; U.S. Department of Energy, 2017). At the fifth annual Science Fair at the White House, President Barack Obama proclaimed that it is not of significance to merely increase the number of students involved in the STEM field, however, STEM advocates must target females and males from all races and backgrounds (Neuhauser, 2015). Since science is useful to all individuals, our educational sectors and classroom environments as well as science laboratories and workforces must reflect a diverse population of individuals in STEM education and careers.

Boscia's (2013) research is in direct alignment with the U.S. Department of Energy (2017) initiative to target the most vulnerable, underrepresented STEM populations. In addition to local school districts across the U.S., colleges and universities are now developing and implementing STEM programs to provide ethnic minorities, females, and low-income students residing in urban and rural regions more exposure to STEM careers (Boscia, 2013; Neuhauser, 2015). Despite the development and implementation of STEM across various school districts throughout the U.S., the underrepresentation of women in science, technology, engineering, and mathematics still remains apparent. Statistics revealed that females account for approximately 25% of the STEM workforce, however, only about 10% of that STEM population is comprised of racial and ethnic minorities inclusive of Black Americans, American Indians, and Hispanic Americans (Boscia, 2013). This signifies the need for additional pathways and strategies for underrepresented groups to obtain STEM education and careers. These underserved populations need to personally experience the aspects of STEM jobs, projects, and the importance of STEM within society (National Action Council for Minorities in Engineering, 2013; U.S. Department of Energy, 2017; Williams, 2014).

Programs that emphasize the integration of STEM within society often take place outside of the regular classroom experience. In a meta-analysis of 15 studies on student STEM interest, Young, Ortiz and Young (2017) found that taking part in STEM-based programs outside of the normal school routine had a significant impact on creating STEM interest within students. However, the researchers note that these activities should be social in nature in order to help students connect with their respective communities and the environment (Young, Ortiz & Young, 2017). A study on gender and STEM identity formation during a STEM camp showed that two groups (one co-ed and one all girls) both had similar enhancement of STEM identities after taking part in the camp (Hughes, Nzekwe, & Molyneaux, 2013). The results indicate that the identity formation for girls in the co-ed group was not impeded by the presence of their male counterparts as may be the case in other settings.

Climate Change Science

Today's society faces unrelenting issues pertaining to climate change. Climate change science has thus received increased attention over the last several years thereby accounting for the significant increase in scholarly articles and publications (Haunschild, Bornmann, & Marx, 2016; Hillier, Kelly, & Klinger, 2016). Jones (2015) and Hillier et al. (2016) characterize climate change as the release of greenhouse gases and emissions that adversely affects the climate. In accordance to projected greenhouse emissions in the future, higher temperatures are correlated with an increase in the duration, frequency, and overall intensity of heat waves (Jones, 2015). These changes are linked with health risks to populations regardless of age, ranging from younger children to older adults and the elderly. Climate change also causes floods and droughts, which affects the availability of food supplies and impacts animal and plant species (Jones, 2015). An understanding of climate change science is essential in bridging the effects of climate change with efforts to conserve the environment (Chornesky, 2016).

Anthropogenic Climate Change

Climate change and anthropogenic climate change are terms that are often used to describe the same weather phenomena, but anthropogenic climate change tends to signify the negative impact of humans on the planet. The Intergovernmental Panel on Climate Change (IPCC), National Academies of Science (NAS), and National Research Council (NRC) have contended since the mid-1990s that climate change is related to greenhouse gas emissions caused by human activity (NASA, 2016a, 2017a). Similar findings were identified in a number of peer-reviewed journals that proclaim that approximately 97% of all scientists specializing in climate science agree with the notion that over the past century, climate change is primarily associated with human activities (NASA, 2017b). Ocean acidification, which is mainly caused by humankind's CO_2 emissions, affects the chemical composition of the environment and negatively impacts many oceanic species (Kelley, Hanson, & Kelley, 2015).

On a worldwide scale, scientifically-based organizations such as the American Association for the Advancement of Science (AAAS), American Chemical Society (ACS), American Geophysical Union (AGU), American Physical Society (APS) and the Geological Society of America all support this stance. These organizations are composed of scientists who are using scientific data and have determined that human activities are responsible for climate change. This anthropogenic alteration of global climate poses a threat to both modern society and global terrestrial and marine ecosystems. The APS argued that greenhouse emissions must be significantly reduced in order to minimize disruptions to the ecological systems, physical systems, social systems alongside health and security (NASA, 2017b). Despite the impact of climate change over the course of the last 50 years, society's prompt response to human-induced changes in climate can radically diminish the negative effects and outcomes of such changes on a global scale (Pachauri & Reisinger, 2007).

Public Perception of Climate Change

Despite the volumes of research from climate scientists, climate change remains one of the United States' most misconceived topics (Cordero, Todd & Abellerra, 2008). Misunderstandings and knowledge deficits exist in learners of all levels as well as adults (Bodzin et al., 2014; Shepardson , Niyogi, Roychoudhury, & Hirsch, 2012; Versprille & Towns, 2014). Not only is the topic misunderstood, climate change is also a hotly contested subject among large segments of the American public (Douglas & Sutton, 2015). To put it simply, public perception may differ from what the science is telling us (Etkin & Ho, 2007).

According to polls from 1997-2007, roughly 60% of the public believed that scientists are in disagreement about the occurrence of global warming (Cook et al., 2013). Moreover, approximately 57% of the public disagrees or lacks awareness that human activity is causing global warming (Cook et al., 2013). A total of 11,944 articles, papers, and other publications were analyzed and found to support the existence of human-caused climate change yet, results gathered from surveys show that a majority of Americans either disagree or are unaware of such findings (Cook et al., 2013).

According to a study conducted by the Pew Research Center, 48% of Americans shared the common perception that increased temperatures due to global warming were based on human activities (Cook et al., 2013). Additionally, recent studies have shown an increase in the public's belief in climate change as well as the human causation associated with it (Milfont, Wilson, &

Sibley, 2017). Contrarily, climate change and global warming skeptics reported that changes to climatic patterns and recent shifts are not severe or fail to stem from human activity (Lewandowsky, Oreskes, Risbey, Newell, & Smithson, 2015). The consequences and outcomes of climate changes and disruptions are daunting (Cook et al., 2013). Therefore, skeptics lend support to climate models that seem to overly stress the threats associated with greenhouse emissions. A recent report by Wallace, D'Aleo and Idso (2017), contended that climate data from NASA, NOAA, EPA and the Hadley Centre for Climate Prediction and Research are invalid due to improper data adjustment methods and cannot be used to prove increasing temperatures.

A heightened degree of consensus on anthropogenic climate change is evident, however, peer-reviewed scientific literature is used to question the level of consensus and its accuracy. The attitudes, beliefs, and perceptions of political leaders and climate scientists are important indicators of the level of influence the scientific community has on public opinion within society. From 2013 to 2014, out of a total of 69,406 authors of peer-reviewed articles pertaining to the topic of global warming, only four authors (equivalent to approximately 0.0058%) had opposing views and rejected anthropogenic global warming (Powell, 2016). Opposing views are significantly increased among the U.S. House of Representatives as the number of individuals in opposition to anthropogenic global warming and climate change increased 40-fold compared to those of authors of scientific journal articles (Powell, 2016). Cook et al. (2013) provided a further extension of Powell’s stance regarding the consensus on anthropogenic global warming. The public’s opinion contends that scientists of climate change are in disagreement over the origin and underlying basis associated with global warming (Cook et al., 2013). A larger scale study examined peer-reviewed articles and publications published within a 21-year timeframe, from 1993 to 2003 (Cook et al., 2013). Findings relative to the degree of consensus that anthropogenic climate change is caused by human activity varied from Powell's, one-year study on peer-reviewed articles.

An explanation for this variance of opinion may be linked to an individual's worldview (Priest, 2013). There is a sharp contrast in the political leanings of individuals that subscribe to climate change science and those who reject the idea of anthropogenic climate change. Liberals (and Democrats) tend to have a stronger belief in climate change and anthropogenic climate change than do their conservative (and Republican) counterparts (McCright, Charters, Dentzman, & Dietz, 2016; McCright & Dunlap, 2011). Religion also plays a factor in one's climate beliefs as Buddhists, Atheists, Agnostics and those with no religion are more likely to agree in the existence of climate change and humankind's role in it. Literalist Christians (those who adhere to a literal interpretation of the Bible), however, have opposing viewpoints, while non-literalist Christian (Christians that have a metaphorical view of the Bible and its teachings) views fall in between the two extremes (Morrison, Duncan, & Parton, 2015).

The divide between political parties and even those with differing religious beliefs may not be so far and wide in terms of climate change acceptance. One tremendous caveat to the previously outlined division between Democrats and Republicans is the level in which outdoorsmen and women accept climate change. The majority of hunters and anglers identify as conservative (and Republican), yet acknowledge the problems associated with anthropogenic global warming (The National Wildlife Federation, 2012). This group spends a significant amount of time in nature and cares deeply about climate change's impact on the environment. In fact, hunters and anglers have spent over 10 billion dollars toward fish and wildlife conservation and contribute roughly 75 billion dollars to the economy annually (U.S. Department of the

Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau, 2006).

Outdoorsmen and outdoorswomen that hunt and fish for heritage and recreation may be negatively affected by climate change, but far worse off are those that hunt and fish as a means to provide food and resources for their families. Many indigenous peoples in North America are reliant on populations of moose, deer, elk, caribou and other large game species for survival. Warming temperatures caused by anthropogenic global warming have reduced populations of large game animals that indigenous people and those that "live off the land" depend on for food, clothing and other resources (Struzik, 2010). A few examples of this include a decline in moose population due to heat (Wildlife Management Institute, 2008), unchecked winter tick populations (Bergeron & Pekins, 2014), decrease in caribou caused from receding arctic lands (Struzik, 2010), pronghorn antelope decline as a result of a loss of habitat and food source (Inkley, Price, Glick, Losoff & Stein, 2013) and massive decline in populations of trout and salmon. These fish species are predicted to drop by 50% nationally with certain locations seeing as much as a 97% drop in wild trout (Wildlife Management Institute, 2008).

Results from the National Survey of Hunters and Anglers (Carpenter, 2012) indicate that outdoorsmen and outdoorswomen overwhelmingly agree that children are not spending enough time in nature which is a cause for concern regarding a disconnection from nature. Current trends suggest that Americans are spending less time outdoors and taking part in activities such as hunting and fishing. This should be an area of concern to environmentalists as the data suggests that people who don't visit natural areas are less inclined to fight to protect them (Nielsen, 2008). Louv (2005) presented the negative impact that nature deficit disorder can have on youth and stated that children's absence from the outdoors is by design. This lack of interest in the outdoors may be a result of increased access to other forms of entertainment and recreation such as video games, social media and other technology-dependent activities. It can also be attributed to schools, media, institutions and social discouragement toward outdoor activity (Louv, 2005). Data shows that teenagers in the United States are immersed in media and spend an average of about nine hours per day in front of a technological device (Rideout, 2015). A detachment from nature such as this may contribute to a lack of first-hand knowledge regarding climate change and could lead to attitudes and perceptions of denial or disinterest regarding climate change. However, recent studies have shown an increase in the public's belief in climate change as well as the human causation associated with it (Milfont, Wilson, & Sibley, 2017).

Phenology

One of the ways that outdoorsmen and women and other observers of nature can notice how climate change is affecting the balance of nature is through phenology. Phenology is the observable phases of life cycle within plant and animal activities according to their seasonal occurrence (Lieth, 1970). As the temperature increases and the climate becomes warmer and undergoes changes in precipitation trends, varying species of birds, fish, animals and plants differentially undergo temporal adjustments of fundamental phenological events that alters its ecological relationships (Pecor & Batko, 2017; U.S. Geological Survey, 2017; Pureswaran et al., 2015). Studies have shown that climate change altered traditional patterns causing birds to advance their migratory time and reproductive patterns (Pecor & Batko, 2017), deer to adjust their migration periods (Monteith et al., 2011), fish to migrate and spawn prematurely (Chevillot, Drouineau, Lambert, Carassou, Sautour, & Lobry, 2017), insects to emerge sooner than anticipated (Pureswaran et al., 2015; U.S. Geological Survey, 2017), and plants to begin to grow leaves earlier than expected (Fitchett, Grab, & Thompson, 2015; Pecor & Batko, 2017).

The trend of warmer temperatures disrupting nature is not a new phenomenon. Over the past 30-80 years, the spring season has been extended by 2-3 days and the fall season has been extended by 0.3-1.6 days per decade (Sherry et al., 2007). This artificially extends the growing season which alters the balance in ecosystems. Climate change has caused species to shift phenology and the timing in which key life events inclusive of reproduction and migration typically occur and recur throughout successive seasons. Studies by the Northeast Climate Science Center (NECSC) (2014) and Stenseth & Mysterud (2002) found that shifts in phenology leads to mismatches in the availability of sources of food and habitat, all of which negatively affects the functioning of the ecosystem such as individual fitness and population dynamics and can have ramifications all the way up the food chain (Cleland, Chuine, Menzel, Mooney, & Schwartz, 2007). Phenophase mismatches occur in all ecosystems including aquatic and marine environments. The Match-mis Match Hypothesis (Cushing, 1969) is a prevalent framework that explains how the predator/prey relationship may suffer due to mistimed phenology as a result of climate change.

Further examination by Visser and Both (2005) revealed shifts in phenology across a variety of taxonomy, however, some populations of species failed to demonstrate a phenological shift (Both, Artemyev, Blaauw, & Visser, 2004). One key phenological shift is attributed to the availability of food resources to plants and animals inclusive of birds and marine plankton (Visser & Both, 2005). Findings from the phenology of local bird, insect, and plant species in comparison to the abundance of natural food measurement revealed an insignificant shift in five of the 11 species (45.45%) and a substantial phenology shift in three out of the 11 species (27.27%) studied (Visser & Both, 2005). Since a majority of the species examined have mistimed their migratory and reproductive patterns, researchers are recommended to link their phenology data with this natural food abundance measurement. This correlation aims to ensure proper assessment of mistiming induced by climate change due to the adverse impact on their food and environment (Stenseth & Mysterud, 2002; Visser & Both, 2005; Visser, Both, & Lambrecht, 2004).

Most insect species exhibit a phenological response to temperature and rely on plants as a primary food source. An early emergence may lead to positive or negative effects depending on the species and other variables (Ellwood et al., 2012). The timing of plant budding and blooming phenophases often coincide with insect hatching periods and form a mutualistic relationship. This desynchronization can have adverse effects on one or both species in the relationship, have additional consequences up and down the food chain and can even lead to the extinction of mutualistic populations (Memmott, Craze, Waser, & Price, 2007). For example, winter moths rely on the budding of oak trees to feed hatchling caterpillars. These fresh blooms are suitable for the larval stage insect and if the maternal sequence is off, the offspring may have to feed on old leaves and not receive requisite nutrients (Van Asch, Julkunen-Tiito, & Visser, 2010).

Unlike the phenology of insects, fish and bird species, phenology and changes in vegetation provide a comprehensive indicator of climate variability (Fitchett et al., 2015). Phenology of vegetation is susceptible and responsive to climatic changes based on a biome's level of sensitivity to changes in temperature (Richardson et al., 2013). Over the course of the last five decades, advances in research has revealed plant phenology responses to climate changes relative to location and species (Fitchett et al., 2015). Vast temperature changes and rainfall serve as environmental drivers that alters a plant's adaptation, a key determinant in the plant phenology, plant sustainability, and the provision of plants as food to other species (Fitchett et al., 2015; Richardson et al., 2013). There are species that have plasticity within their migration periods and may be able to adapt to these changes, however, many may experience a negative impact on populations (Kuczynski, Chevalier, Laffaille, Legrand, & Grenouillet, 2017) and changes in climate may even lead to extinction (Møller, Rubolini, & Lehikoinen, 2008).

Plant phenology and response to climate change can impact the plant/pollinator/herbivore dynamic, habitat for various species and the overall health and vitality of the plant. Native plants that are slow to respond to changes in climate may get pushed out by invasive species that can advance phenophases at a faster rate (Wolkovich & Cleland, 2014). In a study that analyzed a 39-year phenology dataset with over two million flower counts, researchers found that changes in climate resulted in one-third of the floral species having a significant increase in floral abundance, a one-month expansion of the flowering season, and significant changes to the overall makeup of ecological communities (CaraDonna, Iler, & Inouye, 2014). Observing the phenological changes in plants, insect, reptiles, birds, fish and mammals may be one of the most convincing ways to highlight the veracity of climate change. Phenology can be an easily-observable phenomenon and may be a significant tool in the education and understanding of climate change among students and the general public that consistently spend time in nature.

Climate Change Understandings and Perceptions in Educational Settings

Phenology can be an easily-observable phenomenon and may be a significant tool in the education and understanding of climate change among students and the general public. As a devastating threat to the environment, climate change and the direct and indirect effects of human activities must be fully understood if there is to be any unified action to help solve this issue. A sensitization of the global public about climate change aids in creating awareness of its impact on the community (Pandve, 2007). Findings from a face-to-face survey of 733 research participants revealed that approximately 91.68% of participants were aware of change in global climate, of which 81.40% believed climate change was attributed to human activity (Pandve et al., 2011). Participants surveyed identified that their source of information about climate change was primarily obtained from the internet, magazines and newspapers, radio, and television by 9.23%, 42.11%, 13.39%, and 59.78%, respectively (Pandve et al., 2011). In terms of formal education, Stevenson, Peterson, Bondell, Moore and Carrier (2014), found that during teenage years, individuals are still forming worldviews and are more likely than adults to overcome skepticism and accept anthropogenic climate change. Similarly, college-aged students are able to significantly increase understanding of climate change even with little instruction on the topic (Lombardi & Sinatra, 2012).

In a comparative study between college students in the United States and their counterparts in China, findings revealed that Chinese students are much more likely to accept climate change, specifically anthropogenic climate change (Jamelske, Barrett, & Boulter, 2013). This result reaffirms themes of political ideologies and religious beliefs as a factor climate change acceptance (McCright, Charters, Dentzman, & Dietz, 2016; McCright & Dunlap, 2011). Education on climate change should begin during the early stages of formal childhood learning. Waiting until high school or college may not be effective if other ideologies and identities have already been solidified. Thus, early childhood educators should have an understanding of climate change in order to educate young minds. The research suggests, however, that this is not the case as primary-level student teachers base their climate beliefs on their own experience and struggle with concepts related to climate change (Lambert & Bleicher, 2013). Since teachers base their understanding of climate change on their individual experiences, programs that incorporate environmental stewardship should be integrated into the classroom to benefit both the students and the teachers. Teachers' attitudes, perceptions and knowledge about climate change can be significantly improved with minimal instruction when framed appropriately in a science methods course (Lambert & Bleicher, 2013).

Climate change awareness should be cultivated in educational settings as well as through effective communication with the global public in order to increase engagement with key stakeholders (Semenza, Ploubidis, & George, 2011). Pandve et al. (2011) compelled local, state, and federal governments to create and implement awareness programs on the effects of climate change. In accordance to the Intergovernmental Panel on Climate Change, campaigns pertaining to climate change were created to enhance awareness and alter the attitudes, behaviors, beliefs, and perceptions of the public (Parant et al., 2017). Dissemination of information via billboards, flyers, leaflets, movies, press, publications, and television advertisements is strongly correlated with increased levels of public awareness (Parant et al., 2017; Zbinden, Souchet, Girandola, & Bourg, 2011). Despite the importance of shared information in creating climate change awareness, Ockwell, Whitmarsh, and O'Neill (2009) and Parant et al. (2017) argue that environmental campaigns fail to adequately promote positive environmental attitudes and behaviors. However, binding communication strategies and techniques often aid in creating and enhancing climate change awareness by improving attitudes toward recycling and positive environmental practices among young individuals (Demarque, Apostolidis, & Joule, 2013; Zbinden et al., 2011; Parant et al., 2017). Public awareness campaigns may not be enough to alter perceptions as Bunten and Dawson (2014) argued that climate science needs to be rigorously taught in schools.

Environmental Stewardship

Although climate change has placed increased burden and pressure on ecosystem function, environmental stewardship serves as a driving force toward a new philosophy with improved economic, environmental, and social context (Azizan & Wahid, 2012). Environmental stewardship focuses on environmental sustainability such as flood management, livestock and wildlife conservation, prevention of water pollution and erosion as well as the protection soil and water (Azizan & Wahid, 2012). The EPA (2016b) proposed that it is every individual's responsibility to ensure optimum environmental quality. Since all actions affect the environment, individuals engaging in environmental stewardship must develop and maintain a strong, healthy relationship with the environment by practicing methods that help nurture the environment in which they live (National Institute of Environmental Health Sciences, 2017). Individually, each person can find ways to practice positive behaviors in their community, home, school, and workplace. Organizations throughout the community inclusive of civic groups, community service organizations, local governments and religious establishments tend to amplify the efforts made by individuals by working collaboratively to take full responsibility of their decisions and actions that affect the environmental (EPA, 2016). Successful environmental stewardship passes effective practices to successive generations to safeguard a sustainable future (EPA, 2016; National Institute of Environmental Health Sciences, 2017).

Promoting Environmental Stewardship through Education

Education and project-based learning serve as avenues by which to promote environmental stewardship. Exposure to education about the environment alongside project-based learning extends beyond the educational sector from elementary school through high school (K-12) and into higher education as individuals explore environmental education in colleges and universities (de Oliveira, 2009). Branagan (2005) argues that education occurs simultaneously with environmental activism, specifically non-violent environmental activism in which individuals seek to educate others about how behavior affects the environment. Individuals use research and education as a means by which to improve their critical thinking skills to acquire more knowledge and address environmental issues and its applicability in the real-world (de Oliveira, 2009).

Through teaching practices about the environment, the Environmental Nature Center (ENC) (2016) designed a number of successful project-based learning programs inclusive of a food garden, native plant habitat garden, recycling projects, waste reduction, weather station as well as composting. Project-based learning programs also enable individuals to develop and implement concepts and key ideas while engaging in scientific inquiry, tracking, measuring, and assessing data applicable to finding the most suitable solution to environmental concerns and issues that arise (ENC, 2016). However, despite one's level of environmental education, project-based learning and the ability to engage in environmental stewardship is dependent on an individual's or organization's partnership with the community (Harvey, 2016) as well as the availability and accessibility of resources (de Oliveira, 2009) and tools to share knowledge (Pacheco-Vega, 2015). Education influences behavior changes and decision making about the environment, which is needed to spark a political movement for environmental change (Barr & Pollard, 2017; de Oliveira, 2009; Pacheco-Vega, 2015).

Citizen Science

Citizen science has gained increased popularity and attention over the course of the past few decades. As a conceptual framework during the mid-1990s, citizen science has steadily increased in number of programs, participation and research. The most significant increase in research articles about citizen science were published around 2010 and thereafter (Kullenberg & Kasperowski, 2016). The increased likelihood and visibility of citizen science since 2010 is based on advancements in web-based digital projects specializing in citizen science with a few examples including: Galaxy Zoom Ebird FoldIT, Genographic Project, and Plant Hunters (Kullenberg & Kasperowski, 2016). However, citizen science is not solely limited to digital projects performed online, but does require the involvement and active participation of citizens as volunteers (Palermo, Laut, Nov, Cappa, & Porfiri, 2017).

Cooper, Shirk, and Zuckerberg (2014), Lamb (2016), and Groulx et al., (2017) posited that citizen science is characterized as a scientific process that increases the public's prospect of actively partaking in the collection of data in a meaningful manner thus enhancing the dissemination of data and information within the real-world. As an amalgamation of earth science, environmental science, life science, and physical science amongst many other scientific inquiries, citizen science aims to advance scientific research by integrating a diverse group of individuals across varying locations (Cooper et al., 2014; Groulx, 2017; Kullenberg & Kasperowski, 2016; Lamb, 2016). Jordan, Ballard, and Phillips (as cited in Groulx, 2017) defined citizen science as an inherent partnership between professional researchers or scientists and laypersons (citizens), which involves the collection, sharing, and analysis of authentic data and information. Citizen science is therefore capable of enhancing collaboration by allowing the public to be represented in the scientific process by conveying information about a select population upon careful observations (Falk, Snow, & Reed, 2016), data collection (Cooper et al., 2014; Palermo et al., 2017) and analysis (Palermo et al., 2017).

Ruiz-Mallén et al. (2016) provides a further extension that citizens contribute to science by providing varying aspirations, interpretations, and political perceptions of a concept deemed abstract in nature. This enhances subjectivity and allots citizens to use real-life, practical experiences to have a voice throughout the entire scientific process (Follett & Strezov, 2015; Shah & Martinez, 2016). Citizen science is correlated with the development of a mutualistic, symbiotic relationship among citizens and other volunteers as well as scientific researchers and professional scientists (Shah & Martinez, 2016). Scientific inquiry challenges citizens as well as researchers and scientists to utilize reflexive learning, transdisciplinary learning, and transformative learning to find ways in which to address the needs and problems within a given community or society (Ruiz-Mallén et al., 2016). Through citizen science, individuals are empowered to actively partake in research under the lead direction of professional scientists regardless of their level of scientific training (Palermo et al., 2017). An acute focus on communication-based education and development is correlated with bidirectional benefits in which researchers and scientists influence a significant number of citizens to engage in data collection and analysis (Palmero et al., 2017; Shah & Martinez, 2016). This enables citizens to strengthen their level of knowledge about scientific research while gaining satisfaction based on their participation in past, current, and prospective scientific endeavors (Palmero et al., 2017).

A large segment of citizen science programs are based around observing the phenological shifts of species and finding trends within that data in order to correlate them with climate change. As such, citizen science can be the vehicle by which the layperson can understand and contribute to the field of phenology and thus, climate change science. Most students may not understand the definition of the term phenology. They can, however, readily understand the concepts related to a phenology-based citizen science program and can actively participate in the process. Participating in this project-based manner and scaffolding the resulting knowledge can lead to a real-world understanding of anthropogenic climate change.

Citizen Science in Schools

Citizen science is characterized as a way in which to measure citizen engagement within a school setting. Some school districts employ the utilization of citizen science in a classroom setting within K-12 schools. This conceptual framework, citizen science, also transcends into higher education. Curriculum development is necessary for schools to establish citizen science programs such as Bee Hunt (Discover Life, 2015), FeederWatch (Cornell University, 2017), Galaxy Zoo (Zooniverse, 2017), Journey North (Annenberg Learner, 2016), Nature's Notebook (USA National Phenology Network, 2017), S'Cool (NASA, 2016b), and World Water Monitoring Day (EarthEcho International, 2017) (Shah & Martinez, 2016). All of these citizen science programs provide students in elementary school, middle school, and high school, the opportunity to engage in hands-on tasks and activities inside and outside the traditional classroom setting. The opportunities to incorporate citizen science in schools are vast as websites such as SciStarter (Science for Citizens LLC, 2017) list over 1,600 citizen science research projects. Many citizen science programs include curriculum implementation guides while some incorporate experts in higher learning who work to increase the number of students and teaching professionals seeking to participate in citizen science (Brown, Abell, Demir, & Schmidt, 2006).

Shah and Martinez (2016) denote the critical need for all citizens to understand the widespread nature of scientific inquiry and the research process. Regardless of the underlying purpose of the citizen science program, citizen science aims to provide all citizens, both students and teachers, the ability to solve real-world problems using K-12 learning (Thrumbull, Bonney, Bascom, & Cabral, 2000). The goal of citizen science programs and school-wide projects is to motivate students to advance interest in science by enhancing scientific literacy and imagination at a young age. This approach has proven to be successful in fostering STEM interest (Johnson et al., 2014; Toomey & Domroese, 2013), motivation toward STEM careers (Hiller & Kitsantas, 2014) and understanding the impact of STEM on education and daily life (Lamb, 2016). However, several challenges persist when implementing citizen science in K-12 schools. The inherent challenges and difficulties are exacerbated when the citizen science activity, project, or task requires teachers and students to possess specialized knowledge and skills (Thrumbull et al., 2000; Shah & Martinez, 2016). Students must be trained to properly collect data in a way that minimizes potential bias, which could affect the expected outcomes of research studies (Nov, Arazy, & Anderson, 2014). Specialization requiring additional training is time consuming and at times costly, both of which restricts its implementation. Schools incur increased costs for specialized tools, resources, and training workshops, however, federal and state funding is available to enhance teaching and learning among students and teachers in K-12 schools throughout the U.S. using a cost-effective model (Shah & Martinez, 2016; Thrumbull et al., 2000; Nov et al., 2014).

In the classroom setting, citizen science teaches students about the importance of critical thinking, practical experience, the scientific process and problem solving abilities (Jordan et al., 2011). Many citizen science projects give students personal knowledge on climate change and experiences related to pro-environmental behaviors which may create pathways toward understanding climate change and instilling environmental stewardship in participants (Johnson et al., 2014; Toomey & Domroese, 2013). Despite its importance, conducting citizen science projects is challenging. However, its challenges can be overcome through the use of staff training workshops and other training opportunities (Shah & Martinez, 2016). Additional findings show that establishing partnerships with other schools, organizations and institutions of higher education and encouraging participation with students provide students a way to become better prepared to solve problems that arise within the community (Shah & Martinez, 2016). The provision of training opportunities will promote scientific inquiry among teachers as well as the methodological skills needed to improve their teaching practices and will increase student learning (Bonney et al., 2009; Cronje, Rohlinger, Crall, & Newman, 2011).

One of the difficulties with implementing citizen science in schools stems from the fact that a majority of science teachers have never experienced scientific inquiry in their educational endeavors so it is challenging for them to understand how authentic scientific inquiry looks from an outside perspective (Shah & Martinez, 2016). Science teachers and teachers in other STEM areas of study must not simply reinforce science, technology, engineering and mathematics, rather they must learn how to apply scientific research processes into the various subjects within the classroom. Due to the lack of experience teachers in K-12 schools have with scientific inquiry, elementary schools, middle schools, and high schools must work proactively to establish partnerships with institutions of higher education. STEM professors will therefore sponsor and endorse K-12 STEM teachers to undergo training to educate them on ways to lead students through the entire scientific research process (Shah & Martinez, 2016). Exposure to the scientific inquiry approach and hands-on experience has not only proven to be beneficial to K-12 teachers and the students in which they teach but will also be valuable to students and professors in partnering colleges and universities (Shah & Martinez, 2016).

Citizen science and underlying initiatives related to citizen science is beneficial to students and school personnel. Shah and Martinez (2016) proclaim that citizen science in schools provide students in kindergarten to 12th grade engaging, exciting, insightful, and meaningful opportunities to explore the environment around them. It is a mutually beneficial relationship, where school-aged children are stimulated to partake in scientific research and contribute to their community while school personnel become highly trained and educated professionals (Shah & Martinez, 2016). Interconnectedness in the education sector improves the connection among schools, students, and teachers by employing citizen science-based activities that extends beyond data collection and science (Shah & Martinez, 2016). Citizen science offers hands-on educational experiences that aid climate change learning and can create pro-environmental ethos where participants seek to improve their community (Meyer et al., 2014). Students are exposed to conservation and sustainability issues and must find ways to mitigate these problems. Their involvement with citizen science on a school-wide scale will broaden their horizons on prospective career opportunities related to their citizen science experience (Shah & Martinez, 2016; Ford & Wargo, 2007).

Citizen Science and Environmental Stewardship

Citizen science promotes environmental activism through climate change action, in both collective and individual practice. McBride, Brewer, Berkowitz and Borrie (2013) declared that environmental literacy and advances in public knowledge of key environmental problems spark a paradigm shift toward positive changes within the environment. Additional findings by Lamb (2016) contend that scientific literacy about the environment and awareness of nature endorses advocacy for conservative practices. Through environmental stewardship, individuals work collectively to ensure the benefits of their actions and coordinated efforts (Rydin & Pennington, 2000; Shirk et al., 2012) are shared despite individual costs (Levin Cashore, Berstein, & Auld, 2012). In addition to collective action, citizen science promotes individual action through experiential learning until such learning changes an individual's environmental attitudes, beliefs, and perceptions about the world (Nisbet, Zelenski, & Murphy, 2009).

Citizen Science and Climate Change Awareness

Citizen science is strongly correlated with climate change awareness as the public fosters, develops, and enhances their perceptions, awareness, and responses to vast changes in temperature. Groulx, Bribois, Lemieux, Winegardner, and Fishback (2017) proclaimed that citizen science enhances scientific literacy across a multitude of sciences inclusive of environmental science and climate change. This serves as a catalyst to enhance the acquisition of competencies and knowledge about the emergence of key issues in the environment and its causes (Groulx et al., 2017). Climate change and the ecological and social impact of such changes lends political support by significantly increasing and expanding public awareness and understanding of the goals of citizen science (Brulle, Carmichael, & Jenkins, 2012). Groulx et al. (2017), Leiserowitz, Maibach, Roser-Renouf, Feinberg, and Rosenthal (2015) argue that when there is high public awareness, attitudes and beliefs can change over the course of time. Heightened public awareness and understanding is deemed essential as approximately 40% of the general public is unaware of changes in climate (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015).

As a problem measured in accordance to social mobilization, there exists an inherent need to foster and promote individual awareness and knowledge of climate change. Through education and engagement, citizen science and its research has increased the awareness of climate-based issues and problems that affect society. Collectively, formal and informal action must be taken to develop ways to advance adaptation and mitigation when additional information about climate change is provided to citizens and the global public (Adger, 2003; Groulx et al., 2017; Ostrom, 2010). Citizen science serves as the link by which to enhance the interconnectedness of communication and involvement in order to foster and support collective responsiveness to climate change and climate variability (Bonney, Phillips, Ballard, & Enck, 2016; Wals, Brody, Billon, & Stevenson, 2014). A study by Cooper et al. (2014) revealed that citizens with awareness of climate change contributed research data to well over 50% of studies on climate change and avian migration. Statistics such as this cannot be ignored and speak to the tremendous impact citizen science has on climate change research, action and education.

Citizen Science and Interest in STEM Education and Careers

A study by Ruiz-Mallén et al., (2016) demonstrated how a long-term citizen science project can increase high school students' attitudes, perceptions and interest in STEM fields. Student participants noted that the active involvement of scientists in the project significantly increased the interest level of all participants in both research and science across varying disciplines. Students reported the friendliness commonly portrayed by scientists as an encouraging factor to generate interest in STEM education and STEM careers. Enhancing student confidence was attributed to the development of trust and transparency between researchers or professional scientists and students or the global public at large (Ruiz-Mallén et al., 2016). A majority of research participants in the Ruiz-Mallén's et al. (2016) study reported feelings of motivation to pursue careers in science and technology, however, two students failed to demonstrate any form of interest in scientifically-based careers yet revealed a fond interest in social sciences and humanities after taking part in the program.

Citizen science provides authentic scientific experiences for participants and creates pathways for increased scientific knowledge and interest in STEM education and careers (Meyer et al., 2014). Hiller and Kitsantas (2014) found that eighth grade students that took part in a citizen science project related to horseshoe crab observations had much higher knowledge acquisition and enhanced interest in STEM careers than the non-treatment group. Similarly, a study by Wallace and Bodzin (2017) reveals that ninth grade students that took part in a citizen science project related to plant phenology had significantly increased interest in STEM education and careers compared to students that did not participate in the citizen science project. With the number of citizen science projects currently taking place globally and the amount of scholarship related to STEM as well as citizen science, there is a surprisingly minute number of studies which address the impact of citizen science on STEM interest in high school students.

While citizen science is not the panacea to all educational issues in the United States, it does provide opportunities for improvement in a number of critical areas. Research has proven that students that take part in citizen science may be more inclined to take part in positive environmental behaviors and decision-making (Johnson et al., 2014), have an increased interest in STEM education (Price & Lee, 2013; Ruiz-Mallén's et al., 2016; Wallace & Bodzin, 2017) and STEM careers (Hiller & Kitsantas, 2014; Wallace & Bodzin, 2017) and have a better understanding of climate change (Yoho & Vanmali, 2016). The impact of citizen science on STEM education and career interest is an underexplored theme in the literature and may be an effective avenue in which conservation and environmentally-minded STEM interest can be formed.

Fostering Citizen Science Identity

In the very few scholarly articles that address citizen science identity, it is discovered that when formed, these identities have value in several important educational areas. Wallace and Bodzin (2017) found that participants that form citizen science identities had significantly increased interest in STEM careers. Gaydos and Squire (2012) contend that participants that formed citizen science identities had increased understanding of climate change and had enhanced feelings of environmental stewardship. As there are no other studies on the formation of citizen science identity, other theoretical frameworks related to learning and identity must be examined.

According to Mezirow (1978), transformative learning changes an individual's perceptions, frames of reference and habits of mind. As a result, the individual may ultimately change behaviors. Transformative learning is more than just a cognitive effort, however, as Mezirow (2009) later added the need for social, environmental and emotional change to take place within the individual. Illeris (2013) contends that transformative learning deals more with shaping one's identity, which is a complicated and fluid process. Due to the reflective and cognitive aspects of transformative learning theory, it is mostly thought of as an adult learning theory and may not be suitable for learners in the target population of this study. Moreover, the majority of transformative research is solely qualitative and deviates from the primary research method in this study (Taylor, 2007). As such, this study seeks to employ a conceptual framework to address the formation of citizen science identity and the interconnected facets of STEM interest, CEmSTEM, mobile learning, climate change and environmental stewardship.

Mobile Learning

Since citizen science can play a quintessential role in climate awareness and the pursuance of STEM education and STEM careers, schools have adopted the use of mobile learning teachings to enhance traditional learning in the classroom. Schools readily use mobile learning apps as a way in which to provide students and teachers the opportunity to quickly access more information about any given subject matter. Mobile learning has proven to be advantageous as it has transformed the traditional teacher-centered classroom into a modern day student-centered classroom focused on mobile learning and expanding student learning methods.

Mobile learning opportunities in schools generally encompass an array of apps, audio, images, and information while enabling students to make observations and collect data accordingly (Ranieri & Pachler, 2014; Shah & Martinez, 2016). The advent of mobile learning devices such as iPads, mobile apps, smartphones, and tablets can be used to transform any student into a citizen scientist (Ranieri & Pachler, 2014). Mobile learning includes apps that are useful to teachers by increasing student interest in a given field of study. Apps such as Beach Health Monitor (a pollution app), FoldIt (a molecular biology app), Galaxy Zoo (an astronomy app), Google Earth (a geography app), Lichen AQ (a climate change app), and Project Noah (a life science app) are used to provide interactive ways for students to learn, thereby enhancing student engagement, student learning, and overall student performance (Shah & Martinez, 2016).

Affordances of Mobile Learning in Education

The increased availability of affordable mobile devices is responsible for enhancing its accessibility within education (Willemse & Bozalek, 2015). The advent of the Internet and innovative technological advancements enhanced the facilitation of learning opportunities for teachers and students in K-12 (Shah & Martinez, 2016) as well as students in higher education (Willemse & Bozalek, 2015). MacCallum, Skelton and Verhaart (2017) confirmed the affordances of mobile learning across three differing learning approaches including collaborative learning, connectivism and experiential learning. These case studies proved the efficacy of integrating mobile learning across multiple learning approaches and in a variety of subject matter. In each instance, mobile learning enhanced and advanced each of the respective educational environments. Similar findings were observed in Lai, Yang, Chen, Ho, and Chan's (2007) and Liu's et al. (2014) studies, which revealed an interchange between the affordances of mobile technology, instructional practices, and student learning. Additional findings showed that the use of mobile learning, particularly personal digital devices (PDAs) in 5th grade classrooms improved the acquisition of knowledge through experiential learning (Lai et al., 2007).

In addition to enhancing learning and the learning environment, the use of mobile technologies in the learning process has been shown to significantly improve student engagement and confidence in subject areas (Bray & Tangney, 2016; Al Mosawi & Wali, 2016). The work of Heflin, Shewmaker and Nguyen (2017) showed that students using mobile technologies to learn have positive attitudes related to collaborative learning. The researchers cautioned, however, that mobile learning may lead to less critical thinking when used to construct written responses. Additionally, the use of mobile devices in the classroom may cause students to become distracted and therefore less engaged in learning (Witecki & Nonnecke, 2015). Outcomes such as this should be reminders to educators that the use of mobile technologies in the teaching and learning process should be carefully constructed and purposeful.

Ubiquitous Knowledge Construction

Ubiquitous knowledge construction is directly associated with the ubiquity of computing, which allows users to access technologies on-demand. According to Hummel and Hlavacs (2003), ubiquitous computing encompasses an array of embedded systems that are interconnected to build an environment that enables users to access content from any location at any given time. Hill, Reeves and Heidemeier (2000) provide a further extension of Hummel and Hlavacs (2003) stance on ubiquitous computing and adds that ubiquity is widespread, an enhanced conceptual framework that provides computing as deemed necessary. The conceptual framework of ubiquitous knowledge construction is based on a hierarchical scale that begins with learners and tools inclusive of mobile learners and ubiquitous computing then transitions to pedagogical methods such as constructivism and lifelong learning (Peng, Su, Chou, & Tsai, 2009).

Once a vision is developed for ubiquitous computing, ubiquitous knowledge construction is key to future learning (Baloian & Zurita, 2012; Peng et al., 2009). Utilization of laptops, PDAs, personal computers (PCs), smartphones, and tablets enhances the provision of knowledge communication while promoting the dissemination of knowledge and knowledge construction (Baloian & Zurita, 2012). In accordance to the Mobile Collaborative Knowledge Construction (MCKC) system, three pilot studies revealed the importance of the facilitation of brainsketching and brainwriting, contextualization of information, social interaction (face-to-face), and visualization of knowledge presentation (Baloian & Zurita, 2012). Despite such findings, the key to ubiquitous knowledge construction is that individuals should be empowered to learn only when they are stimulated.

Mobile Learning and Identity

The increased accessibility to mobile learning devices has influenced user identity. Stald (2008) identifies the role of mobile learning in the lives of all users with an emphasis on young users. Mobile learning and the use of technological devices shapes a young person's identity. Ranieri and Pachler (2014) further extends Stald's (2008) stance by focusing on the impact that mobile learning has on the formation of adult learner identity and self-representation. In today's society, identity particularly among adolescents who partake in mobile learning, is deemed fluid since one's identity develops and changes in accordance to the time and experiences inclusive of social experiences (Stald, 2008; Ng, 2011). Adolescents tend to encounter intellectual and emotional challenges while using mobile devices. Identity, a continuously changing phenomenon, forces adolescents to continually negotiate who they are with associates, friends, and family members (Stald, 2008) and impacts their degree of social awareness (Ng, 2011).

Through documentation, mobile learning enables users to access, coordinate, and update information at any given time (Baloian & Zurita, 2012; Stald, 2008). Mobile learning is known to influence individual identity, however, recent data have shown that mobile learning also establishes and alters group identity. The constant exchange of information and data between friends and family is needed in identity formation yet the insecurities of life can be detrimental to the construction of individual and group identity relative to mobile learning (Stald, 2008; Ng, 2011).

Due to the amount of time students allocate to technological devices, social media is now being used as a mobile learning tool by which to attract and attain the attention of students. In high schools throughout the U.S., social media has been used in the classroom, particularly in citizen science and other sciences. Since students in today's society are inspired by the latest social media platform and apps, schools began to utilize this social media trend to heighten student interest levels in scientific activities, experiments, inquiry and research. An example of this can be found at Appleton East High School, a Wisconsin school that has employed social media apps as mobile learning apps (Shah & Martinez, 2016). This school embraces social media in mobile learning having used Facebook, Instagram, Snapchat, Trivia Crack, and Vines to foster and develop student inquiry and encourage a level of interest and passion for the science field. The students at Appleton East High School use Vines, a social media platform, to post videos of their most recent science experiments as six second clips (Shah & Martinez, 2016). The use of Vines at this Wisconsin high school, has sparked interest in science and has enabled students outside of the school to view the videos and become fascinated with science (Shah & Martinez, 2016). Although Vines is used at Appleton East High School, its implementation is quite challenging due to the school's policy of prohibiting cellular devices on school premises

(Shah & Martinez, 2016). Moreover, a significant portion of the student population at Appleton East High School was unfamiliar with the app, so time was allocated to introduce all high school students to this app (Shah & Martinez, 2016). Even with such obstacles, mobile learning is a tool in which educators can meet students on their "playing field". Utilizing mobile technologies as part of an educational program can impact student learning, interest in educational and career fields and even help shape identity.

Authentic Practice

In addition to mobile learning, authentic practice serves as an instructional approach designed to help individuals examine and analyze concepts and constructs needed to solve real-world issues. Authentic practice provides a more in-depth learning experience commonly assessed through attributes and characteristics inherent among individual learners. Watagodakumbura (2013) describes authentic practice as a way of learning that removes learners away from the traditional didactic approach to learning to an approach that engages students in a discussion. Open-ended questions serve as a guide that challenges thinking and makes students more involved in the authentic learning process by forcing them to deduce all the data and information collected to generate their own unique answer (Watagodakumbura, 2013).

Knotts, Henderson, Davison, and Swain (2009) identified four essential elements to authenticity within a teacher-student or teacher-learner dynamic. Knotts et al., (2009) stated the significance of being and remaining present in a classroom setting, identifying and being aware of how to utilize the context, actively engaging in authentic practice-based learning activities, and possessing ownership of learning within a student-centered framework. One key learning outcome that serves as an extension of Knotts et al. (2009) key elements of authenticity, relies on a learner's aptness of targeting real-world concerns that are in alignment with obtaining twenty-first century skills (Bell, 2010). In the workforce, individuals are evaluated based upon their competencies in performing tasks and not on outcomes designed around an assessment. Therefore, authentic, real-world experiences aid in the learning process as well as in preparing individuals for the workforce.

The development and utilization of scientific inquiry and higher order critical thinking skills serve as a primary aspect of authentic practice learning outcomes (Ormrod, 2004). By researching and exploring concepts, contexts, facts, formulae, and information, learners will be able to better understand the activities that are in alignment and relevant to real-world tasks (Ormrod, 2004). Identification of tasks and underlying tasks essential in completing a major task in a sustained timeframe, is fundamental to authentic practice learning outcomes. However, completion of such tasks requires collaboration as a form of empowerment that highlights shared leadership and decision making abilities (Katz & Henry, 1988; Knotts et al., 2009; Ormrod, 2004). Such collaboration is achieved on an individual and collective scale, both within the classroom and the real-world. Studies conducted by Brookfield (2002), Cranton and King (2003), and Huber, Hutchings, Richard, Miller, and Breen (2007) highlight critical reflection on a learner's individual practice as well as the practice of fellow learners. Reflecting on such practices has led to the development of the ideology that an equitable balance must be sustained between teaching practices and scholarship (Knotts et al., 2009).

Authentic Practice and Subject Matter Interest

Although authentic practice learning outcomes are universal in nature, authentic practice influences interest in subject matter to varying degrees. Knotts et al. (2009) argues that authentic practice learning provides teachers the innate opportunity to establish a strong relationship with their subject matter as well as a dynamic relationship between teachers and students. Good authentic practice learning is therefore measured in accordance to a subject-centered approach and has been shown to positively impact teacher attitudes toward instruction (Hursen, 2016). However, the relevance of authentic practices and activities is not solely limited to one particular subject matter yet extends well beyond one subject matter and into an entirely different discipline of study (Knotts et al., 2009). Research has shown that authentic learning methods create student engagement and subject matter interest in a wide variety of content areas, with a few examples including: curriculum development (Hursen, 2016), reading (Moodley & Aronstam, 2016), physics (Murphy, Lunn, & Jones, 2006), and chemistry (Prins, Bulte, Van Driel, & Pilot, 2009).

Conducting activities outside of the normal classroom is important because it may provide a setting in which authentic experiences can take place. Authentic practice creates real-world scenarios where students can build problem solving and critical thinking skills (Morrison, Roth McDuffie & French, 2015) and can increase a student's capacity toward scientific reasoning (Moore, 2012). Authentic practice, even when completed using a simulation, has positive effects on learner engagement, motivation and STEM interest (Hsu & Ching, 2012). Authentic learning creates interest in STEM in a multidisciplinary manner (Marshall, 2009) as well as through individual foci in science (Quigley, 2014), technology (Hill & Smith, 2005), engineering (Rust, Richardson, Davis, Soled, & Heckel, 2006) and mathematics (Mohr-Schroeder et al., 2014).

Authentic Practice and Identity Formation

Authentic learning is an inherent aspect of identify formation. Research literature posits that authentic learning challenges learners to solve problems that are measured in accordance to a number of varying interpretations from distinct cultural perspectives (Knotts et al., 2009). As this occurs, learners will begin to identify its relevancy within the real-world. Learners are obliged and encouraged to collaborate with other learners and to use a diverse set of interpretations and solutions to make informed decisions reflective of their learning experience. Despite periods of frustration, learners involved in authentic practice learning are motivated to compare their individual interests with the interests of others employed within the profession. Since all learners vary in the way knowledge and information is retained and disseminated, authentic practice learning establishes a unique way in which learners form their identity as it grants the ability for learners to control and direct their own learning (Stepich, Ertmer, & Lane, 2001; Sternberg, 1998).

There are few studies that examine authentic learning's role in identity development. However, the research that does exist highlights the innate connection between authentic practice and identity formation in learners. Haston and Russell (2012), found that authentic context learning positively impacts the occupational identity in preservice music teachers. Chinn (2009) contends that authentic, situated experiences provide students, who may be typically underrepresented in science education and careers, a method in which to create interest and build science identities. Research by McCune (2009) strengthens this argument as this study observed 59 experienced bioscience students from three separate universities in order to understand the impact of authentic learning on identity. Results indicate that the social integration into a science learning community coupled with authentic practice increased learner engagement, built confidence, improved interest in science and fostered science identity development.

Mobile Learning and Authentic Practice to Foster Citizen Science Identity and CEmSTEM Interest

The combination of mobile learning and authentic practice as an effective approach to learning can be observed in a study where nursing students used mobile learning and authentic practice as part of their nursing education (Pu, Wu, Chiu, & Huang, 2016). Results indicate that this approach to learning was effective in that it directly impacted knowledge construction and increased learning outcomes and efficacy in regard to the subject matter. In addition to improved learning, participants in the intervention group had more confidence in their abilities as nurses. In this case, the addition of mobile learning to the curriculum was considered one of the pieces that contributed to an authentic learning experience. In another example of the efficacy of mobile learning in a real-world context, Chiang, Yang and Hwang (2014) found that students taking part in a project using mobile learning and augmented reality had significant gains in motivation, attention and confidence when compared to the participants that only used mobile technology. The mobile learning and authentic practice approach to teaching and learning is not well-represented in the literature. There are however, a few studies examining mobile learning and authentic practice in varying content areas including: mathematics (Baya'a, & Daher, 2009), instructional design (Hsu & Ching, 2012), computer networking and security (Qian, Yang, Guo, Bhattacharya, & Tao, 2013), nursing (Pu, Wu, Chiu, & Huang, 2016) and cultural learning (De Pietro, 2013).

Mobile learning has shown the capability of creating STEM interest in participants, however there is no current research which examines how mobile learning may impact citizen science identity. Likewise, authentic practice can create STEM interest and help shape identity, but it is not a blanket approach. For the purposes of citizen science identity, the authentic practice must be in a citizen science context. Since many citizen science projects make use of mobile technologies, there is great potential for authentic experiences to take place. The mobile learning and authentic practice (MobiLAP) approach in citizen science contexts is reciprocal and may prove to be a valuable method in creating citizen science identity and CEmSTEM interest in participants. Mobile technologies add an additional layer in citizen science projects which allow participants to have authentic experiences as scientists while using tools for observation, identification, communication, location, recording and reporting data. In many cases, these tools are very similar to or the same as the tools that real scientists may use in research. Additionally, the ubiquity, access and personalization of smartphones create even more opportunities for individuals to dive deeper into a subject and potentially shape interest and identity. It is these technological components, authentic scientific inquiry and real-world problem solving that may increase participant interest in STEM while citizen science may work in concert to develop interest in science and conservation and environmental-mindedness.

Individuals that form citizen science identities are more familiar with the scientific process, better understand climate change, increase content knowledge, feel more connected with nature and are more likely to participate in environmental stewardship as well as future citizen science projects. Identifying as a certain type of individual increases the likelihood that the individual will take part in activities associated with that identity. For example, if one identifies as a citizen scientist, they are more likely to take part in scientific activities and studies. This may ultimately impact their educational and career paths. While there are very few studies related to creating STEM interest with citizen science, to this researcher's knowledge, there is no research literature related to the specific subsection of STEM interest introduced in this study as conservation and environmentally-minded STEM interest.

One method which may foster CEmSTEM interest is the MobiLAP approach. The approach of mobile learning and authentic practice in a citizen science context has been shown to aid in constructing citizen science identity in participants (Wallace & Bodzin, 2017). This study utilized mobile learning and authentic practice in a citizen science context in order to understand participant attitudes and perceptions of citizen science identity, mobile learning and STEM interest. The treatment group showed significant increases in citizen science identity and STEM interest after using the MobiLAP approach to take part in a phenology-based citizen science project. The control group had a “business as usual” classroom experience and did not show any significant increase toward citizen science identity or STEM interest. This implementation had a brief, four-day intervention and observed only one phenophase, yet highlights the positive affect that the MobiLAP approach can have on participant attitudes and perceptions toward citizen science and STEM education and careers.

While there were several salient outcomes to the aforementioned research project, this study did not take into account a number of related variables such as how the MobiLAP approach affects conservation and environmental-mindedness and how these attributes may relate to STEM interest. A more in-depth study that addresses these variables, takes place across two phenophases and offers participants multiple observation periods to recognize changes in patterns is needed. The MobiLAP approach, when utilized in a citizen science context, may create citizen science identity and CEmSTEM interest in participants. The formation of such identity and interest may redound to the benefit of local environments, the United States and society as a whole.

SUMMARY

This chapter detailed the current research literature in areas of interest for this study inclusive of: STEM education, mobile learning, authentic practice, citizen science, climate change, phenology and environmental stewardship. The scholarship for these topics includes many areas of overlap and thus, a multidisciplinary and interconnected approach to solving major issues such as climate change awareness and the need for STEM workers and educators is being proposed in this study. The MobiLAP approach has shown the capability of creating citizen science identity and STEM interest in high school students (Wallace & Bodzin, 2017). This study advances a previous iteration of a MobiLAP study in that it takes into account a wider swath of interconnected variables, creates a new focus in the STEM fields (CEmSTEM) and seeks to contribute potential solutions toward solving two of the Unites States' most challenging educational issues.

Chapter three of this dissertation outlines how the MobiLAP approach was utilized to build upon prior research to determine its effect on citizen science identity, STEM interest, CEmSTEM perceptions, climate change awareness and environmental stewardship in participants. This study builds upon a previous iteration of the MobiLAP approach. In addition to investigating citizen science identity, mobile learning and STEM interest, the MobiLAP approach was utilized to understand how it impacts participants in terms of instilling a pro-environmental ethos. This research was conducted over a longer time frame with multiple observations and sought to understand how the MobiLAP approach fosters citizen science identity and creates a newly-defined concentration of STEM (CEmSTEM) interest in participants.

CHAPTER 3: METHODOLOGY

Introduction

There is a significant lack of well-trained American STEM workers and educators. This has created a need that is recognized as a consensus among government, business and educational sectors (Cook, 2015; National Science Board, 2007; PCAST, 2010). Creating the next generation of STEM workers and educators is of vital importance as pressing issues such as climate change need to be addressed. However, the majority of high school students in the

United States are not prepared for the higher-level math and science courses taught in higher education (Raines, 2012). This lack of preparedness coupled with a pronounced underrepresentation of female, Black and Hispanic populations in STEM fields is cause for additional concern (Boscia, 2013; Neuhauser, 2015). Despite the expansive research on STEM interest in education and careers, it is evident that there are still issues that need to be addressed. Likewise, climate change is one of the most discussed and debated subjects, yet consensus appears to be unlikely. There is overlap and parallels between STEM interest and climate change which may provide educators opportunities to explore such interwoven issues. Developing conservation and environmentally-minded STEM interest could potentially provide solutions to both issues. The U.S. educational system must find ways for individuals to develop a pro-environmental ethos that coincides with educational and career interest in STEM fields.

The purpose of this quasi-experimental study was to determine if the use of the MobiLAP approach promotes citizen science identity, STEM interest, conservation and environmentally-minded STEM interest, climate change awareness and environmental stewardship in participants. This research examined the MobiLAP approach across three groups of participants including: a control group with regular classroom activities, a MobiLAP group (with the use of mobile technologies) and an additional treatment group without mobile devices. All groups had pre and post attitudinal surveys following intervention. The study used a heavily quantitative approach, while qualitative data were analyzed to gain context and further insight into participant perceptions, attitudes and beliefs about citizen science identity, CEmSTEM interest, climate change and environmental stewardship. Both treatment groups took part in group-specific, open-ended questionnaires following the intervention.

Although the qualitative data were limited to a 10-item, post-implementation questionnaire, the responses were processed via a splitting technique (Bernard, 2017) which generated a more nuanced analysis. By splitting the data in this manner, the analysis benefited from identifying smaller, codable moments. The limited amount of qualitative data also allowed for a line-by-line coding analysis which further gleaned insights into participant attitudes and perceptions. Descriptive coding interpreted the data and discovered patterns when more than two codes were discovered.

With respect to anonymity, each participant's identifying information has been removed from data files and documentation and pseudonyms are utilized in this writing. A randomized, group-specific identifier has been assigned to each participant as an alias for the purposes of this study. All files related to participant data are digitized and secured in a password-protected, encrypted drive which is stored in a physically locked area.

This chapter highlights the study's research questions, setting, sample, groups, instruments, design, data collection, analysis and will conclude with a limitations and a summary.

Research Questions

This study seeks to understand how the use of MobiLAP approach creates citizen science identity and conservation and environmentally-minded STEM interest in participants in one control and two intervention groups. As such, the study investigates:

1. How does high school student interest in STEM education and careers change after taking part in the MobiLAP approach?
2. How does the MobiLAP approach affect CEmSTEM perceptions in high school students?
3. How do high school students perceive their identity in regard to citizen science after taking part in the MobiLAP approach?

4. How does using the mobile technologies in the MobiLAP approach impact high school student perceptions of mobile learning?
5. How does the MobiLAP approach impact climate change perceptions in high school students?
6. How might the MobiLAP approach change high school students' perceptions of conservation and environmental stewardship?

Research Hypothesis

This study seeks to understand the following hypotheses in relation to the MobiLAP approach and fostering citizen science identity and CEmSTEM interest in high school students:

1. High school students will have an increased interest in STEM after taking part in the MobiLAP process.
    b. Female and racial minority high school students will have an increased interest in STEM after taking part in the MobiLAP process.
2. High school students' attitudes toward (and acceptance of) climate change will significantly change after taking part in the MobiLAP approach.
3. The MobiLAP approach will significantly increase citizen science identity in high school students.
4. High school students' perceptions toward mobile learning will improve after taking part in the MobiLAP approach.
5. The MobiLAP approach will have a positive effect on climate change perceptions in participants.
6. The MobiLAP approach will have a significant impact on high school students' perceptions of conservation and environmental stewardship.

Setting, Population and Sample

This study took place at a small, suburban vocational high school in the Northeastern United States. The school has a free and reduced lunch rate of twenty-one percent. The student demographic breakdown is 58% White, 13% Asian, 11% Black, 2% Multiracial and 16% whom identify as Hispanic. The school is situated on over 80 acres with a variety of plant life and forested areas which makes it an ideal location for observing and collecting information relevant to the study.

The target population for this study was ninth-grade students entering high school in the United States. Students at this age may be best suited for this application depending on curriculum alignment (study sequence of earth science, environmental science and biology) and other factors such as identity formation and plasticity of educational and career choices. Research literature indicates that forming STEM interest in high school is a vital determinant of future STEM education and career interest (Duncan et al., 2007; Maltese, Melki, & Wiebke, 2014; Sadler, Sonnert, Hazari & Tai 2012; van Tuijl & van der Molen, 2016).

A convenience sample of 137 ninth grade students, ages 14-16, was obtained from science classes at the high school. Intact classes were selected to participate in the project with roughly 45 students in each group. There were a total of three groups with one treatment group taking part in the MobiLAP approach ($n = 48$), the other treatment group completed the project without mobile devices ($n = 45$) and a control group which had a "business as usual" classroom experience ($n = 44$).

Treatment and Control

This study builds on a previous iteration of the MobiLAP approach (Wallace & Bodzin, 2017) in that mobile learning and the authentic practice of a citizen science project will be utilized in order to understand participants' attitudes, interests and perceptions of citizen science identity, mobile learning and STEM education and career interest. Additionally, related topics have been added to the previous MobiLAP study including attitudes and perceptions toward CEmSTEM interest, climate change and environmental stewardship. In an effort to better understand the impact of mobile learning, a second treatment group (taking part in the citizen science project without the use of mobile technologies) was added to this study. Other changes included a five week implementation, an enhanced instrument (which takes into account CEmSTEM perceptions, climate change awareness and acceptance and environmental stewardship) and multiple observations in the field instead of a singular phenophase report. All three groups had a two-week climate change unit taught by existing teachers during the time of this project. Participants in the treatment groups observed tree phenophase data in two distinct phenophases which included leaves changing color and leaves falling from trees. By observing the timing of these naturally occurring events and comparing these data to trends, participants may be able to determine the extent of climate change in their local communities.

Both treatment groups observed and reported phenological changes of local tree species to a citizen science project entitled "Project BudBurst". This national research project requests observations of the phases of phenology of various plants and trees across the United States. The purpose is to observe if changes in climate cause plant life to alter their natural patterns. For example, Project BudBurst data can be used to observe trends and relationships associated with warmer temperatures based on plants entering the blooming phase earlier and entering the fall phase later each year. Over time, these data may show trends regarding the impact of climate change on the patterns of plant species and the organisms that depend on them. Each treatment group made a total of two observations over a five week period across the months of October and

November of 2017. The purpose of selecting this time period for observations was due to the possibility of observing two, or perhaps three, phenophases as the leaves being to change color and fall from the trees. Figure 1 shows the stages of tree phenology at the study's observation site during the first observation period which was the second week of October, 2017. Figure 2 displays the stages of tree phenology at the observation site during the second observation during the second week of November, 2017.

Figure 1. Photo collage of observation area during first observation. This image displays the stages of tree phenology at the observation site during the first observation (second week of October, 2017).

Figure 2. Photo collage of observation area during second observation. This image displays the

stages of tree phenology at the observation site during the second observation (second week of November, 2017).

Prior to the start of the project, participants in the MobiLAP group completed the Citizen Science Identity, Mobile Learning and Conservation and Environmentally-minded STEM Interest Survey (CSI-CEmSTEM) (Appendix A). Additionally, the researcher delivered general information regarding the scope of the project via lecture format and facilitated instruction based on the Project BudBurst implementation guide, educational standards and supplemental activities for grades 9-12 (Chicago Botanic Garden, 2017). The MobiLAP group utilized a bring your own device (BYOD) approach with mobile technologies to observe and report data to Project BudBurst. There were 10 iPads available for use in the event participants did not have access to smartphones, but none were utilized. A series of smartphone apps enabled participants to identify tree species, locate the coordinates of the species, photograph the species and submit informational data about the species of plant they are observing. The LeafSnap app (Columbia University, 2011), a free app for iOS, was used to identify trees from the types of leaves participants sampled. This app uses an algorithm similar to facial-recognition software which matches leaves to a tree species. Once a leaf is “snapped”, a series of potential results are provided and users are able to observe additional characteristics (such as photos of bark, fruit, flowers, seeds and descriptive text) to properly identify each tree. Once participants correctly identified trees, they completed an observation report where they identified the date, tree species, location and what stages of phenology the tree was currently in. Figure 3 shows a collection of screenshots from processes in the LeafSnap app.

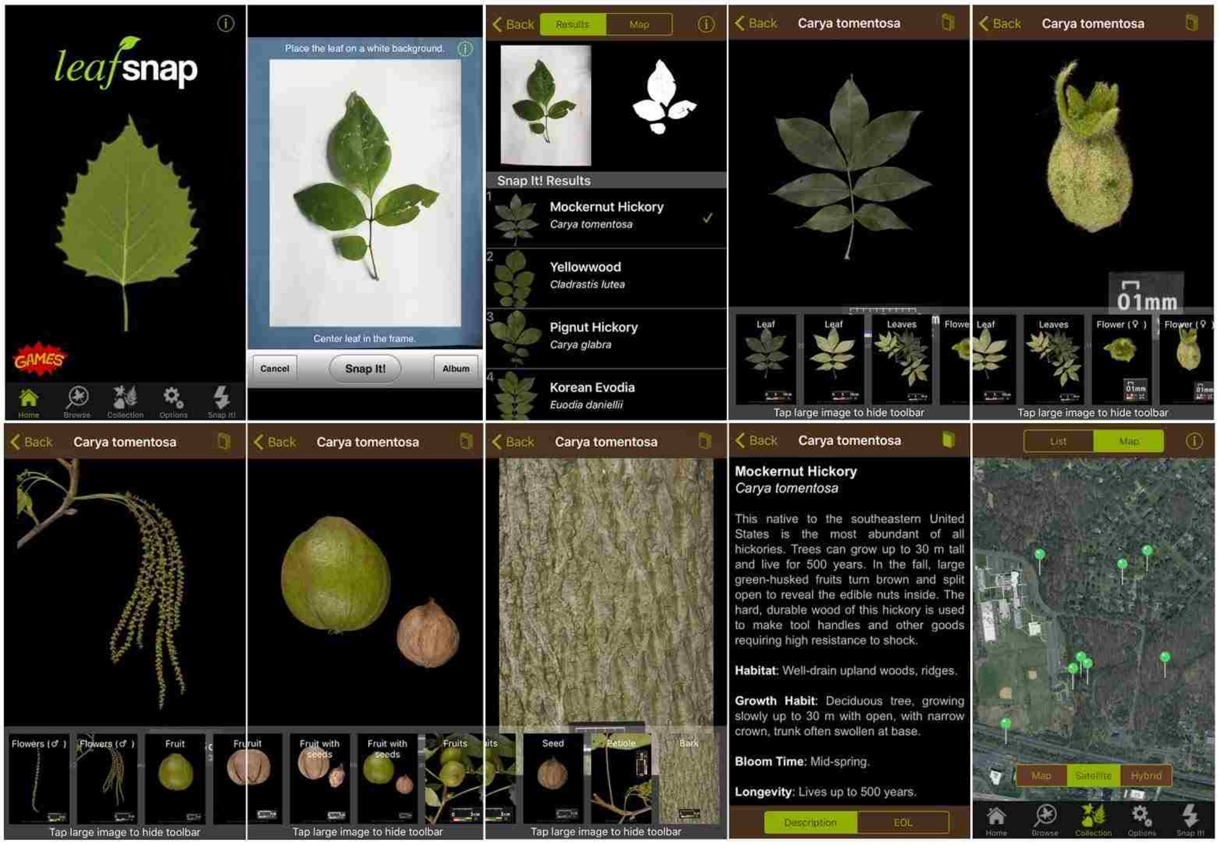

Figure 3. Screenshots from the LeafSnap app. This image shows a series of screenshots and processes a user might experience when using the LeafSnap app for tree identification.

In the previous iteration of the MobiLAP approach, only the LeafSnap app was available for tree identification and it was only for iOS devices. Since then, a number of new tree and plant identification apps have become available for iOS and Android devices. Participants in the MobiLAP group with Android devices made use of the PictureThis app (Dana Technology Inc., 2017), a free app for iOS and Android, which functions similarly to the LeafSnap app. Figure 4 shows screenshots and processes from the PictureThis app. Once the observations were made and data were collected, participants returned to the classroom. While in the classroom, the MobiLAP group submitted their observations to Project BudBurst via the project website. After the data were submitted, the researcher led a recap, reflection and discussion about the project.

MobiLAP participants then completed the CSI-CEmSTEM survey once again along with a 10 item open-ended questionnaire (Appendix B). In addition to this project's activities, the MobiLAP group had a standard two-week climate change curriculum based on global climate change concepts. While the researcher did not directly observe this instruction, teachers confirmed maintaining their respective curricula in order to maximize this study's potential impact.

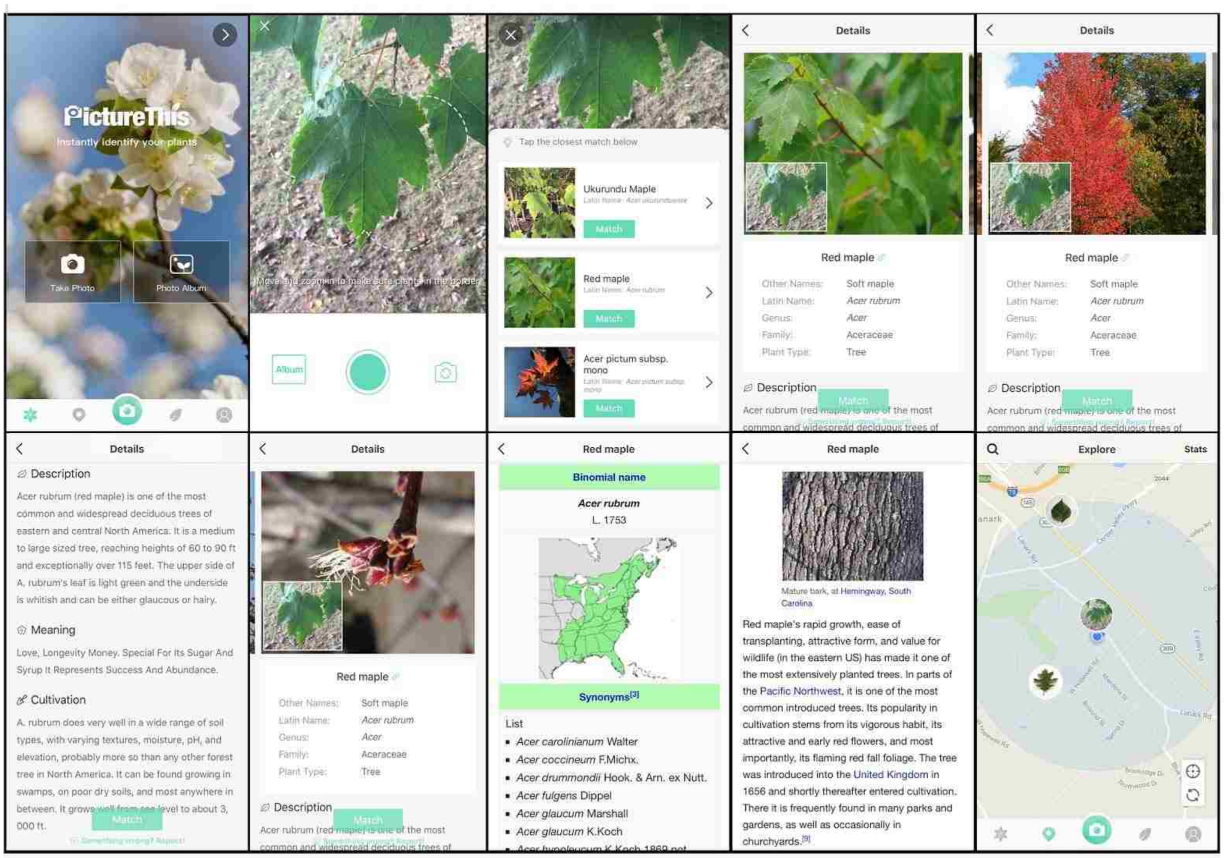

Figure 4. Screenshots from the PictureThis app. This image shows a series of screenshots and processes a user might experience when using the PictureThis app for tree identification.

The Non-mobile Technology (NMT) treatment group completed the CSI-CEmSTEM survey before beginning the intervention. Following the survey, information about the project was provided in a lecture format by the researcher. The researcher facilitated instruction based on the Project BudBurst implementation guide, educational standards and supplemental activities for grades 9-12 (Chicago Botanic Garden, 2017). This group identified trees by using a pocket-sized field guide with dichotomous key (Watts, 1963). Figure 5 shows images from the pocket-sized field guide. After each tree was identified, participants observed and recorded the stages of phenology each tree species was currently in. A paper form, clipboard and pen were used to record their observations while out in the field. Once back in the classroom, they submitted their findings through the Project BudBurst website. A recap, reflection and group discussion took place to discuss the project. In addition to project activities, the NMT group took part in a two-week climate change curriculum where they learned existing curriculum based on global climate change concepts. Following the intervention, participants again completed the CSI-CEmSTEM survey as well as an open-ended questionnaire with 10 items. Figure 6 shows participants in both treatment groups taking part in the project and identifying trees via various methods.

Figure 5. Images of the pocket-sized field guide. This image shows several examples of the field guide the Non-mobile Technology group used to identify trees.

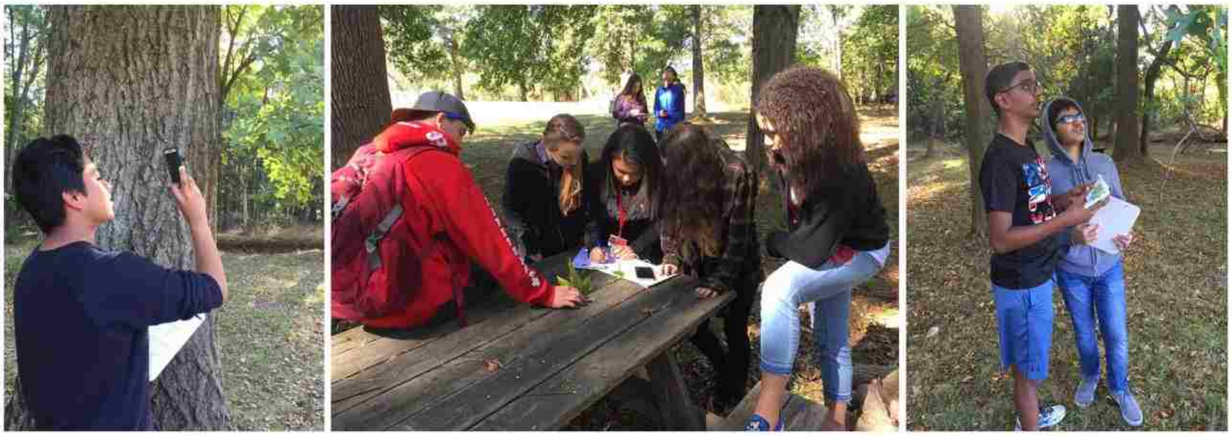

Figure 6. Participants in both treatment groups use various methods to identify trees. This image (L-R) shows participants using the PictureThis app, LeafSnap app and pocket-sized field guide to identify trees.

Prior to the intervention, the control group completed the CSI-CEmSTEM survey. The control group had a “business as usual” classroom experience where they learned about climate change and anthropogenic climate change over a two-week period during the implementation. Teachers ensured that they would not deviate from existing curriculum in order to support the integrity of the study. While not directly observing separate classroom instruction, teachers reported teaching about climate change with global examples and confirmed they did not use local examples or take part in citizen science activities related to climate change. This was a purposeful consideration in an effort to contrast the global (and perhaps abstract) concept of climate change with the treatment groups’ local and hands-on learning about climate change (through citizen science). Classroom activities included lectures, videos, presentations, “do-nows” or other “warm up” activities and projects. Topics of study and projects included: understanding science and technology as it related to ethics and morals, predicting global energy consumption project, using a computer simulation to see how the ocean, atmosphere and biosphere are affected by human activities, and theorizing a solution to benefit climate change activity. Attention was paid to the significant work scientists and engineers can do to develop technologies that reduce the level of pollutants and ultimately aid in environmental conservation and sustainability. Students were also given research and presentation assignments based around climate change on a global scale such as reporting on habitat loss for animals such as polar bears in the Arctic and conducting computer simulations of global warming. Following the five week intervention, the control group participants once again completed the CSI-CEmSTEM survey.

All three groups completed the pre and post-intervention survey CSI-CEmSTEM (Appendix A). The MobiLAP group took part in an open-ended, group-specific questionnaire following the intervention (Appendix B). The NMT group also completed an open-ended, group-specific questionnaire after the intervention (Appendix C). Prior to the intervention, all participants completed a brief demographic survey which captured data such as age, race and gender.

Instruments

The Scientific Citizenship, STEM Interest and Mobile Learning (SCI-ML) Survey (Wallace & Bodzin, 2017) was modified to include additional items related to climate change, conservation and environmentally-minded STEM interest and environmental stewardship. The original SCI-ML instrument has four subscales and a total of 41 items with good internal consistency as determined by a Cronbach's alpha (Cronbach, 1951) of 0.850 for the entire instrument. Possible scores for this 41 item instrument range from 41 to 205. A further breakdown of the subscales also displayed good internal consistency as Cronbach's alpha for each of the four subscales was between 0.784 and 0.912. The instrument's validity was established through the testing and recommendations of two independent experts in the fields of environmental science and education. Additionally, a student in the target population took part in testing the instrument and providing feedback on language and layout choices.

Due to the significant changes to the SCI-ML instrument, a rebranding needed to take place and the new survey is named the Citizen Science Identity, Mobile Learning and Conservation and Environmentally-minded STEM Interest Survey (CSI-CEmSTEM) (Appendix A). Several subsections and items from SCI-ML have been refined to better fit this study. Two of the subscales from the original SCI-ML instrument were derived from the Student Interest in Technology and Science (SITS) Survey (Romine, Sadler, Presley, & Klosterman, 2014). These subscales include *Ideas about learning* and *Ideas about careers* and were modified to capture more relevant information. The CSI-CEmSTEM instrument consists of six subsections and 66 items.

The first subsection consists of 18 items related to ideas about STEM interest in education and careers; select items include *I enjoy using technology to learn science*, *I would like to become a scientist* and *I will probably choose a job that involves using technology*. All items in this section were derived from the SCI-ML instrument (Wallace & Bodzin, 2017) and had good internal consistency of 0.912. The items in this subsection have established validity through a thorough examination by two education and environmental science faculty who are experts in their respective fields.

The second subsection consists of 10 items related to ideas about CEmSTEM interest; select items include *STEM innovations are important even if they harm the planet*, *I am interested in a STEM career that will help the environment* and *STEM careers are interesting because they have the potential to positively impact the environmental problems in our world.* Since CEmSTEM is a newly defined concept, there are no current attitudinal measurements in the literature. As such, items 19-25 were created specifically for this study. Validity for these items was established by two faculty in education and environmental sciences. Items 26-28 in this subsection were derived from the STEM Career Interest Survey (STEM-CIS) (Kier, Blanchard, Osborne & Albert, 2014). Items were selected for use based on relevance to the MobiLAP study. These three items were slightly modified to include an environmental component.

The third subsection consists of 13 items related to ideas about citizen science; select items include *Citizen Science helps me understand climate change*, *I am a Citizen Scientist* and *Citizen Science makes science seem more real*. Each item in this subsection is taken from the SCI-ML instrument (Wallace & Bodzin, 2017) and had good internal consistency of 0.892 in the first iteration the MobiLAP study. All items were validated by two education and environmental science faculty.

The fourth subsection consists of 10 items related to ideas about mobile learning; select items include *Using my smartphone/mobile device helps me learn*, *I use my smartphone/mobile device for schoolwork* and *My smartphone/mobile device helps me understand the world around me*. This subsection has been adapted from the SCI-ML (Wallace & Bodzin, 2017) with minor wording changes to include "smartphone". In the previous MobiLAP study, this subsection had a good internal consistency of 0.912. Two faculty members in education and environmental sciences validated the subsection.

The fifth subsection consists of seven items related to ideas about climate change; select items include *Climate change is caused mostly by human activities*, *Climate change is caused mostly by natural changes in the environment* and *I am concerned about climate change*.. Items 52-55 have been modified from the Climate Stewardship Survey (CSS) (Walker & McNeal,

2013) and were selected based on relevance to this study. Validity for the CSS was established through a panel of experts as well as through pilot testing. Items 56-58 were adapted from the American Teens' Knowledge of Climate Change survey (Leiserowitz, Smith & Marlon, 2011). This survey was conducted by the Yale Project on Climate Change Communication and was part of a national study on climate change understandings and perceptions in teenagers in the United States.

The sixth subsection consists of eight items related to ideas about environmental stewardship; select items include *Environmental protection starts with me*, *Engaging in environmental behaviors is important to me* and *If I had enough time or money, I would certainly devote some of it to working for environmental causes.* Items 59 and 60 are derived from the Perceived Environmental Responsibility scale (PER) and were selected for use based on relevance to this study (Paço & Gouveia Rodrigues, 2016). Items 61-66 are taken from the Environmental Identity (EID) scale (Clayton, 2003). The items used from the EID survey were selected for use based upon their relevance to the environmental stewardship aspects of the study.

Cronbach's alpha (Cronbach, 1951) was employed to determine internal consistency of the CSI-CEmSTEM instrument. Along with the entire instrument, each subscale was analyzed to determine if any negatively correlated items exist in either pre or post survey items. Results of the analysis indicate a high level of internal consistency for the entire instrument with a pre-survey Cronbach's alpha of 0.941 and a post-survey Cronbach's alpha of 0.971. Additionally, the Cronbach's alpha for all six subscales was between 0.714 and 0.951. Originally, the climate change perceptions subscale had a low level of internal consistency with pre-survey Cronbach's alpha of 0.478 and a post-survey Cronbach's alpha of 0.679. The instrument was optimized by removing five negatively correlated items in the climate change subscale and this resulted in a high level of internal consistency with Cronbach's alphas of 0.714 (pre) and 0.873 (post). Table 1 displays Cronbach's alpha for the entire CSI-CEmSTEM instrument as well as each subscale. A correlation table (Table 2) shows that each of the subscales had a positive correlation with each other.

Table 1

Internal consistency (Cronbach's alpha) of CSI-CEmSTEM instrument by subscale

Scale/Subscale	Pre-survey alpha (n=137)	Post-survey alpha (n=137)
Entire Instrument (66 items)	0.947	0.971
STEM interest (18 items)	0.910	0.924
CEmSTEM perceptions (10 items)	0.769	0.832
Ideas about Citizen Science (13 items)	0.905	0.951
Ideas about Mobile Learning (10 items)	0.876	0.934
Climate Change Perceptions (7 items)	0.714	0.873
Environmental Stewardship (8 items)	0.881	0.909

Table 2

Pearson correlations for main study variables

	STEM interest	CEmSTEM perceptions	Ideas about citizen science	Ideas about mobile learning	Climate change perceptions	Environmental stewardship
STEM interest	1	.694**	.741**	.422**	.535**	.663**
CEmSTEM perceptions	.694**	1	.819**	.448**	.548**	.776**
Ideas about citizen science	.741**	.819**	1	.407**	.622**	.787**
Ideas about mobile learning	.422**	.448**	.407**	1	.401**	.373**
Climate change perceptions	.535**	.548**	.622**	.401**	1	.653**
Environmental stewardship	.663**	.776**	.787**	.373**	.653**	1

** Correlation is significant at the 0.01 level (2-tailed)

A group-specific, open-ended questionnaire was distributed to both treatment groups following the intervention. While the questionnaires are similar, there are a few minor differences related to mobile learning. The MobiLAP group completed a 10 question survey (Appendix B) related to citizen science identity, mobile learning, CEmSTEM interest, climate change and environmental stewardship. Several items relate specifically to the use of mobile technologies in the citizen science project. The NMT treatment group also completed a 10 question survey (Appendix C) which relates to citizen science identity, mobile learning, CEmSTEM interest, climate change and environmental stewardship. The NMT survey had several items related to completing the project without the use of mobile technologies. This open-ended format provided further insight into participants' attitudes, beliefs and perceptions related to the aforementioned topics. Select items from the open-ended survey include *How might this experience change your future career path, course of study or interest in STEM, How* *important is it to consider the environment when creating STEM innovations* and *How have your feelings toward climate change been effected by this process?*

Data Collection and Analysis

This study relies heavily on quantitative data and utilized an open-ended qualitative component for context, corroboration (or conflict) and further insight into participants' attitudes, perceptions and beliefs. Even though the study makes use of a newly-created instrument and places more importance on the quantitative responses, the analysis sought to utilize a parallel analysis where the findings of both qualitative and quantitative data were equally important. Both quantitative and qualitative survey responses were collected through Qualtrics web-based service. In regard to privacy, each participant was assigned an identifier to ensure anonymity throughout the study.

An initial round of a priori coding occurred (see Appendix D) based on the results from the literature review. Following the initial round of coding, additional coding methods were utilized to revise codes for emerging categories and themes. Due to the epistemological nature of this study's research questions, Saldaña (2015) suggests several coding methods which will discover the most important concepts from participant responses. Of the coding methods recommended, a simultaneous, line-by-line and split-coding technique was used for first cycle coding and employed several coding methods such as in vivo and thematic analysis in order to discover patterns in the dataset (Denzin & Lincoln, 2011). Participant responses were coded to nodes in NVivo V 11 software and further analyzed as outlined below. Codes shared by at least one quarter of respondents warranted consideration for further analysis (Harding, 2013) with many becoming major themes. When possible, open-ended items were quantitized in order to add to quantitative findings. Analytical memos were recorded after each analytical phase.

The second cycle coding utilized a pattern coding technique to understand relationships and further develop themes. Emergent themes were examined for insight into participants' beliefs, attitudes and perceptions of citizen science identity, mobile learning, CEmSTEM perceptions, climate change perception and environmental stewardship. These themes lead to theoretical assumptions and assertions by the researcher. A member check with 10-12 participants in each treatment groups took place to verify open-ended responses. This process consisted of the researcher reading several open-ended responses to each group of participants and asking if the responses represented their thoughts on each item. In addition, a peer-debriefing took place in order to ensure reliability and validity. A complete listing of revised codes with member check can be found in Appendix E.

Quantitative data were processed with IBM SPSS V 20 software. A two by three mixed analysis of variance with repeated-measures (pre-post) and between groups was employed to process the data. Additionally, posttest mean differences across the three groups were compared by using an analysis of covariance which controlled for pretest performance. Finally, a multiple regression analysis was utilized to understand variables such as race and gender among the three groups.

Limitations of Study

This proposed study has several limitations. Having three groups of participants will provide better understanding of the impact that mobile devices have on the study, however, the addition of a third group decreases the number of each group to approximately 45 individuals. Having only 45 participants per group threatens the validity of the study by diminishing the number of participants per group. Additionally, obtaining participants via convenience sampling methods may negatively impact the generalizability of the outcomes across the target population.

While this study had two observation/collection periods over several phenophases in a five week period, participants did not have a steady immersion into the phenology and citizen science-related material as this project implementation was a curriculum enhancement. While the project was in alignment with the regular course of study on climate, the project's intermittent focus on the study's topics may not have the impact necessary to form citizen science identity and shape CEmSTEM perceptions in participants. The additional time allotted for this project took teachers and students away from rigid curricula which, in many cases, has been mandated by the state.

The limited amount of qualitative data obtained in this study does not qualify it as a true mixed methods study. Due to the number of items in the quantitative instrument, the researcher limited the open-ended items to 10. Survey fatigue was a consideration and therefore, only a few additional questions were added. Even with the large number of items, most respondents did provide substantive open-ended responses. However, this study could have benefitted from other types of qualitative data such as interviews, observations and focus groups.

Summary

Ninth-grade students in high school serve as the primary target population for this study. The sample is 137 ninth-grade students in a vocational high school in the Northeastern United States. Participants consisted of three groups including: a control group (n = 44) with a "business as usual" classroom experience, a Non-mobile Technology treatment group without mobile devices (n = 45) and a treatment group (n = 48) with mobile devices (MobiLAP group). Each group completed a pre and post intervention attitudinal survey through the use of Qualtrics. The intervention groups also completed a group-specific, open-ended survey following the intervention. Quantitative data were processed via IBM SPSS V 20 while the qualitative data were coded to nodes, analyzed and themed in NVivo V 11 software.

CHAPTER 4: RESULTS

The aim of this study was to understand how mobile learning and the authentic practice of a citizen science project impacts citizen science identity, STEM interest, CEmSTEM interest, mobile learning perceptions, climate change awareness and environmental stewardship in ninth-grade students. A 66 item instrument was created and implemented at pre and post intervention time points to address these questions. A 10 item open-ended questionnaire was created and delivered to both treatment groups following intervention. Quantitative data were collected via Qualtrics and analyzed with IBM SPSS. The qualitative results were collected via Qualtrics and processed through NVivo 11 where codes were identified and coded to nodes in the software. As a result, several themes emerged related to research questions from each of the treatment groups.

Description of the Population

A total of 137 ninth-grade science learners agreed to participate in the study and were able to finish the project and assessments. The demographic breakdown consisted of 61 males, 73 females and three individuals that chose "Other/not sure/I'd rather not say" for gender designation. A total of 55 participants identified as White, 14 identified as Black, 11 identified as Asian, 10 identified as Hispanic/Latino, four identified as Native Hawaiian/Pacific Islander, 12 participants selected more than one race or ethnicity, while 31 identified as "Some other Race/Ethnicity". The average age of the participants was 14 years. Each participant personally signed an informed consent form and had their parent or guardian sign a separate informed consent form. There were several students that were absent for one or more project activity or dropped out of the study by not completing assessments or participating in activities. All 137 participants completed the CSI-CEmSTEM instrument before and after the project was implemented. Both treatment groups completed the 10 item open-ended questionnaire following implementation, however, not every item was completed by all participants.

The control group (*n* = 44) means for the entire instrument were 216.43 (pre) and 211.55 (post) with standard deviations of 27.80 and 34.28 respectively. The NMT group (*n* = 45) means were 220.89 (pre) and 239.22 (post) with standard deviations of 24.82 and 41.11. The MobiLAP group (*n* = 48) means were 217.46 (pre) and 233.71 (post) with standard deviations of 33.86 and 26.91. The means and standard deviations for each subscale of the instrument are listed in Table 3. A complete listing of means and standard deviations for each of the 66 items in the CSI-CEmSTEM instrument is located in Appendix F. Additionally, Table 4 provides effect sizes (Cohen's *d*) for the entire instrument as well as each subscale according to treatment group.

Table 3

Means and Standard Deviations of the pre and posttest scores for the entire CSI-CEmSTEM instrument and its subscales by the type of intervention.

Scale of Measurement	Control Group Mean (SD)		Non-mobile Technology Group Mean (SD)		MobiLAP Group Mean (SD)	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Entire Instrument	216.43 (27.80)	211.55 (34.28)	220.89 (24.82)	239.22 (41.11)	217.46 (33.86)	233.71 (26.91)
Section 1: STEM interest (18 items)	58.63 (9.74)	55.84 (11.68)	57.84 (12.56)	61.68 (14.48)	57.43 (12.74)	61.14 (10.21)
Section 2: CEmSTEM perceptions (10 items)	30.90 (5.93)	29.84 (6.02)	30.68 (3.15)	33.95 (5.39)	29.95 (5.56)	32.62 (5.24)

Section 3: Ideas about citizen science (13 items)	39.84 (6.89)	39.18 (8.51)	40.20 (6.51)	47.64 (9.53)	40.06 (8.74)	46.89 (6.07)
Section 4: Ideas about mobile learning (10 items)	36.65 (6.65)	36.02 (8.53)	39.66 (5.98)	39.53 (7.66)	39.00 (6.86)	38.91 (6.38)
Section 5: Ideas about climate change (7 items)	25.18 (4.28)	25.34 (4.06)	26.09 (2.95)	27.93 (5.06)	25.60 (4.59)	26.71 (3.99)
Section 6: Ideas about environmental stewardship (8 items)	25.20 (4.98)	25.31 (4.52)	26.40 (3.68)	28.46 (5.69)	25.39 (5.82)	27.41 (4.10)

Table 4

Effect sizes (Cohen's d) for the entire CSI-CEmSTEM instrument and its subscales by treatment group.

Scale of Measurement	Non-mobile Technology Group	MobiLAP Group
	d	*d*
Entire Instrument	0.73	0.71
Section 1: STEM interest (18 items)	0.44	0.48
Section 2: CEmSTEM perceptions (10 items)	0.72	0.49
Section 3: Ideas about citizen science (13 items)	0.94	1.04
Section 4: Ideas about mobile learning (10 items)	0.43	0.38
Section 5: Ideas about climate change (7 items)	0.56	0.34

Section 6: Ideas about environmental stewardship (8 items)	0.61	0.49

Note: Effect sizes (Cohen's *d*) of 0.2 are considered small, 0.5 are considered medium and 0.8 or greater are considered large effect sizes (Cohen, 1988).

A 2x3 mixed ANOVA analysis was performed for the analysis of the entire instrument with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was a significant main effect of time [F (1, 134) = 17.768, $p < .001$, partial eta^2 = .117], group [F (2, 134) = 3.683, $p = .028$, partial eta^2 =.052] and interaction between the different time periods and the type of group [F (2, 134) = 9.773, $p < .001$, partial eta^2 = .127].

Further analysis using analysis of covariance of the posttest mean differences for the entire CSI-CEmSTEM instrument across the three groups controlling for pretest performance revealed that there was a statistically significant difference on the posttest scores between the groups when adjusted for the pretest performance [F (2, 133) = 4.017, $p < .020$, partial eta^2 = .058]. The pairwise comparison showed that for the overall score, the NMT group has a statistically higher score than the control group with a mean difference of 24.257 [$p < .001$]. Also, the MobiLAP group has a statistically higher mean score than the control group, exceeding it by 20.831 [$p = .001$]. The mean difference between the scores of the MobiLAP and NMT groups was insignificant [p = 1.000].

RQ1: STEM Interest

The first research question was: How does high school student interest in STEM education and careers change after taking part in the MobiLAP approach? This research question was broken down into three separate categories inclusive of STEM education, STEM careers and general STEM interest. This study also hoped to understand how STEM interest may have changed in traditionally underrepresented groups in STEM (such as females, Black Americans and Hispanic/Latinos). The CSI-CEmSTEM instrument includes an 18 item subsection which focuses on STEM interest and the group-specific, open-ended questionnaire that included four items which directly relate to STEM interest.

A 2x3 mixed ANOVA analysis was performed for the STEM interest subscale with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was a main effect of time [F (1, 134) = 5.239, p = .024, partial eta^2 = .038] and no statistically significant main effect was determined for the type of group [F (2, 134) = 0.629, p = .535, partial eta^2 = .009]. However, there was a significant interaction between the different time periods and the type of group where the student belongs to [F (1, 134) = 9.819, p < .001, partial eta^2 = .128].

Further analysis using analysis of covariance of the posttest mean differences across the three groups controlled for pretest performance revealed that there was a statistically significant difference on the posttest scores on the STEM interest subscale between the groups when adjusted for the pretest performance [F (2, 133) = 10, p < .001, partial eta^2 = .131]. Pairwise comparison shows that the NMT group had a statistically higher score than the control group with a mean difference of 6.482 [p < .001]. Additionally, the MobiLAP group had a statistically higher score than the control group with a mean difference of 6.264 [p < .001]. The mean difference between the scores of the MobiLAP and NMT groups was not significant [p = 1.000]. Mean comparisons for the STEM interest subsection can found in Table 3.

A multiple regression analysis was utilized to understand the effect of race and gender on each subsection as well as the entire instrument. The analysis showed that only the STEM interest subscale was significant. The remaining subscale analysis along with the entire instrument analysis was found to be non-significant. The regression equation representing the STEM interest subscale is:

STEM interest score = 61.813 + 1.665 (underrepresented race/ethnicity) – 4.776 (female)

This equation shows that belonging to typically underrepresented races or ethnicities in STEM fields (inclusive of Black and Hispanic populations) increases STEM score by 1.665 on average after taking part in the project. Contrarily, another underrepresented population in STEM fields (females) have lower STEM interest score by 4.776 on average. Regression coefficients and standard errors can be found in Table 5.

Table 5

Summary of Multiple Regression Analysis for Underrepresented Groups in STEM

Variable	B	SE_B	β
Intercept	61.813	1.644	
Race/ethnicity	1.665	2.563	.055
Female	-4.776	2.099	-.193

Note. *$p < .05$; B = unstandardized coefficient; *SE_B = Standard error of the coefficient; β = standardized coefficient*

RQ1: Qualitative Results

The qualitative data resulted in the emergence of following theme: Citizen science and the use of mobile technologies in citizen science projects generate interest in STEM. A list of codes, code definitions and examples related to this theme can be found in Table 6. The open-ended survey questions which yielded data supporting this theme and addressing the first research question were: (1) How might using mobile technologies to gather environmental data change your future career path, course of study or interest in STEM? (2) How important is it to consider the environment when creating STEM innovations? (3) How has this project influenced how you think about citizen science? (4) Did using your smartphone for this project make you more interested in any STEM fields? If so, how? (5) Would using your smartphone for this project make you more interested in any STEM fields? If so, how? Student responses were generally limited to one or two sentences, but provided insight into their feelings toward STEM after taking part in this project. A member check with 10 to 12 students from each treatment group was conducted on the data to ensure accuracy. Additionally, peer-debriefing took place to ensure validity and reliability.

Participants responded with statements that conveyed an increased general interest in STEM. Often, they pointed to citizen science or "the project" as having a direct correlation to their enhanced interest due to increased understandings of climate change. Jack stated "Taking part in this citizen science project advanced my interest in STEM, since it helped me to understand the natural world and the effect of climate change on it." Additionally, students that took part in the study may not have previously had local outdoor learning experiences where they interact with and observe nature for the purpose of solving real-world issues. Taking part in this citizen science project provided them with opportunities that they may have thought were unattainable in high school. Hugo responded that "this definitely changed my interest in STEM, because this project helped me interact with citizen science and environmental problems that I thought were beyond me in school."

Several participants such as Claire noted an enhanced interest in a specific STEM subject area (science education). "I feel that taking part in this citizen science project will persuade me to take it one step further and maybe take a science course or something similar to learn more about climate change and nature." John, another participant, expressed a desire to further their learning in science as well as potentially looking into a science-focused career. "This project gave me more insight into what scientists do. I may pursue more advanced scientific jobs or studies in my future."

Participants reported having increased interest in STEM related careers after taking part in this citizen science project. Penny stated "This Citizen Science Project is making me more likely to take a STEM related career as I now better see how making better tools and innovation can lead to scientific observation." Often, they associated outdoor activities and interaction with plant life as key reasons for an increased interest in STEM careers such as in the following example from Ricardo:

> Being outside and studying the leaves has definitely increased my interest in stem, especially the science aspect of it. I did not know that research is so specific, like knowing the rate at which the leaves unfold. I think this could somewhat change my future career plan.

The primary difference between the MobiLAP group and the NMT group was that the MobiLAP group was permitted to use smartphones for the project and the NMT group was not permitted. As such, the questionnaires were identical except for the mobile technology-related questions. Both treatment groups reported that using smartphones for the project had (or would have) generated interest in STEM. For example, Charlie, a participant in the MobiLAP group stated: "Mobile technologies are going to make STEM more interesting because it's a hands on thing for kids and adults to do." Similarly, the NMT group perceived that the use of smartphones would have resulted in an increased interest in STEM. Libby stated "Using my smartphone would have made me more interested in any STEM fields because I would have been using technology. I may have become more interested in the way that it works while using it."

Table 6

Codes, definitions, and examples for the theme Citizen science and the use of mobile technologies in citizen science projects generate interest in STEM.

Code	Definition	Examples
STEM Interest	Participants respond with affirmations of interest in STEM or science	1. "Citizen science has made me consider different careers. Also, it has made me consider a different course of study. IT has increased my interest in STEM and how it could help the environment." 2. "Taking part in this citizen science project advanced my interest in STEM, since it helped me to understand the natural world and the effect of climate change on it." 3. "This definitely changed my interest in STEM, because this project helped me interact with citizen science and environmental problems that I thought were beyond me in school."
STEM Career	Participants respond with positive feelings related to careers in STEM	1. "This Citizen Science Project is making me more likely to take a STEM related career as I now better see how making better tools and innovation can lead to scientific observation." 2. "Being outside and studying the leaves has definitely increased my interest in stem, especially the science aspect of it. I did not know that research is so specific, like knowing the rate at which the leaves unfold. I think this could somewhat change my future career plan." 3. "It gave me another career path to look into. STEM is a very flexible science meaning as there is a lot you can do in going in STEM."
Science Interest	Participants specifically point to having an increased interest in Science.	1. "This project gave me more insight into what scientists do. I may pursue more advanced scientific jobs or studies in my future." 2. "I feel that taking part in this citizen science project will persuade me to take it one step further and maybe take a science course or something similar to learn more about climate change and nature." 3. "Taking part in this can help making science more interesting"
Mobile	Participants point to	1. "Using technology to gather data may make you

Generates STEM Interest	the use of mobile technologies as a contributing factor in generating STEM interest.	have a stronger connection to the subject. Using technology like phones may make you more interested in STEM since it's a daily item you use and can relate it to the subject." 2. "Naturally using my smartphone would have made the project easier so it's more likely that with the positive opinion towards citizen science projects using a smartphone would have generated, I would have been more likely to be interested in STEM fields." 3. "Using my smartphone would have made me more interested in any STEM fields because I would have been using technology. I may have become more interested in the way that it works while using it."

The qualitative findings reveal that participants in the both the NMT and MobiLAP groups generated interest in stem education and careers following intervention. Participants responded to open-ended questions with affirmations of interest in general STEM or science. Codes related to general STEM interest totaled 32 in the MobiLAP group and 28 in the NMT group. Many participants made statements with positive feelings toward STEM careers. There were 19 instances of data coded in the "STEM Career" category for the MobiLAP group and 16 instances in the NMT group. Some participants responded with specific interest toward science. The "Science Interest" code had 12 occurrences in the MobiLAP group and 15 in the NMT responses. The final code related to STEM interest is "Mobile Generates STEM Interest". This code consists of 13 instances (in each treatment group) where participants point to the use of mobile technologies as a contributing factor in creating STEM interest.

RQ2: CEmSTEM Perceptions

The second research question was: How does the MobiLAP approach affect CEmSTEM perceptions in high school students? Since CEmSTEM is a newly-defined subsection of STEM, the items related to this research question were framed in a way that required respondents to consider positive and negative environmental impact when thinking about STEM. The CSI-CEmSTEM instrument has one subsection with 10 items specifically geared toward CEmSTEM perceptions and the open-ended questionnaire has several items related to CEmSTEM.

A 2x3 mixed ANOVA analysis was performed for the CEmSTEM perceptions subscale with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was a main effect of time [F (1, 134) = 16.354, $p < .001$, partial eta^2 = .109] and no statistically significant main effect was determined for the type of group [F (2, 134) = 1.866, $p = .159$, partial eta^2 =.027]. However, there was a significant interaction between the different time periods and the type of group where the student belongs to [F (2, 134) = 11.187, $p < .001$, partial eta^2 = .143].

Further analysis using analysis of covariance of the posttest mean differences across the three groups controlled for pretest performance revealed that there was a statistically significant difference on the post test scores on the CEmSTEM perceptions subscale between the groups when adjusted for the pretest performance [F (2, 133) = 11.669, $p < .001$, partial eta^2 = .149]. Pairwise comparison shows that the NMT group had a statistically higher score than the control group with a mean difference of 4.263 [$p < .001$]. Also, the MobiLAP group had a statistically higher score than the control group with a mean difference of 3.425 [$p = .001$]. The mean difference between the scores of the MobiLAP and NMT groups was not significant [p = 1.000]. Complete means for the CEmSTEM subsection are located in Table 3.

RQ2: Qualitative Results

Analysis of the qualitative data resulted in the following theme which addresses research question two: The conservation and environmentally-minded aspects of and relationship to

STEM are very important. A list of codes, code definitions and examples related to this theme can be found in Table 7. The open-ended survey items that correspond to this research question include: (1) How important is it to consider the environment when creating STEM innovations? (2) How have your feelings toward climate change been effected by taking part in this citizen science project? (3) How has this project influenced how you think about citizen science? (4) How has this citizen science project changed the way you think about humankind's impact on climate change? (5) How has taking part in this project impacted your thoughts on caring for the environment? The majority of participants responded to the questions with at least one or two sentences. Ten to 12 students from each treatment group took part in a member check on the data to ensure accuracy. In addition, peer-debriefing took place to ensure validity and reliability.

One of the primary open-ended questions related to research question two (How important is it to consider the environment when creating STEM innovations?) resulted in a high response rate with 35 responses from the MobiLAP group. Of those, 29 participants stated that is was “important” or “very important” to consider the environment when creating STEM innovations. Similarly, 37 participants from the NMT group responded to this question with 31 of them stating that it is “important” or “very important” to consider the environment when creating STEM innovations. In total, 83.33% of all participants that answered the questions felt as though it is important or very important to consider the environment when creating STEM innovations. Danielle conveyed this succinctly by stating:

> It is very important to consider the environment when creating STEM innovations because if you’re making changes but they are harming our planet, what is that point? Science, technology, engineering and math should all work to fix our planet, not harm it further.

Another sentiment related to the conservation and environmentally-minded aspects of STEM was that STEM innovations have the capability of helping (and not harming) the environment. Christian provided evidence supporting this thought: "It is important, because if we make innovations that will harm the environment in any way, obviously the environment will be harmed. We can create STEM innovations that can benefit the environment." Students were able to point to specific STEM innovations as a means by which the environment could be helped. For instance, Benjamin stated "STEM could help make things better like switching to electric cars" while Miles remarked "STEM innovations can find better fuel alternatives or how we can use less fossil fuels" and Charlotte commented that STEM innovations can be used "to create and build things that can reduce the fossil fuel emission like using wind power, hydraulic power, etc."

Table 7

Codes, definitions, and examples for the theme The conservation and environmentally-minded aspects of and relationship to STEM are very important.

Code	Definition	Examples
CEmSTEM Perceptions	Participants note an understanding of the relationship between STEM and the environment.	1. "It is very important, because some of the most pressing issues in our nation and world are climate change and pollution, so we should make extra effort to not contribute to those problems, but instead create STEM innovations that help the environment." 2. "It is very important to consider the environment when creating STEM innovations because if you're making changes but they are harming our planet, what is that point? Science, technology, engineering and math should all work to fix our planet, not harm it further." 3. "Sometimes, STEM innovations can be very beneficial for human development and technological advances. However, in some cases,

	these innovations could greatly harm the environment. When creating STEM innovations, it's important to consider the environment because it's something very precious and if harmed, can pose great effects."

The qualitative findings reveal that participants in both treatment groups positively changed CEmSTEM perceptions following intervention. One of the most salient takeaways from the data, is that when participants were asked how important it is to consider the environment when creating STEM innovations, over 80% said that it was "important" or "very important". Participants indicated the important relationship between STEM and the environment which resulted in the "CEmSTEM Perceptions" code. There were 37 MobiLAP responses and 41 NMT responses related to this code.

RQ3: Citizen Science Identity

The third question for this study was: How do high school students perceive their identity in regard to citizen science after taking part in the MobiLAP approach? Citizen science identity was measured via quantitative responses from a 13 item subsection of the CSI-CEmSTEM instrument and from several open-ended items in the post-implementation questionnaire.

A 2x3 mixed ANOVA analysis was performed for the citizen science identity subscale with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was a main effect of time [F (1, 134) = 56.747, $p <$ .001, partial eta^2 = .297] as well as for the type of group [F (2, 134) = 5.423, p = .005, partial eta^2 =.075]. There was also significant interaction between the different time periods and the type of group where the student belongs to [F (2, 134) = 18.319, $p <$ .001, partial eta^2 = .215].

Further analysis using analysis of covariance of the posttest mean differences across the three groups controlled for pretest performance revealed that there was a statistically significant difference on the post test scores on the citizen science identity subscale between the groups when adjusted for the pretest performance [F (2, 133) = 934.468, p < .001, partial eta^2 = .246]. Pairwise comparison shows that the NMT group had a statistically higher score than the control group with a mean difference of 8.231 [p < .001]. The MobiLAP group also had a statistically higher score than the control group with a mean difference of 7.571 [p < .001]. The mean difference between the scores of the MobiLAP and NMT groups was not significant [p = 1.000]. Means for the citizen science identity subscale for each group are listed in Table 3.

RQ3: Qualitative Results

The qualitative data resulted in the following emerging theme which relates to research question three: Authentic citizen science practices provide interesting, real-world, collaborative and enjoyable experiences that foster citizen science identity. A list of codes, code definitions and examples related to this theme can be found in Table 8. The open-ended survey items that correspond to this research question include: (1) How have your feelings toward climate change been effected by taking part in this citizen science project? (2) How has this project influenced how you think about citizen science? (3) How has this citizen science project changed the way you think about humankind's impact on climate change? (4) How has taking part in this project impacted your thoughts on caring for the environment? (5) Did using your smartphone for this project make you feel like a citizen scientist? If so, how? (6) Would using your smartphone for this project make you feel like a citizen scientist? If so, how? The majority of participants responded to the questions with at least one or two sentences. Several students (10-12) from both the MobiLAP and the NMT group took part in a member check to ensure accuracy. A peer-debriefing session also took place to ensure reliability and validity.

The majority of participants had not heard about citizen science prior to this study. After taking part in an authentic citizen science project that addresses real-world issues such as climate change, they were able to describe several key affordances of citizen science. One participant, Desmond, was able to identify one of the salient points in the use of citizen science to conduct large scale scientific studies: “Citizen science projects have helped scientists come to conclusions about subjects that would have taken years to find out alone. I believe it is a helpful tool.” Many participants enjoyed the “hands on” and outdoor learning approach of the project and stated that citizen science helped them understand science and the scientific process and also made science “seem more real”. Additionally, they commented that they thought the project was interesting and had fun while taking part in it. These positive experiences led to several participants stating that they would like to do more citizen science projects in the future.

One of the realizations that participants noted after taking part in the citizen science project was that anyone can be a citizen scientist. Participants like Naomi and Bernard noted this with responses such as: “I think that citizen science is actually helpful to scientists and anyone can do it” and “It makes me realize that citizen science is something anyone can do and take part in, and it really makes a difference”. Participants such as Frank and Kate also recognized the use of mobile technologies as a tool which would allow anyone to act as a citizen scientist with statements like: “Yes, since I as a regular person with a phone can do anything”, “I was able to use my own phone to be a citizen scientist” and Alex stated:

> Using my smartphone did make me feel like I was a citizen scientist since it showed me that the little things I use, such as my phone, can be great tools to help real scientist gather data and info to help construct a way to help the environment.

Participants recognized that anyone can be a citizen scientist and many of them made statements that acknowledge their own identities as citizen scientists after taking part in the project such as: "I did not know about citizen science before this, but now since I did the actual project I am a citizen scientist and can help the environment", "I enjoyed doing this project because it gave students a chance to go outside and conduct an experiment on their own and feel like a part of the citizen science community as well" and "It has made me notice that climate change is real, and by being a citizen scientist, I can help scientists research on how to fix all the issues we are facing." One of the more interesting details about student concepts of citizen science identity, is that participants view citizen scientists and their work as having a direct impact in helping the environment. Their responses often combine their identity as a citizen scientist with aiding scientists or helping the environment. A few examples of this came from Michael, Shannon and Walt: "It has made me notice that climate change is real, and by being a citizen scientist, I can help scientists research on how to fix all the issues we are facing", "Being a citizen scientist can help by giving a hands on approach to learning more about it" and "(As citizen scientists) we are helping to prevent climate change and benefitting our environment."

The majority of responses from the MobiLAP group point to the use of mobile technologies as a reason for citizen science identity formation. Examples of this include Daniel's, Jacob's and Nikki's respective responses: "Using my smartphone for this project did make me feel like a citizen scientist because it shows how easy it is to conduct research, because all you need is an app", "I was able to use my own phone to be a citizen scientist. It made me feel like being a citizen scientist is easier than I thought" and "Yes (my smartphone made me feel like a citizen scientist), since I as a regular person with a phone can do anything." Likewise, a few members from the NMT group stated that the use of smartphones would have fostered citizen science identity. A couple responses that reflect this feeling were stated by Gina and

Juliet: "Using my smartphone would have made me feel like a citizen scientist because I would have been accomplishing the same task as using the field guide" and "I think using my smartphone would help because all of the data would be easier to find and compare with." Several members from the NMT group, however, stated that they felt like citizen scientists despite not using a smartphone with responses such as James: "I would feel like a citizen scientist whether I had my smartphone or not" and Jin's response "No I don't think just because if I use a smartphone for this project it will make me feel like a citizen scientist. I already feel like one." One NMT participant , Anna, contended that the use of a smartphone would actually have an adverse effect on forming citizen science identity and stated the following:

> No, using my smartphone would not make me feel like a citizen scientist. To me, citizen science is going out there and making observations, not going to a tree, checking off a few boxes, and then having something identify the leaf for me. I would want to identify the tree myself, using the guidebook, because it makes me feel like I did the work and I completed my part.

Table 8

Codes, definitions, and examples for the theme Authentic citizen science practices provide interesting, real-world, collaborative and enjoyable experiences that foster citizen science identity.

Code	Definition	Examples
CS Identity	Participants respond with feeling like or being a citizen scientist.	1. "It has made me notice that climate change is real and by being a citizen scientist, I can help scientists research on how to fix all the issues we are facing." 2. "I did not know about citizen science before this. but now since I did the actual project I am a citizen scientist and can help the environment" 3. "Being a Citizen Scientist helped me understand how scientists observe organisms and I liked the

		research part were we went outside to actually observe trees.”
Mobile Fosters CS Identity	Participants state that the use of mobile technologies make them feel like citizen scientists.	1. “Using a smartphone would make me feel like a citizen scientist because I could be accurate in my results and record them more efficiently than on a worksheet. The feeling of giving immediate results that are accurate would make me feel more like a citizen scientist.” 2. “Using my smartphone would have made me feel like a citizen scientist because I would have been accomplishing the same task as using the field guide.” 3. “I think using my smartphone would help because all of the data would be easier to find and compare with. I still think that it would take away from the hands-on experience of being a citizen scientist.”
CS Anyone	Participants state that anyone is able to be a citizen scientist.	1. “It makes me realize that citizen science is something anyone can do and take part in, and it really makes a difference.” 2. “This project showed me that anybody can be a scientist. A person does not necessarily have to be a professional figure working in a laboratory to be a scientist. Citizen science is a great way for anybody to learn and experience how to collect data and input it.” 3. “This project teaches me that anyone can be a citizen scientist and discover new things no matter how hard they work there are always discoveries to be made”
CS Affordances	Participants comment on the attributes related to taking part in citizen science.	1. “I had never heard of citizen science before this project, and introducing citizen science to my life will definitely change my thought process on how science works, and how we can contribute to it.” 2. “I feel more connected to the world around me through the data I have gathered.” 3. “I really enjoyed doing this project and I think it is a great way for people to learn about science, STEM, and their environment, while still helping scientists gather research to discover more about climate change. Overall, I think that this project is wonderful and very efficient.”

The qualitative findings reveal that participants in the both the NMT and MobiLAP groups generated identities as citizen scientists after intervention. Participants responded to open-ended questions with statements that point to the formation of citizen science identity. Codes related to forming citizen science identity across treatment groups totaled 30 for the MobiLAP group and 26 for the NMT group. Participants in both treatment groups stated that the use of (or potential use of) mobile technologies made them feel like they were citizen scientists. There were 21 instances from the MobiLAP group and 17 from the NMT group responses coded in the "Mobile Fosters CS Identity" category. Some participants made statements that contend anyone can be a citizen scientist. The "CS Anyone" code lists 14 MobiLAP and 15 NMT occurrences respectively. The final code related to citizen science identity is "CS Affordances". This code consists of 14 MobiLAP instances and 12 NMT occurrences where participants comment on the attributes related to taking part in citizen science.

RQ4: Mobile Learning Perceptions

The fourth research question was: How does the MobiLAP approach impact high school student perceptions of mobile learning? This study seeks to understand what impact the mobile technologies have on STEM interest, CEmSTEM perceptions, citizen science identity, climate change perceptions and environmental stewardship. As such, one treatment group utilized mobile technologies in the project and the other group used a paper-based, dichotomous key field guide to identify trees. A 10 item subsection of the CSI-CEmSTEM instrument focuses on the use of mobile technologies and several items on the group-specific, open-ended questionnaire address the use of mobile technologies in education.

A 2x3 mixed ANOVA analysis was performed for the mobile learning perceptions subscale with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was no significant main effect of time [F (1,

134) = .288, p = .592, partial eta^2 = .002] as well as interaction between the different time periods and the type of group where the student belongs to [F (2, 134) = .110, p = .896, partial eta^2 = .002]. However, there was a significant main effect for the type of group [F (2, 134) = 3.308, p = .040, partial eta^2 =.047].

Further analysis using analysis of covariance of the posttest mean differences across the three groups controlled for pretest performance revealed that there was no statistically significant difference on the posttest scores on the mobile learning perceptions subscale between the groups when adjusted for the pretest performance [F (2, 133) = 83.389, p < .512, partial eta^2 = .10]. Since the results did not yield a significant difference, pairwise comparison is not necessary. A listing of means for the mobile learning perception subscale can be found in Table 3.

RQ4: Qualitative Results

The qualitative data analysis resulted in the following emerging theme which relates to research question four: Mobile technologies, such as smartphones afford learners a personalized, accessible, engaging and efficient way to learn science and scientific principles. A list of codes, code definitions and examples related to this theme can be found in Table 9. The open-ended survey items related to this research question include: (1) How might using mobile technologies to gather environmental data change your future career path, course of study or interest in STEM? (2) How has this project influenced how you think about citizen science? (3) How has using a smartphone for this project to identify trees, plot location, conduct research and take photos impacted your thoughts on learning with your smartphone/mobile device? (4) Did using your smartphone for this project make you feel like a citizen scientist? If so, how? (5) Did using your smartphone for this project make you more interested in any STEM fields? If so, how? (6) Would using your smartphone for this project make you feel like a citizen scientist? If so, how?

(7) Would using your smartphone for this project make you more interested in any STEM fields? If so, how? Most participants responded to the questions with at least one sentence. One class from each treatment group (roughly 10-12 students) took part in a member check to ensure accuaracy in the open-ended responses. A peer-debriefing also added to the realiability and validity of the data.

Many of the participants in both treatment groups were able to cite benefits of mobile technologies regarding their learning and ability to do school-related tasks. The majority of respondents noted that using smartphones in conjunction with the citizen science project would make identifying tree species faster and easier when compared to paper-based methods. A few responses regarding this perception included Paulo's, Ilana's and Pierre's respective comments: "I feel that smartphones and technology become efficient. They could show me easily which species, the location and everything, which would have made my study a lot easier", "Using a smartphone is making learning easier and more fun. If we didn't use a smart phone, then we would have had a very hard time getting information" and "It made the discovery of different tree types easier and quicker." More specifically, several participants like Eloise pointed to the accessibility of information that comes with having access to the internet: "The project would be much much MUCH easier with smartphone technology as there would be real pictures to compare to and an unlimited amount of information to base findings off of", "If we didn't use a smart phone, then we would have had a very hard time getting information" and "Using a phone to identify and research makes me realize how dependent we are on technology for the right reasons. Phones can help us in a million ways with finding out new information." Students such as Rose and Ethan also identified the "just in time" nature and accessibility of mobile learning with comments such as: "(mobile technology) can help us learn what we need to know faster than reading an entire book about it" and "It was very easy and faster to use a smartphone rather than looking through a book or something or having to remember".

Participants in the MobiLAP group touched on the personalized aspect of using their own smartphones and appreciated the familiarity by making statements like Tom's "It made it seem more real when we're using something we always have with us" and Boone's "It's easy to learn on something you are so used to using and know how to work with". Several participants even mentioned that they may extend the learning beyond the classroom as a result of having the apps available on their own smartphones. A couple examples of this sentiment include Sayid's: "I really liked working with my phone to take pictures and look at data bases full of different types of trees and I will probably keep the app I downloaded to look at more trees sometimes later" and Elizabeth's "It's interesting so I might explore trees in my own area."

Although the quantitative data did not reflect this in a significant manner, participants in both treatment groups reported that mobile technologies aided their learning. Several examples of this metacognition from the MobiLAP group include responses similar to Cindy's: "For me, learning with my phone is easy and fun, so this project helped with that. It made this project more entertaining and interactive, which helped me learn better", "The smartphone is really helpful in learning new things, especially to do with science and climate change" and "I think learning with phones helps us relate and understand more than if we didn't." Participants in the NMT group also shared thoughts related to understanding their own learning with mobile technologies such as Vincent's and Emma's responses: "Yes, because I would have quick access to a very large amount of information about STEM fields. In addition, I feel that using technology would help enhance my learning experience" and "Using my smartphone would definitely have been easier and it would have allowed for a deeper understanding."

Several Non-mobile Technology respondents touched on a crucial component of citizen science projects; obtaining accurate data. These participants remarked that using mobile technologies for tree identification would result in more accurate results. A few of these comments such as Scott's, Steve's and Martin's were: "Using a smartphone would make me feel like a citizen scientist because I could be accurate in my results and record them more efficiently than on a worksheet", "Using a smartphone/mobile device would have been a lot faster and accurate" and "It could be more accurate and it could take less time." Participants in the MobiLAP group did not record any issues with accuracy or lack of confidence in their tree identifications. They recorded statements which conveyed confidence in tree identification such as: "We could determine the type of tree or plant in a matter of seconds", "We were deep into learning about the trees and finding more information about them" and "It made the process of figuring out what were the names of the plants and leaves simple."

The MobiLAP group pointed to the use of their smartphones as a method to explore nature. Several examples like Goodwin's include: "It really shocked me that my phone can take a picture of a leaf and the app shows the leaf's information. Exploring outside was better when you have the information right there" and "Using cell phones and technology throughout this project made seeing nature more in detail and more interesting." They also noted that using mobile technology in a natural setting helped them to be engaged in the activities and learning. Select examples of this sentiment include responses like Zoe's and Roger's: "Using my smartphone made me more engaged with looking at the trees" and "It made this project more entertaining and interactive."

Participants in both treatment groups reported that the use of mobile technologies created (or would create) STEM interest. The NMT group responded with perceptions of how using mobile technologies in the project would have impacted their interest in STEM. A few examples included: “Using my smartphone would make me more interested in STEM fields because I could see the connection between technology and science”, “Naturally using my smartphone would have made the project easier and I would have been more likely to be interested in STEM fields” and “Using my smartphone would have made me more interested in any STEM fields because I would have been using technology. I may have become more interested in the way that it works while using it.” Several examples of a gain in STEM interest from the MobiLAP group include Omar’s: “Yes, because the science and technology helping us understand what type of tree the leaf came from. So I would be more interested in doing more science and technology projects in school”, Stuart’s “It (the use of a smartphone) did make me more interested in STEM fields” and Danny’s “Using technology to gather data may make you have a stronger connection to the subject. Using technology like phones may make you more interested in STEM since it’s a daily item you use and can relate to the subject.”

Table 9

Codes, definitions, and examples for the theme Mobile technologies, such as smartphones afford learners a personalized, accessible, engaging and efficient way to learn science and scientific principles.

Code	Definition	Examples
Mobile Learning Affordances	Participants record opportunities for learning and working with mobile technologies.	1. “It would have been a lot easier. I feel that smartphones and technology have become efficient. They could show me easily which species, the location and everything which would have made my study easier.” 2. “I really liked working with my phone to take pictures and look at databases full of different types of trees and I will probably keep the app I downloaded to look at more trees sometimes later.” 3. “Using a phone to identify and research makes me realize how dependent we are on technology for the

		right reasons. Phones can help us in a million ways with finding out new information."
Mobile Generates STEM Interest	Participants point to the use of mobile technologies as a contributing factor in generating STEM interest.	1. "Mobile technology can change the way I look at stem. It can make it seem more fun and might make me want to be more involved." 2. "Using technology to gather data may make you have a stronger connection to the subject. Using technology like phones may make you more interested in STEM since its a daily item you use and can relate it to the subject." 3. "I'm more interest in STEM because it made it seem more real when we're using something we always have with us."

The qualitative findings displayed participant understandings of learning with mobile devices. Many statements from both treatment groups indicated that participants see mobile technologies as tools that make learning faster and easier. These and other examples comprise the "Mobile Learning Affordances" code which had 38 MobiLAP and 33 NMT instances where participants identified opportunities for learning and working with mobile devices. Another aspect of learning with mobile devices was apparent as 13 responses from each treatment group were coded to the "Mobile Generates STEM Interest" code. Responses in this code point to the use of mobile technologies as a contributing factor in generating STEM interest.

RQ5: Climate Change Perceptions

Research question number five was: How does the MobiLAP approach impact climate change perceptions in high school students? This study seeks to understand how participants perceive climate change and anthropogenic climate change after taking part in the MobiLAP approach in a citizen science context. A seven item subsection of the CSI_CEmSTEM instrument focuses on climate change while several items in the open-ended questionnaire relate to climate change.

A 2x3 mixed ANOVA analysis was performed for the climate change perceptions subscale with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was a significant main effect of time [F (1, 134) = 8.590, p = .004, partial eta^2 = .060]. However, there is no significant main effect for the type of group [F (2, 134) = 2.539, p = .083, partial eta^2 =.037] as well as interaction between the different time periods and the type of group where the student belongs [F (2, 134) = 1.856, p = .160, partial eta^2 = .027].

Further analysis using analysis of covariance of the posttest mean differences across the three groups controlled for pretest performance revealed that there was no statistically significant difference on the post test scores on the climate change perceptions subscale between the groups when adjusted for the pretest performance [F (2, 133) = .384, p = .682, partial eta^2 = .006]. Since the results did not show a significant difference, pairwise comparison is not necessary. The means for the climate change perceptions subsection can be found in Table 3.

RQ5: Qualitative Results

The qualitative data resulted in the emergence of the following theme: Citizen science promotes meaningful awareness of and knowledge about climate change where participants may personally experience climate change. A list of codes, code definitions and examples related to this theme can be found in Table 10. The open-ended survey questions which yielded data supporting this theme and addressed the fifth research question were: (1) How have your feelings toward climate change been effected by taking part in this citizen science project? (2) How has this project influenced how you think about citizen science? (3) How has this citizen science project changed the way you think about humankind's impact on climate change? Student responses were typically limited to one or two sentences. A member check was conducted with 10-12 participants from each treatment group. A peer-debriefing also took place to ensure reliability and validity.

After completing the citizen science project based on phenology (and ultimately climate change), participants in both treatment groups responded with affirmations of an increased understanding of climate change. Several respondents Like George, Horace and Phil offered comments such as: “I can see the changes that have occurred in the environment, which furthers my understanding on global warming, which I take seriously”, “I now know that most of the climate change is caused by the greenhouse effect, which is happening because of us” and “Trees and plants are killed by the greenhouse gases going out into the environment, causing unhealthy carbon dioxide.” A specific connection participants made in their understandings was in the area of anthropogenic climate change. Several student responses, like the following from Leslie, Karl and Edward, proclaim that they now understand that humans are primary cause of climate change: “I have come to think that humans have a huge impact on climate change. Much of our modern machines give off harmful chemicals that do terrible things to the climate”, “Human activity affects global warming harshly, and I can see that the late changes in the changes in the trees is because of not only natural causes, but human activity as well” and “I realized how big of an impact humankind has on climate change after conducting this experiment because there are many actions humans do that slowly kill off organisms needed for us to survive.”

In addition to a better understanding of climate change, participants recorded feelings of being more aware of climate change. Many respondents like Zach said that climate change seems more real after taking part in the project. A few examples included: “I have realized that climate change isn't just one word that is about to happen. It's happening, right now, in front of us and there are steps we can take to change this” and “It impacted my thoughts because it shows me how climate change is real." One participant , Sun, summed up nicely the connection between the citizen science project and his observations of how climate change has impacted tree phenology:

> After completing this citizen science project and seeing how even the trees show signs of the planet being much warmer for more days on average, my trust in the idea of climate change being a reality is now more solid.

Perhaps one of the most important aspects of this citizen science project is that participants felt as though they have personally experienced climate change by observing tree phenology in their local environment. Many of the participants such as Caesar, Beatrice and Cassidy stated examples of how they personally experienced climate change as a result of this project such as: "Due to this study I finally experienced climate change with my own eyes, which makes me more conscious of the environment", "I always knew it (climate change) existed, but now I have a real-life example of climate change" and "I think of citizen science as something that you can really do to help the world and it isn't some far away thing. Climate change is happening right in front of our eyes, as we observed from the trees!"

Another important point which relates to citizen science and participants' feelings of experiencing climate change personally, is that many of them remarked how "it expanded my awareness of how climate change is very much real in our community." Additional examples of students observing climate change in their local communities include responses like Alvar's and Gary's: "Seeing climate change affect something around the corner from my school or house definitely makes me want to go out there and do something about it" and "I've realized that climate change is happening right now right outside the windows. The process happens so slowly that no one notices, but after taking part in this project, I've realized that the climate change is actually right here." This community-based realization takes the concept of climate change from abstract to reality as Amy mentions in the following statement:

> I didn't fully realize the impact climate change had on the community and environment around me. Before I thought of climate change as this abstract idea that was only affecting the glaciers farther north and south. Now I realize that climate change is happening everywhere and it is really affecting us.

Table 10

Codes, definition, and examples for the theme Citizen science promotes meaningful awareness of and knowledge about climate change where participants may personally experience climate change.

Code	Definition	Examples
CS Promotes CC Understandings	Participants identified citizen science as a way to better understand climate change.	1. "Taking part in this project has taught me that climate change may be more serious than some people consider it to be and even the slightest concepts such as tree phenology can demonstrate the effects of climate change." 2. "My feeling towards climate change have become stronger. i have realized the effects from climate change, and the majority of them are bad." 3. "My feelings towards climate change have strengthened from doing this project. Seeing that the world is warming, it can harm the ecosystems and life on earth, which applies to myself and the people around me. I can see the changes that have occurred in the environment, which furthers my understanding on global warming, which I take seriously."
Climate Change Awareness	Participants responded with obtaining an increased awareness or understanding of climate change after taking part in	1. "Human activity affects global warming harshly, and I can see that the late changes in the changes in the trees is because of not only natural causes, but human activity as well." 2. "The animals who live in these environments are really being negatively impacted by climate change and they are not having any place to live with safe climates for them that they are used to." 3. "Trees and plants are killed by the greenhouse gases

	the study.	going out into the environment causing unhealthy carbon dioxide."
Personally Experienced CC	Participants make statements regarding personally experiencing climate change as a result of the citizen science project.	1. "This project gave me a new approach on how to help it. Seeing the trees delay their change because of the climate change is real proof that we need to change." 2. "Before I never really paid attention to the trees and didn't really observe what was happening to our community in terms of the landscape but this citizen science project has allowed me to see what I could do to help raise awareness about climate change and I have a new understanding of our environment being affected by warming temperatures." 3. "I see how climate change can affect trees and how they develop, which opens my eyes more in how climate change is real."

The qualitative findings revealed that participants in the NMT group and the MobiLAP group have changed perceptions, increased awareness and have personal experience related to climate change. Many participants recorded responses (43 MobiLAP and 39 NMT) which were coded to the "CC Understandings" code in which they identify citizen science as a way to better understand climate change. Additionally, participants made statements regarding an increased awareness or understanding of climate change. These responses garnered 21 MobiLAP and 23 NMT instances in the "Climate Change Awareness" code. Perhaps one of the most important outcomes of this study, is that participants made statements of personally experiencing climate change as a result of taking part in the phenology-based citizen science project. These responses were coded to "Personally Experienced CC" and consisted of 17 instances for the MobiLAP group and 21 instances in the NMT group.

RQ6: Environmental Stewardship

The final research question was: How might the MobiLAP approach change high school students' perceptions of conservation and environmental stewardship? The CSI-CEmSTEM instrument's subsection on environmental stewardship has eight items related to conservation and environmental stewardship. The open-ended questionnaire also contains several items related to conservation and environmental stewardship.

A 2x3 mixed ANOVA analysis was performed for the environmental stewardship subscale with the group (NMT, MobiLAP and control) as the between-subjects factor and time (pre and post) as the within-subjects factor. There was a significant main effect of time [F (1, 134) = 10.934, p = .001, partial eta^2 = .075]. However, there was no significant main effect for the type of group [F (2, 134) = 2.980, p = .054, partial eta^2 =.043] as well as interaction between the different time periods and the type of group that the participant represents [F (2, 134) = 2.266, p = .108, partial eta^2 = .033].

Further analysis using analysis of covariance of the posttest mean differences across the three groups controlled for pretest performance revealed that there is a statistically significant difference on the post test scores on the environment subscale between the groups when adjusted for the pretest performance [F (2, 133) = 4.558, p = .012, partial eta^2 = .064]. The pairwise comparison showed that the NMT group has a statistically higher score than the control group with a mean difference of 2.585 [p = .014]. There was no significant difference between the MobiLAP and NMT groups nor the MobiLAP and control groups [p = 1.000]. Total pre and post means for the environmental stewardship subsection are located in Table 3.

RQ6: Qualitative Results

The qualitative data resulted in the emergence of following theme: Citizen science develops knowledge, skills and attitudes which lead to an action-oriented, pro-environmental ethos. A list of codes, code definitions and examples related to this theme can be found in Table

11. The open-ended survey questions which yielded data supporting this theme and addressing the sixth research question were: (1) How important is it to consider the environment when creating STEM innovations? (2) How has this project influenced how you think about citizen science? (3) How has this citizen science project changed the way you think about humankind's impact on climate change? (4) How has taking part in this project impacted your thoughts on caring for the environment? Student responses were typically limited to one or two sentences. A member check with 10-12 participants was conducted on the data to ensure accuracy. To further ensure the validity and reliability of the data, a peer-debriefing was utilized. Individuals that have a better understanding of climate change, recognize that it is real and happening right in their communities, may be more likely to consider conservation and environmental efforts. Citizen science projects promote pro-environmental ethos in participants. Several examples of this include the following statements from Pryce, Nadia and Matt: "Taking part in this project has impacted my thoughts on caring for the environment since it shows me that no matter how little I do, it helps no matter what", "After taking part in this project, I am now more convinced regarding the need for citizens like me to care for the environment" and "The Earth is impacted in so many different ways and the faster humans make an effort to help the environment, the better it will be." Participants also viewed citizen science itself as an approach to help the environment. A few participant responses that demonstrated this were: "It taught me we can help the environment and further research just by taking a small time and observing/noting down trees", "Collecting data was our way of helping the environment" and "This was a great project! I am happy I helped the environment, and I had fun!"

Many of the participants that demonstrated a pro-environmental ethos are concerned for the future. Several commented on the negative impact climate change may have on the future if action is not taken. Select examples include statements from Helen and Mikhail: “If we don't protect the environment now, we won't get it back later when it's gone”, “The environment is filled with MANY MANY MANY different species, and types of trees and it’s so important to take care of the environment because if there's no care given to them such beautiful species will be gone forever” and “It makes me think more about the environment makes me want to fight for this because we want younger generations to live in a world which they can learn about these things.”

The affordances of citizen science projects may ultimately lead participants to move toward action-oriented environmentalism. Many participants expressed a want, need or desire to personally do something to help mitigate or reverse climate change. One of the areas that participants identified that will help the environment was that “awareness should be spread to other people.” A few examples include statements from Aaron, Greg and Lucia respectively: “It reminded me about how I should help the protect the environment more and spread awareness about environmental problems and how they could be solved”, “This citizen science project has allowed me to see what I could do to help raise awareness about climate change” and how one participant could “make sure that myself and the people around me make an effort to help the environment.” In addition to spreading awareness, several of the participants mentioned working “to help the environment by recycling” while others such as Sawyer, Teresa and Jason point to other actions that will help the environment: “It changed the way I do things around my house to save energy and to bike instead of driving”, “I will now watch what I do and how much fossil fuels I release into the air” and “I will now take care of the environment and now I know that small actions can help the environment and benefit it.”

Table 11

Codes, definition, and examples for the theme Citizen science develops knowledge, skills and attitudes which lead to an action-oriented, pro-environmental ethos.

Code	Definition	Examples
CS Promotes Pro-environmental Ethos	Participants identify citizen science as a method that is benefiting the environment.	4. "This project opened up my eyes to how citizen science can actually be used to better the Earth's situation and how everyday citizens, who are not scientists, can still get involved in helping the environment." 5. "Taking part in this project has impacted my thoughts on caring for my environment by probably trying to do more for the environment as a whole." 6. "The environment is very important to our health and we should take care of it as much as we can. It is the only planet we have."
Moving Toward Action-oriented Environmentalism	Participants discuss a need or desire to care for the environment.	1. "Before I never really paid attention to the trees and didn't really observe what was happening to our community in terms of the landscape, but this citizen science project has allowed me to see what I could do to help raise awareness about climate change." 2. "It has made me want to take a better interest in the environment. Also I want to do more to improve the well being of the environment." 3. "Taking part in this project has impacted my thoughts on caring for the environment since it shows me that no matter how little I do, it helps no matter what."

Student perceptions of conservation and environmental stewardship were positively impacted as is evident in the qualitative findings. Many participants made statements that identify citizen science as a method by which the environment is benefitted and promotes a pro-environmental ethos. Statements related to this were coded to "CS Promotes Pro-environmental Ethos" and amounted to 45 MobiLAP and 42 NMT instances respectively. Many students took pro-environmental ethos a step further by describing a need or desire to care for the environment. Responses regarding this sentiment were coded to "Moving Toward Action-oriented Environmentalism" and consisted of 19 occurrences in the MobiLAP group and 21 in coded responses in the NMT group.

Conclusion

In conclusion, quantitative analysis related to research question 1 (STEM interest) resulted in both the NMT and MobiLAP groups having significantly improved scores when compared to the control group. Qualitative data from both treatment groups support the quantitative findings as participants responded with increased interest in STEM careers and subject areas. Data related to research question 2 (CEmSTEM perceptions) showed significant mean differences in both treatment groups when compared to the control group and qualitative data resulted in themes relating to considering negative impacts on the environment from STEM innovations and helping the environment with STEM. Quantitative data for research question 3 (citizen science identity) showed significant mean improvements in both treatment groups. Likewise, the qualitative data supports this as both the NMT and MobiLAP groups reported feeling like (or being) citizen scientists. Quantitative data regarding research question 4 (mobile learning perceptions) resulted in no significant mean differences among groups. However, the qualitative data resulted in themes which participants in both groups responded with understanding that using a smartphone for learning is faster or easier than without. Research question 5 (climate change perceptions) showed no significant mean difference in any group. The qualitative data for both treatment groups resulted in an increased understanding or awareness of climate change. The final research question (environmental stewardship) resulted in a significant mean difference in the NMT group, but not the MobiLAP group. The qualitative data from both groups, however, cite the need for an increase in pro-environmental behaviors.

The quantitative data results support that high school student interest in STEM education and careers increased after taking part in the MobiLAP approach when compared to the control group. Qualitative findings support these results, noting the increased interest in STEM careers and subject areas as indicated by student responses in the post-implementation questionnaire. Likewise, the quantitative data results indicate that high school student perceptions toward CEmSTEM improved significantly after completing the MobiLAP approach with qualitative data confirming the findings. The quantitative data results also indicate that the MobiLAP approach fosters citizen science identity in high school students. The post-implementation questionnaire results support the quantitative findings as students conveyed feelings of actually being a citizen scientist, acting as a citizen scientist or feeling like a citizen scientist. The quantitative data results showed no significant difference in mobile learning perceptions after taking part in the MobiLAP approach. However, the qualitative data results indicate that high school students understand the value that mobile devices can bring to their learning in terms of efficiency, accessibility, ubiquity and socially. Quantitative data results indicate that high school students did not have significantly improved perceptions of climate change after completing the MobiLAP approach. The qualitative data, however, shows that the approach did have an impact on improving participant attitudes and perceptions toward the understanding, acceptance and personalization of climate change. The quantitative data results indicate that participants in the NMT group had significantly improved perceptions of environmental stewardship, while the MobiLAP group showed improved score, but they were not statistically significant. Both groups, however, made statements of personally experiencing climate change as a result of the phenology-based citizen science project. Additionally, the qualitative results indicate that high school students had developed a pro-environmental ethos and were moving toward an action-oriented environmentalism.

CHAPTER 5: DISCUSSION

The prior chapter examined the findings from this study's research questions. This chapter synthesizes the quantitative and qualitative results with the current literature in an effort to understand the relationships between mobile learning and the authentic practice of a citizen science project and its impact on citizen science identity, CEmSTEM interest, climate awareness and environmental stewardship.

Summary of Findings

The quantitative data showed that many of the theorized outcomes were found to occur after treatment groups took part in the project such as: increased interest in STEM, increased CEmSTEM interest and fostering citizen science identity. However, two hypothesized outcomes (perceptions of mobile learning and increased acceptance of climate change) showed no improvement, while attitudes toward environmental stewardship significantly improved for the NMT group. Additionally, the project did have a positive impact on traditionally underrepresented groups in STEM according to race/ethnicity (Black and Hispanic Americans), but not for gender (females).

Interpretation of Findings

There were several expected and a few unexpected results from this study. Participants that took part in the project had an increased interest in STEM, CEmSTEM and fostered citizen science identity. While both treatment groups had similar outcomes in these areas, the MobiLAP group's qualitative responses showed that the use of mobile technologies benefitted their identities as citizen scientists, while the Non-mobile Technology group seemed to appreciate the "hands on" approach to the project.

The use of mobile technologies was expected to have a greater impact in terms of participants understanding the affordances of mobile learning. This subsection of the CSI-CEmSTEM instrument was the highest scored subscale across all three groups at the pre-implementation time point. However, participant perceptions of mobile learning displayed the lowest increase in score across all three groups when compared to the other subscales in the post-implementation survey. The qualitative data for both treatment groups revealed that participants felt that smartphones made learning faster or easier. The participants understood the value their smartphones can bring to their learning, but they did not connect that idea with this project. Since smartphones are such an integral part of teen life, it is possible that teens do not grasp the metacognition associated with learning via mobile technologies. The ubiquity and accessibility of mobile devices may cause individuals to take their smartphones for granted in terms of using them as a learning tool. According to Terras and Ramsay (2012), learners need to develop specific metacognitive skills to understand the benefits and challenges of mobile learning.

Motivation is another contributing factor which helps to determine a learner's level of metacognition in mobile learning (Sha, Looi, Chen, Seow, & Wong, 2012). Terras and Ramsay (2012), contend that metacognition is essential to mobile learning and that learners must have the psychological infrastructure to learn in this manner. While teens are motivated to use their smartphones for a variety of personal reasons, they may not be motivated to use them as a formal learning tool or understand how mobile device impact their learning. In fact, research by Common Sense Media reveals that 59% of parents believe that their teens are addicted to smartphones while 50% of teens feel as though they are themselves addicted to smartphone use (Common Sense Media, 2016). However, a study by Chen, Liu and Hwang (2016), found that the type of mobile learning used can improve student motivation to learn. The Chen, Liu and

Hwand study examined two groups of learners using two different forms of mobile learning. While both groups gained in terms of learning achievement, only the mobile learning group that used a gaming strategy significantly improved motivation to learn. While the MobiLAP study did not measure motivation, participants did cite being engaged in the learning via use of their mobile devices.

The quantitative results from the climate change perceptions subscale showed no significant difference in any of the groups surveyed. The scores for both treatment groups did increase following the intervention, but it was not found to be a significant improvement. It is possible that individuals (even at 14 years of age) may have already shaped their worldview in this controversial area. However, the open-ended themes that emerged contrast the quantitative results in both treatment groups. Both treatment groups reported having an increase in climate change awareness/acceptance and point to the citizen science project as a method to better understand climate change. The last point is especially important as respondents remarked how citizen science "in their own backyard" helped them to understand climate change and experience it personally where previously it was an abstract construct to them.

Quantitative results from the environmental stewardship subscale revealed a significant improvement for the NMT group, but not the MobiLAP group. These findings are similar to the Gaydos and Squire (2012) study where participants increased perceived environmental stewardship after caring for a virtual lake system. Interestingly, the qualitative data from this MobiLAP study showed that citizen science fosters a pro-environmental ethos in participants regardless if technology is utilized in the project. Students in both the MobiLAP and NMT group made statements related to changing consumptive behaviors in order to care for the environment.

Context of Findings

Findings from this study are linked to relevant research in the following section. STEM interest, citizen science identity, mobile learning, climate change perceptions and environmental stewardship outcomes from this study will be connected to outcomes within current scholarship. Outcomes are synthesized and assumptions and assertions are made by the researcher.

Connections to Literature on Creating STEM Interest

Several studies have determined that an individual's high school years are a crucial time period to create and maintain career interest in STEM (Maltese, Melki, & Wiebke, 2014; Sadler, Sonnert, Hazari & Tai 2012). Other research has shown that having STEM experiences between the ages between 8 and 16 years is a vital determinant of STEM education and career decisions (van Tuijl & van der Molen, 2016). Participants in the MobiLAP group and the NMT group displayed a significant increase in STEM interest when compared to the control group. This study also corroborates studies that contend that citizen science can be a motivating factor in choosing STEM careers (Hiller & Kitsantas, 2014) and building and sustaining STEM interest (Johnson et al., 2014; Toomey & Domroese, 2013; VanMeter-Adams, Frankenfeld, Bases, Espina, & Liotta, 2014).

This study expands on the work of Wallace and Bodzin (2017) in that using mobile learning and the authentic practice of a citizen science project creates STEM interest in participants. The MobiLAP approach when used in citizen science contexts leads to interest in both STEM education as well as STEM careers. Results from this study reaffirm findings from the first iteration of the MobiLAP approach. Participants in the MobiLAP group had a significant increase in STEM interest when compared to those in the control group. The NMT group also had a significant increase in STEM interest when compared to the control group.

Interestingly, the empirical evidence suggests that the specific use of mobile technologies as a component of the citizen science project did not significantly alter student attitudes toward STEM interest more than participants in the NMT group as was hypothesized. The qualitative data, however suggests that the MobiLAP group's use of mobile technologies did have an impact in terms of creating STEM interest. Participants in this group point specifically to the use of smartphones as a cause for increased interest in STEM fields.

Traditionally underrepresented populations in STEM fields such as women and racial minorities often lose interest in STEM due to negative experiences (Carli, Alawa, Lee, Zhao, & Kim, 2006; Thoman et al., 2014). This study sought to understand how underrepresented groups in STEM may have been impacted by the MobiLAP approach and a multiple regression analysis was conducted for the STEM interest subscale. The majority of female participants in this study provided positive feedback regarding STEM interest after taking part in the project, however the regression analysis determined that they were less likely to have increased interest in STEM after taking part in the study. This may be due to the normative expectations of females in STEM fields and could be additional evidence of stereotype threat. Black and Hispanic populations, however, were determined to have an increased STEM interest after taking part in the project.

Creating CEmSTEM Interest

Conservation and environmentally-minded STEM interest is a new topic of discussion based upon the researcher's prior work. Results from this study offer a unique insight into an important component of STEM. The idea builds from the work of Gaydos and Squire (2012) in that it combines the environmental stewardship and climate change aspects of citizen science identity. It also extends previous research by Wallace and Bodzin (2017) in using mobile learning, authentic practice in citizen science context and STEM interest. Both studies utilized technology and citizen science concepts to foster citizen science identity. The outcomes of creating citizen science identity is what this study sought to understand.

When responding to items from the CEmSTEM subscale, participants in both treatment groups scored significantly higher on the post-survey when compared to the pre-survey. This subscale aimed to force the respondent to look inward where a moral or ethical decision must be made for each item in regard to STEM. After taking part in the citizen science project, participants have a much stronger sense to consider the environment before making decisions that may negatively impact the earth.

As in the Gaydos and Squire study (2012), participants that took part in a citizen science project had an increased interest in climate change and responded with increased feeling of environmental stewardship. These attributes when combined with STEM interest (as in this study) may lead to a conservation and environmentally-minded concentration in STEM fields. When faced with the moral dilemma of innovation versus the environment, participants in both treatment groups responded with a significant change in attitude in CEmSTEM interest. While participants gained interest in STEM, they also placed an increased value on the environmental impact that may stem from technological innovations. In fact, over 80% of both treatment groups responded that is important or very important to consider the environment when creating STEM innovations. Participants in the treatment groups far surpassed the control group in terms of positive changes in CEmSTEM interest in pre and post-surveys.

Although there aren't any previous studies directly related to CEmSTEM interest, there are very few which address individual careers that may be considered part of the CEmSTEM web. Interest in environmental science careers, for instance, has been found to be cultivated through social supports for White students, but not for Black student populations (Quimby, Seyala & Wolfson, 2007). The same study found that ethnic minorities showed less concern about environmental problems which was a key determinant toward their lack of environmental science career interest. This study demonstrated that Black and Hispanic student populations can generate STEM interest.

The lack of STEM workers and educators has, for quite some time, been a concern in the United States. Part of the issue may be the ambiguity of the STEM acronym as well as the broad range of subjects associated with it. Unfortunately, STEM education is often thought to be primarily focused in the sciences (English, 2016). The STEM acronym has also morphed into STEAM which includes an educational art component. The fact is, since STEM, and now STEAM, includes such a vast web of subjects, specializations and foci, it may be difficult to isolate a specific strand of education or careers to focus on. If STEM can be further refined and parsed out so that concentrated subsections emerge (such as CEmSTEM), it may benefit learners as they make important choices about the future.

Connections to Literature on Fostering Citizen Science Identity

Students should have community-based, authentic learning experiences that allow for real-world problems and solutions (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016). The MobiLAP approach is based on authentic learning, community-connectedness, real-world issues and has been proven to have a significant impact on fostering citizen science identity in participants (Wallace & Bodzin, 2017). Authentic scientific inquiry has the capacity to impact identity (Farnsworth, 2010). This study allowed participants to have additional experiences with citizen science which afforded them to have multiple observations across two phenophases. Additionally, the observations took place on their high school campus which may have instilled a sense of community, realness and identity in regard to the proximity of the project.

Citizen science identity can be constructed virtually (Gaydos & Squire, 2012), using mobile technologies (Wallace & Bodzin, 2017) and from the authentic practice of taking part in a citizen science project as was found in this study. Participants in the previous MobiLAP iteration (Wallace & Bodzin, 2017) remarked how the project made science and citizen science seem more real and how taking part in it made them feel like citizen scientists. This study had similar responses from participants in both treatment groups. The quantitative data shows that both the NMT group and the MobiLAP group had a significant increase in citizen science identity after implementation. Many of the participants in the NMT group pointed to the "hands-on", paper-based approach as a factor in their citizen science identity. The mobile technologies used by the MobiLAP group did not have a significant positive impact in terms of mobile learning perceptions. The qualitative results, however, showed that the mobile technologies did make this group feel more like citizen scientists. Students in all groups recognized the value that their smartphones have in terms of learning and completing learning-related tasks.

One of the most exciting things about citizen science is that with the use of a smartphone, any student can become a citizen scientist (Ranieri & Pachler, 2014) and contribute to research. Forming an identity as a citizen scientist has implications regarding several intertwined variables such as climate change awareness, environmental stewardship, STEM interest and CEmSTEM interest. Instilling a pro-environmental ethos through these means can lead to positive environmental behaviors no matter what career or educational path individuals may take. It is part of a holistic education that focuses on the entire individual.

Similar results were found in prior MobiLAP research in a citizen science context (Wallace & Bodzin, 2017) where participants in the treatment group had a significant gain in citizen science identity after taking part in a citizen science project. The results from this current MobiLAP study are similar to other research (Johnson et al., 2014; Toomey & Domroese, 2013) which contend that citizen science helps to scaffold personal knowledge about climate change and can create pro-environmental attitudes within participants. Participants in both the MobiLAP and NMT group had significant increasing in attitudes toward climate change and an increase in environmental stewardship after taking part in this study.

Participants in this MobiLAP study gained satisfaction by contributing to a citizen science project. These findings are similar to a 2017 study by Palmero et al, where participants reported feelings of satisfaction after taking part in a citizen science project. Palermo et al., (2017) contends that citizen science empowers individuals to partake in research and aid the environment. Similar results occurred in the MobiLAP study as many participants described how their contributions made them happy that they could do something to help the planet and their local communities. Participants also viewed their participation in citizen science as a way that they were helping the environment.

Many of the participants in both the MobiLAP and NMT groups noted that taking part in the activity was fun and it was good to get out of the regular classroom. Figure 7 shows students enjoying the outdoor activities associated with the Project BudBurst citizen science project. Creating a fun and interactive learning environment leads to student engagement and deep learning (Robinson & Kakela, 2006). When teaching science, an element of fun can improve student motivation to learn (Liu, Horton, Kang, Kimmons, & Lee, 2013). When individuals have fun doing something, they will most likely spend more time doing it which can lead to behavioral changes and, ultimately, identity formation.

Figure 7. Students having fun while working outdoors on a citizen science project.

Connections to Literature on Impacting Student Perceptions of Mobile Learning

Prior research has shown that mobile learning can help to create STEM interest in participants (Gilliam, Bouris, Hill, & Jagoda, 2016; Metcalf, Milrad, Cheek, Raasch, & Hamilton, 2008; Terkowsky, Haertel, Bielski, & May, 2013). The findings from this study are similar to other research as participants in the MobiLAP group had significant increases in STEM interest after taking part in the project. Participants in the NMT group also had a significant increase in STEM interest. Additionally, both groups also reported significant increases in CEmSTEM interest when compared to the control group and pre-implementation scores.

Using mobile technologies instills learner confidence in the subject matter (Bray & Tangney, 2016; Al Mosawi & Wali, 2016) and, when used to learn about climate change, can provide learners with additional tools to scaffold knowledge and understand content (Pettit, & Kukulska-Hulme, 2011). The MobiLAP group used apps on their smartphones to contribute to a citizen science project related to climate change. Students used scientific processes to make observations, identify tree species, determine phenophases, compare data and consider the impact that climate change has on their local environment. As a result, they improved scores on climate change perception when compared to the control group as did participants in the NMT group. However, several participants in the NMT group seemed to lack confidence in their observations and commented that using mobile devices to identify tree species would be faster and more accurate than their paper-based method. Qualitative data from both treatment groups highlight a better understanding of climate change after taking part in the study.

Even though school-issued iPads were available, all participants owned and used a smartphone which highlights the availability of mobile devices and their accessibility within education (Willemse & Bozalek, 2015). Participants in this study were able to access tree information on-demand which is a central benefit of mobile technology (Hummel & Hlavacs, 2003). Tools such as this afford learners with a ubiquitous knowledge construction that they can take advantage of during formal and informal learning opportunities (Peng, Su, Chou, & Tsai, 2009). Several participants from the MobiLAP group expressed interest in continuing learning with mobile technologies outside of regular class time.

The results of this study indicate that the mobile technologies were especially effective in aiding the contextualization and visualization of knowledge (Baloian & Zurita, 2012). MobiLAP participants benefitted by comparing tactile samples and observations with vivid photos and descriptions of tree species in their own community. Allowing participants to observe tree phenology in the context of their own community, seems to have greatly shaped their understandings of climate change. Many participants made statements related to personally experiencing climate change which turned an abstract concept into a reality. If “seeing is believing” then students who observed the delay in tree phenophase due to unseasonably warm temperatures were afforded an appropriate context and visualization of knowledge to believe climate change is real and happening in their communities. Experiential learning such as this is similar to findings in MacCallum, Skelton and Verhaart (2017).

In addition to visualization of knowledge and contextualization, mobile learning also provides opportunities for collaborative learning and connectivism (MacCallum, Skelton & Verhaart, 2017). While not directly collaborating with each other via mobile device, participants worked together and make statements related to feeling like part of the citizen science community. The observations made with mobile devices were ultimately submitted to Project BudBurst which caused participants to feel as though their contributions were helping scientists in their research as well as aided environmental efforts. Participants also described being more “connected” to nature or the outdoors. They also reported that taking part in the project made science and citizen science seem more real.

This study also confirms findings by Ranieri and Pachler (2014), in that mobile technologies afford any student with the opportunity to be a citizen scientist. Participants in the MobiLAP group had a significant increase in citizen science identity when compared to the control group. This confirms prior findings (Wallace & Bodzin, 2017) which concluded that using the MobiLAP approach created citizen science identity within participants. While mobile technologies provide pathways toward citizen science identity, so too does the authentic practice of taking part in a citizen science project. In this case, the NMT group also formed citizen science identities after contributing to a citizen science project. It should be noted, that the qualitative responses from the MobiLAP group point to the use of smartphones as a contributing factor of citizen science identity. Both qualitative and quantitative data confirm prior research (Bray & Tangney, 2016; Al Mosawi & Wali, 2016) that using mobile technologies as part of a citizen science project help to form citizen science identity and they also help to increase student engagement.

Connections to Literature on Impacting Attitudes toward Climate Change

Climate change is one of the most misunderstood issues in the United States (Cordero, Todd & Abellerra, 2008). As such, climate change awareness needs to be fostered in educational settings (Semenza, Ploubidis, & George, 2011) and phenology-based citizen science programs may be a viable way to teach climate change in schools, at all grade levels. The results of this study's data related to climate change, did not display a significant increase in attitudes toward climate change, however, the qualitative data showed that participants' views of climate change were positively impacted by this study. In fact, one of the most important themes from the qualitative data was that participants felt as though they experienced climate change personally as a result of this project.

Participants observed tree phenology which was delayed due to unseasonably warm weather. For example, the average temperature for the location where this research took place for the month of October in the year prior to the study (2016) was 56 degrees. During the course of this study, the average temperature for October of 2017 was 60 degrees (National Centers for Environmental Information, 2017). Warmer temperatures in the region delayed the seasonal leaf color change (Merlin, 2017). The unseasonably warm temperatures throughout the 2017 autumn season afforded participants to see the resultant delay in tree phenophase change.

Participants were able to record phenophase data from the first observation with the majority of observations listing the color change to be less than five percent of each tree observed and leaf fall to also be less than five percent of leaves on each tree species observed. One month later, during the second observation, the majority of participants recorded that trees observed had at least 95% leaf color change and about 50% of the leaves had fallen from the species observed. As such, participants were able to observe the delay in fall phenophases as well as at least two different stages of the fall phenophase. This may have had a substantial impact on climate awareness and could be a primary contributing factor in the qualitative results of the study.

Since about 57% of the public lacks awareness about the human-caused aspects of climate change (Cook et al., 2013), this study sought to understand if a phenology-based citizen science project could alter those perceptions. The results were conclusive in that participants that took part in the project had a positive change in climate change perception and anthropogenic climate change when compared to participants in the control group. Most importantly, participants remarked that they were able to see climate change happening in their own backyard and experienced it for themselves. Having experiences such as this may turn what once was an abstract thought into a reality.

Coincidentally, near the end of September (less than two weeks before the start of this study), the school where the study took place had to have early dismissals at noon due to excessive heat in the buildings. With temperatures in the low 90's, classrooms, hallways and other locations were too hot and students were dismissed at noon on two separate days. Another piece of anecdotal information which may have contributed to participant attitudes toward climate change is the national news story that highlighted the hottest World Series of Baseball game in the history of the sport. At the time of the opening pitch at 8:09 pm on October 24th, 2017 in Los Angeles, the temperature was 103 degrees Fahrenheit (Jacobo, 2017). This number is much higher than the previous World Series record of 94 degrees in 2001. The normal high temperature in the region for that time of year is 78 degrees (Rathbun, 2017). Students commented on both of these examples of unseasonably warm temperatures in the post-implementation discussions.

As previously discussed, many individuals may see climate change through a religious or political lense (McCright, Charters, Dentzman, & Dietz, 2016; McCright & Dunlap, 2011; Morrison, Duncan, & Parton, 2015). The goal of this study was not to change one's political or religious ideology, but to find the ways in which people can agree and support efforts to reverse the negative impact of increasingly warmer temperatures. Since outdoorsmen and outdoorswomen have politically conservative leanings yet acknowledge climate change due to their extensive time in nature (The National Wildlife Federation, 2012), it makes sense to leverage this strategy and provide students with outdoor learning opportunities where they may also observe climate change for themselves.

This researcher feels strongly that phenology may be the primary method by which regular observers of nature can observe climate change. As noted in this study, participants felt as though they were able to see climate change occurring based on the tree phenology they observed in their local environment. Of course, one needs to spend time outdoors in order to make these observations. If individuals can see for themselves that warmer temperatures are causing the fall season to start late, winters to shorten and the spring to being early, it will have a much greater impact upon climate change perceptions and attitudes than learning about it through other methods. People tend to trust their own experiences. One way to have outdoor experiences that may expose individuals to climate change is citizen science.

Connections to Literature on Creating Environmental Stewardship

This research project took place on the participants' high school campus. Aside from occasional physical education activities, many students do not spend time outdoors as part of their curriculum. Schools, in fact, are to blame for discouraging student involvement in outdoor activities (Louv, 2005). Educational institutions should be providing outdoor learning activities so students may connect with the environment and their communities (NGSS Lead States, 2013). Participants in both treatment groups of this study showed positive increases in attitudes toward environmental stewardship. One of the aspects that may have supported this change is the proximity of the project to the high school where the students attend classes. Since students are familiar with the location, they may be more likely to feel a sense of environmental stewardship toward it since they interact with it on a daily basis.

Education must coincide with environmental stewardship so that individuals may understand how their actions affect the environment (Branagan, 2005). It is through education that environmental behaviors can change and ultimately lead to policy change (Barr & Pollard, 2017; de Oliveira, 2009; Pacheco-Vega, 2015). Qualitative results from the MobiLAP group show that attitudes about environmental stewardship can be changed which may lead to behavioral changes in participants. For example, many of the participants commented that they have changed, or will change, consumptive behaviors as a result of this study. Although this group had an increase in environmental stewardship after completing this project, it was not statistically significant. The NMT treatment group, however, did have a significant positive change in attitudes about environmental stewardship after taking part in the citizen science project (both in the quantitative and qualitative responses).

Learning about the environment and the challenges therein can create positive change where individuals seek to protect the environment (McBride, Brewer, Berkowitz & Borrie, 2013). This thought is consistent with both treatment groups as they learned in and about their local environment and ultimately created a sense of stewardship for it. The control group remained in the classroom and learned about climate change, but the content was not directly related to their local environment and therefore may have been an abstract concept.

Citizen science projects are collective in nature as they seek input from individuals across large geographic ranges. Often, groups of individuals such as classes and after school clubs collectively work together as citizen scientists. The resultant environmental stewardship may also be a collective effort with social implications (Rydin & Pennington, 2000; Shirk et al., 2012). Research shows that scientific literacy about the environment and awareness of nature advances conservation efforts (Lamb, 2016). Participants worked in teams of two to identify trees, determine phenophase and submit data to the citizen science project. However, the responses from the MobiLAP group conveyed a larger group mentality when dealing with environmental stewardship. Most responses from this group noted that humankind or "we" need to protect the environment. This points to a sense of community and possibly identity formation as part of a social group. Participants in this group understood that while they are an important part of taking care of the environment, there must be a concerted effort by a larger community of stewards.

One of the more interesting takeaways from this study is that the NMT group's open-ended responses related to environmental stewardship point to a personal responsibility to caring for the environment. While both groups commented on personally changing behaviors in an effort to help the environment, the majority of this group's responses conveyed a sense that "I" need to do more to help the environment (instead of humankind or "we"). It is difficult to determine what role mobile technologies had in forming a social connectedness or how the "hands-on" paper-based method could have created a sense of personal empowerment. Whatever the cause, this change in attitudes toward environmental stewardship is important as an increased public awareness about climate change is an essential step toward changing behaviors (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015).

Citizen science projects increase public awareness about climate change (Brulle, Carmichael, & Jenkins, 2012), have been found to provide experiences that aid climate change learning and foster environmental stewardship in participants (Gaydos & Squire, 2012; Meyer et al., 2014). The results from this study suggest that not only does citizen science positively impact climate change understandings and create a pro-environmental ethos in participants, it may also be a predictor of pro-environmental behaviors.

CHAPTER 6: IMPLICATIONS AND RECOMMENDATIONS

This study examined the attitudes, perceptions and beliefs of ninth-grade science learners after completing a project using the MobiLAP approach in a citizen science context. Three separate groups including a Non-mobile Technology group, MobiLAP group and a control group took part in the study. All three groups completed the 66 item CSI-CEmSTEM instrument before and after the intervention. Each treatment group also completed a group-specific open-ended questionnaire following the implementation.

Outcomes from the quantitative and qualitative data show that participants in both treatment groups had significant gains in citizen science identity, STEM interest and CEmSTEM interest. The quantitative data showed that none of the groups had a significant change in mobile learning perceptions or climate change awareness. However, the qualitative data suggests that both treatment groups greatly valued smartphones in learning and had an increase in climate change awareness and acceptance. While the NMT group had a significant quantitative increase in environmental stewardship, the open-ended data suggests that both treatment groups gained in environmental stewardship and an increase in perceived pro-environmental behaviors.

Significance of Study

The need for qualified STEM workers and educators and the urgency in solving major issues such as climate change could potentially be solved by promoting citizen science identity and CEmSTEM interest in learners. In both iterations, the approach of mobile learning and the authentic practice of a citizen science project is a mechanism which created citizen science identity in participants. Citizen science identity is an important, yet under-researched, topic. Fostering this identity may lead individuals to care more deeply about the environment, have an increased interest in STEM and have a more positive attitude toward climate change. Additionally, this multidisciplinary approach to teaching and learning science has proven to be effective in creating conservation and environmentally-minded STEM interest in participants. The individuals in this study may continue to strengthen their respective identities and interests that may lead to positive change in the areas of continuing STEM education, choosing STEM careers and caring for the environment.

This study also demonstrated the practical application of the MobiLAP approach which adheres to many key components of the Next Generation Science Standards. The conceptual framework of NGSS lends itself to mobile learning and the authentic practice of taking part in a citizen science project. Participants that took part in this project benefitted from outdoor learning activities, addressing real-world problems, engaging in community and educating in an authentic manner. The aforementioned aspects of this project directly connect to NGSS standards which may aid teachers that are required adopt the standards.

Implications

This study provides several potential implications which may benefit teachers, learners, instructional designers, curriculum writers and educational systems. In a time where STEM education reform and climate change awareness are two of the United States' biggest educational issues, several possible approaches are discussed which may aid one or both of these challenges. This study also contributes to the literature by creating a new instrument, developing a conceptual framework for citizen science identity and branding a new subsection of STEM (CEmSTEM).

The MobiLAP Approach

The research literature calls for a multidisciplinary approach to teaching and learning STEM. Studies also show the value of authentic learning experiences as well as the affordances of mobile learning. This study utilized an approach in which citizen science identity, STEM interest and CEmSTEM interest may be formed. Additionally, this approach showed promise in increasing climate change awareness and environmental stewardship. Mobile learning and the authentic practice of citizen science offers learners a hands-on, project-based and real-world approach to learning. Additional outcomes include participant beliefs of personally experiencing climate change by using authentic data collection and naturalistic observations.

The MobiLAP approach offers several key alignments with NGSS and can provide schools with an inexpensive, accessible and easy-to-implement method by which to strengthen science programs. The MobiLAP approach in citizen science contexts takes advantage of key NGSS standards including: outdoor learning activities, connection to community, using real-world issues and learning 21st Century skills. One of the aspects of MobiLAP that makes it an easy-to-adopt program is the potential for implementing it as a BYOD approach.

Most high school students own smartphones. Teachers will often deter students from using phones in the classroom for a variety of reasons. Smartphones often become a distraction in the classroom and reduce student engagement (Witecki & Nonnecke, 2015). There is great potential, however, of leveraging the ubiquity of the devices to enhance the teaching and learning process. Smartphones can become personalized learning devices that allow individuals to learn anywhere at any time. Mobile learning has been shown to be an effective way to learn subject matter (Pettit, & Kukulska-Hulme, 2011) and has been proven to aid in creating STEM interest (Gilliam, Bouris, Hill, & Jagoda, 2016; Metcalf, Milrad, Cheek, Raasch, & Hamilton, 2008; Terkowsky, Haertel, Bielski, & May, 2013). As technology continues to improve, more learning apps will be developed, prices for hardware will drop and teens will become even more reliant on their smartphones both in and outside of the classroom. Coupling smartphone use with outdoor activity may be an effective way to utilize smartphones for learning and avoid potential distractions.

The MobiLAP approach may be a suitable learning approach in a variety of fields. Apart from the outcomes of this study, research shows it is an effective approach to learning in a variety of fields and disciplines including: computer networking (Qian, Yang, Guo, Bhattacharya, & Tao, 2013), cultural learning (De Pietro, 2013), instructional design (Hsu & Ching, 2012), mathematics (Baya'a, & Daher, 2009) and nurse education (Pu, Wu, Chiu, & Huang, 2016). Mobile learning as part of an authentic practice should continue to be explored in subjects and fields where relevant. It may be particularly effective when paired with subject matter related to many citizen science projects such as outdoor scientific learning, naturalistic observations, the scientific process and climate change education.

Citizen Science in Schools

The state of Oregon has an Outdoor School program in which about 50% of the state's 5th and 6th graders take part in a 3-6 day immersive outdoor educational experience where they learn about the biodiversity of their region (Schlobohm, 2016). The rationale behind using the outdoors as a learning environment is to pique curiosity and provide learners with an authentic and well-rounded education which includes learning about the natural world. A study by Schlobohm (2016), found that students who took part in the Outdoor School program had significant increases in attitudes toward science as well as significant increases in STEM identity in relation to STEM careers. Implementing a form of outdoor education, such as citizen science, may be a method by which schools across the country can achieve higher levels of science and STEM interest in students.

There are other less-explored benefits to taking part in outdoor activities that educators may wish to examine. Research by Shin, Shin, Yeoun and Kim, (2011) highlighted the positive mental attributes that occur while being in natural areas. In this study, participants walked in a natural, forested area and an urban downtown area for 50-55 minutes on two separate occasions. Results showed that spending time in the outdoors significantly increased mood and cognitive function. Walking in the urban area did not significantly improve mood or cognitive function, however, it did have an adverse effect. When walking in urban areas, participants experienced a significantly increase in variables such as tension-anxiety, anger-hostility and fatigue-inertia. These findings confirmed Kaplan's (1995) Attention Restoration Theory that provides a framework in which nature acts as a restorative agent to relieve stress in humans and rejuvenate mental acuity. Therefore, a simple activity in a natural setting can help increase student cognition and improve mood regardless of the learning objective. As such, taking part in an outdoor citizen science project creates an optimal environment for learning. Educators should reverse the trend of discouraging students to explore the outdoors (Louv, 2005) and take advantage of the many positive outcomes associated with learning in nature.

In many cases, students are able to use their smartphones to take part in citizen science projects. Using citizen science projects as part of a science class in an educational setting is not a new concept. However, many of the citizen science projects that take place in schools lack the requisite training, guidance and resources to be successful. Teachers are often burdened with a rigid curriculum and may not have the additional time needed to implement citizen science projects. Citizen science also requires teachers and learners to have specific skills to take part in activities (Thrumbull et al., 2000; Shah & Martinez, 2016). Students must be trained in order to properly collect and submit relevant data (Nov, Arazy, & Anderson, 2014). As with any new initiative, there is a learning curve. While not a focus of this study, teachers from the treatment groups expressed a willingness and desire to continue pursuing citizen science in their classrooms after the project finished.

The citizen science project used in this study (Project BudBurst) examines data based on tree phenophases in which participants may be able to observe trends in climate change. While schools across the nation can observe and submit tree data for this project, locations in the Northeastern United States have the benefit of being one of only three regions of the world which support deciduous forests with a fall color-change phenophase (Pennsylvania Department of Conservation and Natural Resources, 2017). Students that are able to observe the fall color phenophase can observe the direct impact of climate change which may make an otherwise obscure concept real to them. Place-based learning such as this has been proven to be an effective way to teach and learn about climate change (Hallar, McCubbin & Wright, 2011; Hu & Chen, 2016; Oonk et al., 2017). In terms of this study, the unseasonably warm fall season which delayed tree phenophases in the region may have been a primary contributing factor to the change in participant perceptions of climate change. As a result, participants remarked that they were able to see climate change happening for themselves. These personal experiences transform a global and potentially abstract view of climate change to a local and personalized understanding of the issue.

Citizen science identity is a relatively new, yet important concept. It is important for individuals to gather data, have authentic experiences and use evidence-based decision-making as a foundation to promote citizen science identity. This study demonstrated the importance of fostering identity as a citizen scientist. The interconnectedness of STEM, climate change awareness and environmental stewardship with the formation of citizen science identity proves how valuable creating such an identity can be. Therefore, a conceptual framework for citizen science identity has been developed (Figure 8) and should be utilized and refined in future research in order to fully grasp this significant and timely concept.

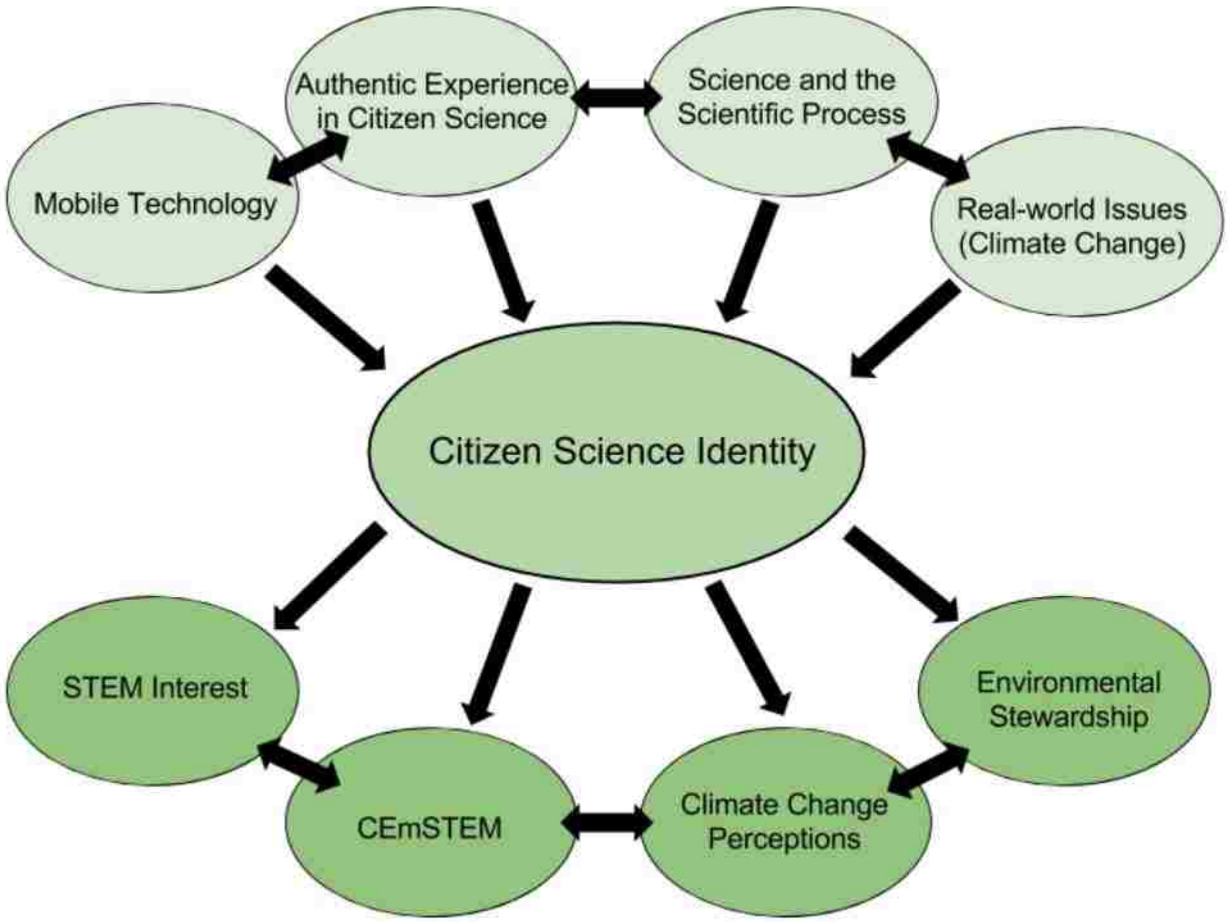

Figure 8. Conceptual Framework for Citizen Science Identity. This image represents a citizen science identity framework relevant to the concepts in this study.

This study demonstrated positive outcomes associated with citizen science in schools including: citizen science identity formation, perceived environmental stewardship, climate change awareness and CEmSTEM interest. It also reinforced existing research that contends citizen science can increase interest in STEM education (Johnson et al., 2014; Toomey & Domroese, 2013), motivation for STEM careers (Hiller & Kitsantas, 2014) and environmental action (Nisbet, Zelenski, & Murphy, 2009). One of the salient points to emerge from the qualitative data was that citizen science was a way for learners to experience climate change for themselves. Additionally, citizen science coincides with the NGSS call for: learning that addresses real-world issues, project-based learning, outdoor learning experiences, engaging in community and cross-cutting and multidisciplinary concepts (NGSS Lead States, 2013). This is an area where schools may be able to align curriculum learning to new science standards while offering an interesting and inexpensive program for teachers and students. The teachers associated with the treatment groups all expressed interest in implementing citizen science projects in their classes in the future. They found citizen science to be a great value to student learning and engagement.

CEmSTEM Interest

The introduction of the conservation and environmentally-minded aspects of STEM and the pro-environmental ethos that accompanies it, are areas in which many research and practical application possibilities exist. CEmSTEM, as defined in this study, is a subsection of STEM that deals primarily with education and careers associated with the conservation and environmentally-minded aspects of science, technology, engineering and mathematics. The next generation of learners may consist of individuals that wish to address environmental issues via STEM practices. Since CEmSTEM is multidisciplinary and rooted in an environment-friendly ethos, learners may expect to have a connection with nature while building critical thinking skills and obtaining content knowledge in several STEM disciplines. This study corroborates other research and shows that STEM education can lead learners to a better understanding of climate change (Kriegler et al., 2014) and that teaching climate change science in a multidisciplinary manner can increase interest in STEM (McCright, O'Shea, Sweeder, Urquhart, & Zeleke, 2013). There is an inherent connection between STEM interest and climate change learning and opportunities exist to construct learning in a multidisciplinary way that may benefit learners and educators alike.

Although this subsection of STEM has been newly defined and branded in this study, conservation and environmentally-minded STEM education and careers already exist. Each cluster on the STEM continuum has within it many foci related to environmental fields that fall into such a category. For example, CEmSTEM interest can be recognized in areas of science such as: environmental science, botany, marine biology and forestry to name a few. It is also found in engineering with environmental engineering and civil engineering. There are many instances in the technology strand of STEM with examples including: environmental technology, energy conservation and alternative and renewable power. Finally, there are even examples of existing CEmSTEM educational tracks and careers in mathematics such as environmental math, environmental statistics and ecological economics. This small sampling of educational and career paths displays the need for the CEmSTEM branding and brings about a new focus on this important concentration of STEM fields. Education and careers in this field should focus on innovation intertwined with conservation.

CSI-CEmSTEM Instrument

This study made use of a new instrument in an effort to understand and measure the interconnected aspects of citizen science identity, STEM interest, CEmSTEM interest, mobile learning, climate change perceptions and environmental stewardship. The CSI-CEmSTEM instrument is a 66 item scale with six subscales. The instrument as a whole was found to be highly reliable as were each of the subscales. This instrument may benefit future research in the aforementioned areas and may help to uncover additional data in these important issues.

Limitations of Study

There were several limitations identified within the design of this study. First, the sample size was small and was acquired via convenience sampling which may cause difficulty in generalizing the findings to other populations. Additionally, the racial and ethnic demographic makeup of the United States is: 76.9% White, 13.3% Black, 1.3% American Indian and Alaska Native, 5.7% Asian, 0.2% Native Hawaiian and Other Pacific Islander, 2.6% Multiracial and 17.8% Hispanic or Latino (U.S. Census Bureau, 2016). This differs from the school's racial and ethnic makeup of: 58% White, 13% Asian, 11% Black, 2% Multiracial and 16% which identify as Hispanic or Latino. Therefore, results should be generalized with caution to populations of similar makeup. Since this study examined the outcomes of two treatment groups and one control group, the sample size was limited as each group consisted of 44, 45 and 48 participants respectively. Acquiring only 137 participants to take part in this study was a sampling limitation.

Another limitation was the BYOD approach utilized for the MobiLAP group. While there are many benefits to students using their own devices to learn, there were also limitations associated with them in this study. The researcher was not able to have uniform devices and could not test each device prior to the implementation. Not all students have the same smartphone with the same cellular phone service, data plan and ability to download apps. As of the time of this writing the Leafsnap app was only available for iOS devices which limits the number of potential users. However, this study also made use of the PictureThis app for Android users. Since students worked in teams of two, this generally wasn't an issue as all students in the group had an iPhone or an Android device. However, not all students had the ability to freely download apps (even though they were free). Some of them needed to ask permission from parents and guardians which added another layer to the process. Additionally, some students had limited data or technical issues that prevented them from using their devices. This required dependence on the school's WiFi which was not ideal in the locations where tree samples were taken. Each participant's skill and comfort level in using apps on their devices was varying in degree, although none of them appeared to struggle with the technology used.

One of the limitations may be in the instrument design. The participants in both treatment groups had 10 open-ended items to respond to if they so chose. Open-ended questionnaires took place at the same time as the posttest. This researcher observed survey fatigue in a few participants as they asked about the number of questions and sometimes struggled to stay on task. It may be appropriate to reduce the number of items in the instrument or to request open-ended responses at another time.

Another consideration is the limited qualitative data that were collected for the study. Because of the rather large quantitative instrument (66 items), a small, 10-item, open-ended questionnaire was employed for qualitative responses from both treatment groups. While these questionnaires provided good data, and many important themes emerged as a result, this study could have benefitted from additional qualitative data collection such as focus groups and observations.

Lastly, a study that incorporates a citizen science project such as this (observing phenological changes in trees) relies on specific time periods in order to make pertinent observations. As such, this study utilized the autumn season to gain insight into several phenophases such as leaves changing color and falling from the trees. The only other significant phenophase occurrences for this study take place in the spring when trees are blooming, flowering and fruiting. Many citizen science projects rely on the seasonal data of species and thus, limit the opportunities to make observations. As with any outdoor activity, weather conditions may prohibit activities that many citizen science projects require. This limitation may impact the opportunities for schools to align projects such as these with curricula and study sequence. Additional considerations should be made for other outdoor-related risks such as walking in un-level areas, insect bites and stings, plant allergies and temperature variations. Risk mitigation helped to eliminate potential problems such as digging up and clearly marking poison ivy in the observation areas, but these methods are not always 100% successful and considerations should be made for these and other issues.

Practical Application

The NGSS recognizes the need for learners and workers with 21st Century skills and understands that the US has fallen behind other nations in terms of STEM learning (NGSS Lead States, 2013). With many states adopting the Next Generation Science Standards for school curriculum, the MobiLAP approach in citizen science contexts offers opportunities for schools to align with many standards in NGSS. These standards call for three dimensional learning including: practices (practical application of scientific investigations), crosscutting concepts (application across many forms of science and related fields, like technology) and core ideas (which emphasize the most vital lessons in science) (NGSS Lead States, 2013). The standards also call for outdoor learning opportunities, authentic experiences, engaging in community and solving real-world issues. The MobiLAP approach in citizen science contexts offers the practical application of authentic scientific inquiry through its use of real-world issues. It also makes use of a variety of crosscutting concepts depending on the area of study and the citizen science project being implemented. Finally, it emphasizes core disciplinary ideas by serving as a primary method to understanding complex ideas, has a broad range of applications across science and technology, can be learned through multiple grade levels and relates very specifically to students' interests and experiences.

The call for three dimensional learning serves as a broad view of NGSS, but much greater detail exists within the conceptual framework and may be realized through the MobiLAP approach. There are several primary areas where MobiLAP may have a significant impact toward the alignment of NGSS standards. These include: utilizing the interconnectedness of science as it applies to the real world, creating a deep understanding and knowledge of the content area, incorporating engineering and technology into science learning and the ability to prepare students for higher education, employment and citizenship.

One of the ways that educators can prepare students for the future is by making use of tools that are readily available to them. Since the majority of US teenagers own a smartphone, the MobiLAP approach is a vehicle that educators may use to facilitate student learning both in and out of the classroom. Since many of the observations in citizen science take place outdoors, students can make use of the tools they already have at their disposal and can continue the learning outside of the classroom and during non-school hours. This access to smartphones, apps and other mobile technologies affords any student the opportunity to be a citizen scientist (Ranieri & Pachler, 2014).

Educator Confidence and Training. Teachers should aim to facilitate learning in a multidisciplinary and project-based approach in order to solve real-world issues (Asghar, Ellington, Rice, Johnson, & Prime, 2012). This may prove difficult however, as many teachers do not receive the support needed to collaborate in a multidisciplinary manner (Slavit, Nelson & Lesseig, 2016). Professional development may tend to be focused in the teacher's primary subject area and may not allow for growth in related content areas. Additionally, educators get comfortable in their own subject and may not wish to collaborate with colleagues in other STEM fields (Zhang, Mclnerney, & Frechtling, 2010). Lack of support and collaboration with other STEM educators may prove to be two factors that may prevent teachers from reaching their potential as facilitators of project-based, multidisciplinary STEM instruction.

Another factor that may contribute to a lack of confidence in STEM educators in the need for specialized skills or knowledge related to project-based activities such as citizen science (Thrumbull et al., 2000; Shah & Martinez, 2016). In fact, many science teachers have not personally experienced scientific inquiry and it may be difficult for them to recognize its attributes when trying to implement it in a classroom activity (Shah & Martinez, 2016). Similarly, student-teachers use their own experiences to understand climate change and may not understand the core concepts associated with the topic (Papadimitriou, 2004). Compounding these issues is the level of technological ability needed to properly conduct project-based learning activities such as citizen science projects. Each project varies in the types of technology and the level of skill needed to effectively use them for the respective project. However, teachers should anticipate a learning curve in terms of subject content knowledge, citizen science project comprehension and technical dexterity related to operating mobile technologies, submission forms and determining coordinates using GPS devices or apps. These unfamiliar areas and the additional effort needed to master them may be enough to dissuade teachers from implementing projects such as these into their curriculum. School districts should provide appropriate professional development learning experiences and support for sustained implementation.

Instructional Time. In today's educational system, where teachers may feel as though they must "teach to the test" in order to satisfy mandates, there is little time for projects that can distract from those goals. Removing students from their regular science classroom to take part in a multi-observational citizen science program could impact instructional time for subject matter that needs to be covered. If the citizen science project includes a field trip component, students may miss content in other subjects which can negatively impact their learning in those content areas. Additionally, since many citizen science projects require the use of technology (often students' own smartphones), this increases the opportunity for students to get distracted and take away from instructional time.

Logistical Barriers. Not every high school in the United States is located in a rural area with a vast supply of natural and forested areas teeming with a variety of species in proximity to the campus. Citizen science projects rely on individuals to make and report observations on a variety of naturally occurring subjects. This may prove a difficult proposition if schools are located in urban areas and do not have direct access to the citizen science subjects they wish to study. In cases such as these, teachers may be required to organize field trips to locations where the requisite observation and reporting of species can take place. There are also opportunities for urban-based citizen science projects that examine pollutants or that make observations of available species such as insects and birds.

Logistically, the addition of a field trip complicates what may otherwise be the very simple process of taking part in citizen science. There are often costs associated with busing needs as well as food and beverage requirements. School districts also have the responsibility of obtaining permission slips, health forms, and providing qualified chaperones for trips away from campus. Since many of the activities associated with citizen science take place outdoors, precautions must be taken place for injuries, allergic reactions and illness. Thus, epipen and glucagon-certified individuals and those with basic first aid training may need to be included as part of the chaperone team. The addition of such individuals may be burdensome to the district financially and they may be in limited supply.

Costs, paperwork and personnel are not the only barriers to successfully implementing citizen science projects in schools. Technology is frequently required in order to observe, record and report data to citizen science projects. The use of technology may bring about several challenges. Students that utilize their own smartphones may incur charges when downloading apps that enable them to complete the project. For example, a citizen science project may require the exact latitude and longitude for any species observed. Some smartphones may not have a built-in GPS for students to mark sample locations and a handheld GPS unit might need to be included to gather a geolocation. The amount of data used to take part in the project may also be a barrier as many smartphone users have a monthly limit on the amount of data they can use. Additionally, since many citizen science projects take place in nature, there may not be cell phone service or WiFi available to transmit data about the project to corresponding third-party apps. There are however, solutions that collect data and synch to the cloud once a network connection becomes available. Lastly, each user has their own level of skill and comfort with the use of technology. If students are not properly trained on the use of project-related technology, the data collected for citizen science projects could be unreliable. Students need to be trained with observational protocols and use of specialized equipment in some projects such as the use of technology that measures water or air quality.

Directions for Future Research

This section outlines three major areas for future research. First, citizen science identity should be explored further to better connect the interwoven areas of climate change, STEM interest and environmental stewardship. Secondly, using the MobiLAP approach in other contexts may be beneficial toward learner identity and knowledge construction in other subject areas. Thirdly, the CEmSTEM subsection of STEM should be further refined and explored to find ways to capitalize on the potential of solving major environmental issues such as climate change.

Citizen Science Identity

The idea of citizen science identity is relatively new and the interwoven aspects of STEM interest, climate awareness and environmental stewardship should be investigated further. Gaydos and Squire (2012) investigated the impact of an educational game on citizen science identity and its connection with perceived, potential environmental stewardship. Although this study was based in a virtual citizen science game, it connected participants' feelings toward their identities as citizen scientists and their perceived potential of taking part in actions that help the environment. The Gaydos and Squire study (2012) connected one of the theorized pieces (environmental stewardship) related with citizen science identity. Wallace and Bodzin (2017) explored additional strands of this interwoven fabric and added STEM interest as a related component of citizen science identity. This current study adds another element (climate change awareness) to the composition of citizen science identity. The results indicate that participants that take part in the MobiLAP approach and form identities as citizen scientists also have increased interest in STEM, CEmSTEM, better climate awareness and perceive that they will take part in activities to help the environment. Figure 8 introduced components of citizen science identity related to this study. Future research may utilize advanced statistical methods to understand how much each component of the framework contributes to the formation of citizen science identity

MobiLAP in Other Contexts

Much like citizen science identity, the educational approach of mobile learning and authentic practice is also a relatively new field of study. There are only a few research studies that have examined this combination and with the ubiquity of mobile devices, additional research is warranted. There are many applications in which mobile learning can pair with authentic practice to provide authenticity to learning and professional development. Fields of study and jobs that require the use of mobile technologies to perform work-related tasks are of particular interest as the use of mobile devices add to the authenticity of the practice. In the case of this study, citizen science fits nicely as many authentic tasks related to observing, recording and reporting data can be completed by using a smartphone.

CEmSTEM Exploration

This study defined a new subsection of STEM which places an emphasis on the conservation and environmentally-minded aspects of science, technology, engineering and mathematics. Many citizen science programs offer experiences where participants can obtain first-hand knowledge about climate change and the environment. This hands-on approach combined with mobile learning demonstrated how participants may create interest in CEmSTEM. A multidisciplinary approach to teaching and learning STEM may provide a holistic view of the problems endangering our world and may create a pro-environmental ethos to aid such issues.

As this is the first study related to CEmSTEM, there is a great need to further develop this newly formed concept. Further definition, correlation and causation needs to take place in order to understand how the next generation of STEM workers and educators may impact and influence our world while adhering to their beliefs as conservationists and environmentally-minded individuals. Longitudinal research needs to occur to determine if STEM interest and CEmSTEM interest generated in early high school years is indeed a predictor of future STEM careers. Likewise, further study needs to take place to see if the climate change perceptions, environmental stewardship and citizen science identity developed in this study have a lasting impact on participants.

Final Thoughts

As the United States educational system develops methods to enhance STEM education and increase climate change awareness, citizen science may be emerging as a viable solution to both issues. Citizen science engages and empowers students to have an active role in their learning and instills a pro-environmental ethos (Groulx, Bribois, Lemieux, Winegardner & Fishback, 2017) while creating STEM interest (Johnson et al., 2014; Toomey & Domroese, 2013). The solution is simple, yet effective, as any student with a smartphone can be a citizen scientist (Ranieri & Pachler, 2014). The formation of citizen science identity may have a long-lasting impact in the areas of STEM interest, climate change awareness and environmental stewardship. With a large majority of teens having access to a smartphone, the adoption of citizen science as a method to enhance STEM education and increase climate change awareness seems to be definitive solution.

There are a plethora of cost-effective educational opportunities within citizen science. SciStarter (Science for Citizens LLC, 2017) boasts more than 1,600 citizen science research projects, many of which have curriculum implementation guides for multiple grade levels (Brown, Abell, Demir, & Schmidt, 2006). Many of these opportunities use mobile technologies to enhance and extend the learning beyond the classroom. As teachers and schools look for low-cost and engaging ways to align to standards and provide students with authentic experiences, the MobiLAP approach in citizen science contexts may be a solution worth consideration.

While citizen science is not the panacea to all of the educational issues in the United States, it does show promise in generating interest in STEM fields, improving STEM education and increasing climate change awareness and understandings. Students that take part in citizen science may be able to see and experience climate change for themselves; turning an abstract concept into a personal reality. Perhaps more importantly, it helps to develop a conservation and environmentally-minded STEM interest in which innovation is intertwined with conservation. Citizen science is not the panacea to all of the educational issues in the United States, but it is a powerful tool that may just change the world.

References

Adams Becker, S., Freeman, A., Giesinger Hall, C., Cummins, M., & Yuhnke, B. (2016). *NMC/CoSN horizon report: 2016 K-12 edition*. Austin, TX: The New Media Consortium

Adams, R. B., & Kirchmaier, T. (2016). Women on boards in finance and STEM industries. *The American Economic Review, 106*(5), 277-281.

Adger, W. N. (2003). Social capital, collective action, and adaptation to climate change. *Economic Geography, 79*(4), 387-404. doi: 10.1111/j.1944-8287.2003.tb00220.x

Al Mosawi, A., & Wali, E. A. (2015). Exploring the potential of mobile applications to support learning and engagement in elementary classes. *International Journal of Mobile and Blended Learning (IJMBL), 7*(2), 33-44. doi:10.4018/ijmbl.2015040103

Anderson, M. (2014, September 15). *The race gap in science knowledge*. Retrieved from http://www.pewresearch.org/fact-tank/2015/09/15/the-race-gap-in-science-knowledge/

Annenberg Learner. (2016). *Journey North*. Retrieved from https://www.learner.org/jnorth/

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal, 49*(5), 881-908.

Archer, L., & Tomei, A. (2014). "I like science but it's not for me": The need to improve STEM careers education. *School Science Review, 95*(352), 112-118.

Asghar, A., Ellington, R., Rice, E., Johnson, F., & Prime, G. M. (2012). Supporting STEM education in secondary science contexts. *Interdisciplinary Journal of Problem-based Learning, 6*(2), 85-125.

Ashforth, B. E., & Mael, F. (1989). Social identity theory and the organization. *Academy of Management Review, 14*(1), 20-39.

Auburn University College of Sciences and Mathematics. (2017). *STEM summer bridge program.* Retrieved from http://www.auburn.edu/cosam/departments/diversity/summerbridge/

Azizan, M. H., & Wahid, N. A (2012). A proposed model on environmental stewardship. *Procedia – Social and Behavioral Sciences, 65*(3), 587-592. doi: 10.1016/j.sbspro.2012.11.169

Baloian, N., & Zurita, G. (2012). Ubiquitous mobile knowledge construction in collaborative learning environments. *Sensors, 12*(6), 6995-7014.

Barr, S., & Pollard, J. (2017). Geographies of transition: Narrating environmental activism in an age of climate change and peak oil. *Environment & Planning*, *49*(1), 47-64. doi: 10.1177/0308518X16663205

Bastedo, M. N., & Jacquette, O. (2011). Running in place: Low-income students and the dynamics of higher education stratification. *Educational Evaluation and Policy Analysis, 33*(3), 318-339.

Baya'a, N. F., & Daher, W. M. (2009). Learning mathematics in an authentic mobile environment: The perceptions of students. *International Journal of Interactive Mobile Technologies, 3*(1), 6-14.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39-43. doi:10.1080/00098650903505415

Bergeron, D. H., & Pekins, P. J. (2014). Evaluating the usefulness of three indices for assessing winter tick abundance in northern New Hampshire. *Alces: A Journal Devoted to the Biology and Management of Moose, 50*(1), 1-15.

Bernard, H. R. (2017). *Research methods in anthropology: Qualitative and quantitative approaches*. Lanham, Maryland: Rowman & Littlefield.

Blue, C. E., Blevins, L. G., Carriere, P., Gabriele, G., Kemnitzer, S., Rao, V., & Ulsoy, G. (2005). The engineering workforce: Current state, issues, and recommendations: Final report to the assistant director of engineering. *National Science Foundation*.

Bodzin, A. M., Anastasio, D., Sahagian, D., Peffer, T., Dempsey, C., & Steelman, R. (2014). Investigating climate change understandings of urban middle-level students. *Journal of Geoscience Education, 62*(3), 417-430.

Bonney, R., Phillips, T. B., Ballard, H. L., Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2-16. doi: 10.1177/0963662515607406

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenburg, K. V., . . . Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience, 59*(11), 977-984. doi: 10.1525/ bio.2009.59.11.9

Boscia, T. (2013). Serious about STEM. *Human Ecology, 41*(2), 9-11.

Both, C., Artemyev, A. V., Blaauw, B., & Visser, M. E. (2004). Large-scale geographical variation confirms that climate change causes birds to lay earlier. *Proceedings of the Royal B: Biological Sciences, 271*(1549), 1657-1662. doi: 10.1098/rspb.2004.2770

Branagan, M. (2005). Environmental education, activism and the arts. *Convergence, 38*(4).

Bray, A., & Tangney, B. (2016). Enhancing student engagement through the affordances of mobile technology: A 21st century learning perspective on Realistic Mathematics Education. *Mathematics Education Research Journal, 28*(1), 173-197.

Brookfield, S. D. (2002). Using the lenses of critically reflective teaching in the community college classroom. *New Directions for Community Colleges, 2002*(118), 3-38. doi: 10.1002/cc. 61

Brown, P. L., Abell, S. K., Demir, A., & Schmidt, F. J. (2006). College science teachers' views of classroom inquiry. *Science Education, 90*(5), 784-802.

Brulle, R. J., Carmichael, J., & Jenkins, J. C. (2012). Shifting public opinion on climate change: An empirical assessment of factors influencing concern over climate change in the U.S., 2002-2010. *Climate Change, 114*(2), 169-188. doi: 10.1007/s10584-012-0403-y

Bunten, R., & Dawson, V. (2014). Teaching climate change science in senior secondary school: Issues, barriers and opportunities. *Teaching Science, 60*(1), 10-18.

CaraDonna, P. J., Iler, A. M., & Inouye, D. W. (2014). Shifts in flowering phenology reshape a subalpine plant community. *Proceedings of the National Academy of Sciences, 111*(13), 4916-4921.

Carli, L. L., Alawa, L., Lee, Y., Zhao, B., & Kim, E. (2016). Stereotypes about gender and science: Women ≠ scientists. *Psychology of Women Quarterly, 40*(2), 244-260. doi: 10.1177/0361684315622645

Carpenter, B. (2012). National survey of hunters & anglers. *National Wildlife Federation*. Retrieved from http://www.nwf.org/~/media/PDFs/Wildlife/Sportsmen/2012PollSlides.ashx

Casey, M. B., Nuttall, R., Pezaris, E., & Benbow, C. P. (1995). The influence of spatial ability on gender differences in math: College entrance test scores across diverse samples. *Developmental Psychology, 31*(4), 697-705.

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal* *of Research in Science Teaching, 51*(5), 555-580. doi:10.1002/tea.21146

Charleston, L. J., George, P. L., Jackson, J. F., Berhanu, J., & Amechi, M. H. (2014). Navigating underrepresented STEM spaces: Experiences of Black women in US computing science higher education programs who actualize success. *Journal of Diversity in Higher Education, 7*(3), 166-176.

Chen, C., Liu, G., & Hwang, G. (2016). Interaction between gaming and multistage guiding strategies on students' field trip mobile learning performance and motivation: Gaming and guiding strategies for mobile learning. *British Journal of Educational Technology, 47*(6), 1032-1050. 10.1111/bjet.12270

Chen, X. (2009). *Students who study science, technology, engineering, and mathematics (STEM) in postsecondary education*. Washington, DC: National Center for Education.

Chevillot, X., Drouineau, H., Lambert, P., Carassou, L., Sautour, B., & Lobry, J. (2017). Toward a phenological mismatch in estuarine pelagic food web? *PloS one, 12*(3), 1-21.

Chiang, T. H., Yang, S. J., & Hwang, G. J. (2014). An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Journal of Educational Technology & Society, 17*(4), 352.

Chicago Botanic Garden. (2017). *Project BudBurst for grades 9-12 educators*. Retrieved from http://budburst.org/education_9-12

Chinn, P. W. (2009). Authentic science experiences as a vehicle for assessing orientation towards science and science careers relative to identity and agency: A response to “learning from the path followed by Brad”. *Cultural Studies of Science Education, 4*(3), 639-647

Chornesky, E. A. (2016). Building bridges between climate-change science and conservative practice. *BioScience, 66*(7), 611-612.

Clayton, S. (2003). Environmental identity: A conceptual and an operational definition. In S. Clayton & S. Opotow (Eds.), *Identity and the natural environment* (pp. 45-65). Cambridge, MA: MIT Press.

Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A., & Schwartz, M. D. (2007). Shifting plant phenology in response to global change. *Trends in Ecology & Evolution, 22*(7), 357-365.

Clements, D. H., & Sarama, J. (2016). Math, science, and technology in the early grades. *The Future of Children, 26*(2), 75-94.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.).* New York: Lawrence Erlbaum Associates.

Columbia University. (2011). *Leafsnap*. Retrieved from http://leafsnap.com/

Common Sense Media (2016, May 3). *Dealing with devices: The parent-teen dynamic. Are we addicted?* Retrieved from https://www.commonsensemedia.org/technology-addiction-concern-controversy-and-finding-balance-infographic#

Cook, J., Nuccitelli, D., Green, S. A., Richardson, M., Winkler, B., Painting, R., . . . Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters, 8*(2), 1-7. doi: 10.1088/1748-9326/8/2/024 024

Cook, M. (2015). Business, tech education emphasized at conference: Wal-mart SVP cites need in NWA for employees educated in STEM fields. *Arkansas Business, 32*(26), 1-3

Cooper, C., Dickinson, J., Phillips, T., & Bonney, R. (2007). Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society, 12*(2), 1-11.

Cooper, C. B. (2011). Media literacy as a key strategy toward improving public acceptance of climate change science. *BioScience, 61*(3), 231-237.

Cooper, C. B., Shirk, J., & Zuckerberg, B. (2014). The invisible prevalence of citizen science in global research: Migratory birds and climate change. *PLoS ONE, 9*(9), 1-5.

Cordero, E., Todd, A. M., & Abellerra, D. (2008). Climate change education and the ecological footprint. *Bulletin of American Meteorological Society, 89*(6) 865-872.

Cornell University. (2017). *FeederWatch*. Retrieved from http://feederwatch.org

Couvet, D., Jiguet, F., Julliard, R., Levrel, H., & Teyssèdre, A. (2008). Enhancing citizen contributions to biodiversity science and public policy. *Interdisciplinary Science Reviews, 33*(1), 95-103.

Cox, C., Reynolds, B., Schunn, C., & Schuchardt, A. (2016). Using mathematics and engineering to solve problems in secondary level biology. *Journal of STEM Education: Innovations and Research, 17*(1), 22-30.

Cranton, P., & King, K. P. (2003). Transformative learning as a professional development goal. *New Directions for Adult and Continuing Education, 2003*(98), 31-37.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297-334.

Cronje, R., Rohlinger, S., Crall, A., & Newman, G. (2011). Does participation in citizen science improve scientific literacy? A study to compare assessment methods. *Applied Environmental Education and Communication*, *10*(3), 135-145.

Cushing, D. H. (1969). The regularity of the spawning season of some fishes. *ICES Journal of Marine Science, 33*(1), 81-92.

Dana Technology Inc., (2017). *PictureThis*. Retrieved from https://www.picturethisai.com

Demarque, C., Apostolidis, T., & Joule, R. V. (2013). Consideration of future consequences and pro-environmental decision making in the context of persuasion and binding commitment. *Journal of Environmental Psychology, 2013*(36), 214-220.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). *The Sage handbook of qualitative research*. Thousand Oaks, CA: Sage.

de Oliveira, W. J. F. (2009). The use of education in environmental activism. *Pro-Posições, 20*(2), 77-92. doi: 10.1590/S0103-73072009000200006

De Pietro, O. (2013). Authentic and situated learning with the use of an adaptive search engine and a QR-code in mobile mode. *International Journal of Digital Literacy and Digital Competence*, *4*(3), 19-30.

Devictor, V., Whittaker, R. J., & Beltrame, C. (2010). Beyond scarcity: Citizen science programmes as useful tools for conservation biogeography. *Diversity and Distributions, 16*(3), 354-362.

Dickinson, J. L., Crain, R., Yalowitz, S., & Cherry, T. M. (2013). How framing climate change influences citizen scientists' intentions to do something about it. *The Journal of Environmental Education, 44*(3), 145-158.

Dickinson, J. L., Shirk, J., Conter, D., Bonney, R., Crain, R. L., Martin, J., . . . Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology & the Environment, 10*(6), 291-297. doi: 10.1890/ 11023L

DiPrete, T. A., & Buchmann, C. (2013). *The rise of women: The growing gender gap in education and what it means for American schools*. New York: Russell Sage Foundation.

Discover Life. (2015). *Bee Hunt!* Retrieved from http://www.discoverlife.org/bee/

Douglas, K. M., & Sutton, R. M. (2015). Climate change: Why the conspiracy theories are dangerous. *Bulletin of the Atomic Scientists*, *71*(2), 98-106.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanou, P., . . . Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1446. doi: 10.1037/0012-1649.43.6.1428.

EarthEcho International. (2017). *EarthEcho Water Challenge*. Retrieved from http://www.worldwatermonitoringday.org/

Ellwood, E. R., Diez, J. M., Ibáñez, I., Primack, R. B., Kobori, H., Higuchi, H., & Silander, J. A. (2012). Disentangling the paradox of insect phenology: Are temporal trends reflecting the response to warming? *Oecologia, 168*(4), 1161-1171. doi:10.1007/s00442-011-2160-4

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM education, 3*(1), 1-8.

Environmental Nature Center. (2016). *Project based learning*. Retrieved from http://encenter.org/visit-us/programs/traveling-naturalist/project-based-learning/

EPA. (2016). *Environmental stewardship*. Retrieved from https://archive.epa.gov/stewardship/ web/html

Etkin, D., & Ho, E. (2007). Climate change: Perceptions and discourses of risk. *Journal of Risk Research, 10*(5), 623-641.

Falk, B. G., Snow, R. W., & Reed, R. N. (2016). Prospects and limitations of citizen science in invasive species management: A case study with Burmese pythons in Everglades National Park. *Southeastern Naturalist, 15*(8), 89-102.

Farnsworth, V. (2010). Conceptualizing identity, learning and social justice in community-based learning. *Teaching and Teacher Education, 26*(7), 1481-1489

Fitchett, J. M., Grab, S. W., & Thompson, D. I. (2015). Plant phenology and climate change: Progress in methodological approaches and application. *Progress in Physical Geography, 39*(4), 460-482. doi: 10.1177/0309133315578940

Follett, R., & Strezov, V. (2015). An analysis of citizen science based research: Usage and publication patterns. *PLoS ONE, 10*(11), 1-14. doi: 10.1371/journal.pone.0143687

Ford, M. J., & Wargo, B. M. (2007). Routines, roles, and responsibilities for aligning scientific and classroom practices. *Science Education, 91*(1), 133-157.

Forgione, P. D. (1998, April 3). *Achievement in the United States: Progress since a nation at risk*. Retrieved from https://nces.ed.gov/Pressrelease/reform/

Gaydos, M. J., & Squire, K. D. (2012). Role playing games for scientific citizenship. *Cultural Studies of Science Education, 7*(4), 821-844.

Gilliam, M., Bouris, A., Hill, B., & Jagoda, P. (2016). The source: An alternate reality game to spark STEM interest and learning among underrepresented youth. *Journal of STEM Education: Innovations and Research, 17*(2), 14-20.

Goldey, E. S. (2010). Leadership for undergraduate STEM reform: Weaving a communal web. *Journal of Leadership Studies, 8*(1), 51-56. doi: 10.1002/jls

Grodsky, E., & Pager, D. (2001). The structure of disadvantage: Individual and occupational determinants of the Black-White wage gap. *American Sociological Review, 66*(4), 542-567.

Grossman, J. M., & Porche, M. V. (2014). Perceived gender and racial/ethnic barriers to STEM success. *Urban Education, 49*(6), 698-727.

Groulx, M., Brisbois, M. C., Lemieux, C. J., Winegardner, A., & Fishback, L. (2017). A role for nature-based citizen science in promoting individual and collective climate change action? A systematic review of learning outcomes. *Science Communication, 39*(1), 45-76. doi: 10.1177/1075547016688324

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*(3-4), 153-166.

Hallar, A. G., McCubbin, I. B., & Wright, J. M. (2011). CHANGE: A place-based curriculum for understanding climate change at storm peak laboratory, Colorado. *Bulletin of the American Meteorological Society, 92*(7), 909-918. doi:10.1175/2011BAMS3026.1

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Gernsbacher, M. A. (2007). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest, 8*(1), 1-51. doi: 10.1111/j/1529-1006.2007.00032.x

Harackiewicz, J. M., Rozek, C. R., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological Science, 23*(8), 899-906. doi: 10.1177/0956797611435530

Harding, J. (2013). *Qualitative data analysis from start to finish*. Thousand Oaks, CA: Sage.

Harkavy, I., Cantor, N., & Burnett, M. (2015). Realizing STEM equity and diversity through higher education-community engagement. *Netter Center for Community Partnerships Supported White Paper*, 1-52.

Harvey, D. C. (2016). The precarious nature of environmental activism. *Humanity & Society, 40*(4), 371-378. doi: 10.1177/01605976166697755

Haston, W., & Russell, J. A. (2012). Turning into teachers: Influences of authentic context learning experiences on occupational identity development of preservice music teachers. *Journal of Research in Music Education, 59*(4), 369-392

Haunschild, R., Bornmann, L., & Marx, W. (2016). Climate change research in view of bibliometrics. *PLoS ONE, 11*(7), 1-19. doi: 10.1371/journal.pone.0160393

Heflin, H., Shewmaker, J., & Nguyen, J. (2017). Impact of mobile technology on student attitudes, engagement, and learning. *Computers & Education, 107*(1), 91-99. doi:10.1016/j.compedu.2017.01.006

Hill, A. M., & Smith, H. A. (2005). Research in purpose and value for the study of technology in secondary schools: A theory of authentic learning. *International Journal of Technology and Design Education, 15*(1), 19-32. doi:10.1007/s10798-004-6195-2

Hill, J. R., Reeves, T. C., & Heidemeier, H. (2000). *Ubiquitous computing for teaching, learning, and communicating: Trends, issues & recommendations* [White paper]. Retrieved from http://www.lpsl.coe.edu/Projects/AAlaptop/pdf/UbiquitousComputing.pdf

Hiller, S. E., & Kitsantas, A. (2014). The effect of a horseshoe crab citizen science program on middle school student science performance and STEM career motivation. *School Science and Mathematics, 114*(6), 302-311.

Hillier, A., Kelly, R. P., & Klinger, T. (2016). Narrative style influences citation frequency in climate change science. *PLoS ONE, 11*(12), 1-12. doi: 10.1371/journal.pone.0167983

Hossain, M., & G Robinson, M. (2012). How to motivate US students to pursue STEM careers. *US-China Education Review, 4*(1), 442-451.

Hsin, A., & Xie, Y. (2014). Explaining Asian Americans' academic advantage over whites. *Proceedings of the National Academy of Sciences, 111*(23), 8416-8421.

Hsu, Y. C., & Ching, Y. H. (2012). Mobile microblogging: Using Twitter and mobile devices in an online course to promote learning in authentic contexts. *The International Review of*

Research in Open and Distributed Learning, *13*(4), 211-227.

Hu, S., & Chen, J. (2016). Place-based inter-generational communication on local climate improves adolescents' perceptions and willingness to mitigate climate change. *Climatic Change, 138*(3-4), 425-438. doi:10.1007/s10584-016-1746-6

Huber, M. T. P., Hutchings, P., Richard, G., Miller, R., & Breen, M. (2007). Leading initiatives for integrating learning. *Liberal Education, 93*(2), 46-51.

Hughes, L. (2003). Climate change and Australia: Trends, projections and impacts. *Austral Ecology, 28*(4), 423-443.

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The single sex debate for girls in science: A comparison between two informal science programs on middle school students' STEM identity formation. *Research in Science Education, 43*(5), 1979-2007.

Hummel, K. A., & Hlavacs, H. (2003). Anytime, anywhere learning behavior using a web-based platform for a university lecture. *Proceedings of the SSGRR 2003 Winter Conference*, L'Aquila, Italy.

Hursen, C. (2016). The impact of curriculum developed in line with authentic learning on the teacher candidates' success, attitude and self-directed learning skills. *Asia Pacific Education Review, 17*(1), 73-86.

Hyde, J. S., Lindberg S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*(5888), 494-495. doi: 10.1126/science. 1160364

Illeris, K. (2013). *Transformative learning and identity*. London, England: Routledge.

Ing, M., & Nylund-Gibson, K. (2013). Linking early science and mathematics attitudes to long-term science, technology, engineering, and mathematics career attainment: Latent class analysis with proximal and distal outcomes. *Educational Research and Evaluation – An International Journal on Theory and Practice, 19*(6), 510-524. doi: 10.1080/13803611. 2013.806218

Inkley, D., Price, M., Glick, P., Losoff, T., & Stein, B. (2013). *Nowhere to run: Big game wildlife in a warming world.* Retrieved from http://www.nwf.org/~/media/PDFs/Global-Warming/Reports/NowheretoRun-BigGameWildlife-LowResFinal_110613.ashx

Jacobo, J., (2017, October 25). 103-degree heat shatters World Series record. *ABC News*. Retrieved from http://abcnews.go.com/Sports/103-degree-heat-shatters-world-series-record/story?id=50695086

Jamelske, E., Barrett, J., & Boulter, J. (2013). Comparing climate change awareness, perceptions, and beliefs of college students in the United States and China. *Journal of Environmental Studies and Sciences, 3*(3), 269-278.

Johnson, M. F., Hannah, C., Acton, L., Popovici, R., Karanth, K. K., & Weinthal, E. (2014). Network environmentalism: Citizen scientists as agents for environmental advocacy. *Global Environmental Change, 29*(1), 235-245. doi:10.1016/j.gloenvcha.2014.10.006

Jones, S. (2015). The role of climate change science and standing in climate change cases: Analysis and implications. *University of Florida Journal of Law & Public Policy, 26*(2), 243-264.

Jones, V. R. (2014). Teaching STEM: 21st century skills. *Children's Technology & Engineering, 18*(4), 11-13.

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge gain and behavioral change in citizen science programs. *Conservation Biology*, *25*(6), 1148-1154.

Kapi'olani Community College. (2012). *STEM program: 2012 summer bridge*. Retrieved from http://stem.kapiolani.hawaii.edu/2012-summer-bridge/

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15*(3), 169-182.

Katz, J., & Henry, M. (1988). *Turning professors into teachers*. New York, NY: MacMillan.

Kelley, A. L., Hanson, P. R., & Kelley, S. A. (2015). Demonstrating the effects of ocean acidification on marine organisms to support climate change understanding. *The American Biology Teacher, 77*(4), 258-263.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 1-11.

Kier, M. W., Blanchard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the STEM career interest survey (STEM-CIS). *Research in Science Education, 44*(3), 461-481. doi:10.1007/s11165-013-9389-3

Knotts, G., Henderson, L., Davidson, R. A., Swain, J. D. (2009). The search for authentic practice across the disciplinary divide. *College Teacher, 57*(4), 188-196.

Koch, A. J., D'Mello, S. D., & Sackett, P. R. (2015). A metanalysis of gender stereotypes and bias in experimental simulations of employment decision making. *Journal of Applied Psychology, 100*(1), 128–161. doi: 10.1037/a0036734

Kriegler, E., Weyant, J. P., Blanford, G. J., Krey, V., Clarke, L., Edmonds, J., ... & Rose, S. K. (2014). The role of technology for achieving climate policy objectives: Overview of the EMF 27 study on global technology and climate policy strategies. *Climatic Change, 123*(3-4), 353-367.

Kuczynski, L., Chevalier, M., Laffaille, P., Legrand, M., & Grenouillet, G. (2017). Indirect effect of temperature on fish population abundances through phenological changes. *PloS one, 12*(4), 1-13.

Kullenberg, C., & Kasperowski, D. (2016). What is citizen science?: A scientometric meta-analysis. *PLoS ONE, 11*(1), 1-16. doi: 10.1371/journal.pone.0147152

LaForce, M., Noble, E., King, H., Century, J., Blackwell, C., Holt, S., ... & Loo, S. (2016). The eight essential elements of inclusive STEM high schools. *International Journal of STEM Education, 3*(1), 1-11.

Lai, C., Yang, J., Chen, F., Ho, C., & Chan, T. (2007). Affordances of mobile technologies for experiential learning: The interplay of technology and pedagogical practices. *Journal of Computer Assisted Learning, 23*(4), 326-337. doi: 10.1111/j.1365-2729.2007.00237.x

Lamb, A. (2016). Citizen science part 1: Place-based STEM projects for school libraries. *Teacher Librarian, 43*(4), 64-69.

Lambert, J. L., & Bleicher, R. E. (2013). Climate change in the preservice teacher's mind. *Journal of Science Teacher Education, 24*(6), 999-1022.

Lareau, A. (2011). *Unequal childhoods: Class, race, and family life, with an update a decade later*. Berkeley, CA: University of California Press.

Lee, T. M., Markowitz, E. A., Howe, P. D., Ko, C., & Leiserowitz, A. (2015). Predictors of public climate change awareness and risk perception around the world. *Nature Climate Change, 5*(1), 1014-1020. doi:10.1038/nclimate2728

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2015). *Climate change in the American mind*. New Haven, CT: Yale University and George Mason University.

Leiserowitz, A., Smith, N., & Marlon, J. R. (2011). *American teens' knowledge of climate* *change.* Yale University. New Haven, CT: Yale Project on Climate Change Communication. Retrieved from http://climatecommunication.yale.edu/wp-content/uploads/2016/02/2011_04_American-Teens%E2%80%99-Knowledge-of-Climate-Change.pdf

Lewandowsky, S., Oreskes, N., Risbey, J. S., Newell, B. R., & Smithson, M. (2015). Seepage: Climate change denial and its effect on the scientific community. *Global Environmental Change, 33*(1), 1-13.

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate climate change. *Policy Science, 45*(2), 123-152. doi:10.1007/s11077-012-9151-0

Liao, C., Motter, J. L., & Patton, R. M. (2016). Tech-savvy girls: Learning 21st-century skills through STEAM digital artmaking. *Art Education, 69*(4), 29-35.

Lieth, H. (1970). Phenology in productivity studies. In: D. Reichle (Ed.), *Analysis of temperate forest ecosystems* (pp. 29-46). New York, NY: Springer.

Liu, M., Horton, L., Kang, J., Kimmons, R., & Lee, J. (2013). Using a ludic simulation to make learning of middle school space science fun. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS), 5*(1), 66-86.

Liu, M., Scordino, R., Geurtz, R., Navarrete, C., Ko, Y., & Lim, M. (2014). A look at research on mobile learning in K-12 education from 2007 to the present. *Journal of Research on Technology in Education, 46*(4), 325-372. doi: 10.1080/15391523.2014.925681

Lombardi, D. I., & Sinatra, G. (2012). College students' perceptions about the plausibility of human-induced climate change. *Research in Science Education, 42*(2), 201-217. doi:10.1007/s11165-010-9196-z

Louv, R. (2005). *Last child in the woods: Saving our children from nature-deficit disorder*. New York: Algonquin Books.

Lowell, B. L., & Regets, M. C. (2006). *A half-century snapshot of the STEM workforce, 1950 to 2000*. Washington, DC : Commission on Professionals in Science and Technology.

Mallinson, C., & Charity Hudley, A. H. (2014). Partnering through science: Developing linguistic insight to address educational inequality for culturally and linguistically diverse students in US STEM education. *Language and Linguistics Compass, 8*(1), 11-23.

Maltese, A. V., Melki, C. S., & Wiebke, H. L. (2014). The nature of experiences responsible for the generation and maintenance of interest in STEM. *Science Education, 98*(6), 937-962.

Mann, A., & DiPrete, T. A. (2013). Trends in gender segregation in the choice of science and engineering majors. *Social Science Research, 42*(6), 1519-1541.

Manson, S. M., Martinez, D. F., Buchwald, D. S., Rubio, D. M., & Moss, M. (2015). Vision, identity, and career in the clinical and translational sciences: Building upon the formative years. *Clinical and Translational Science, 8*(5), 568-572.

Marshall, S. P. (2009). Re-imagining specialized STEM academies: Igniting and nurturing decidedly different minds, by design. *Roeper Review, 32*(1), 48-60.

Massey, D. S. (1993). *American apartheid: Segregation and the making of the underclass*. Cambridge, MA: Harvard University Press.

McBride, B., Brewer, C., Berkowitz, A., & Borrie, W. (2013). Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere, 4*(5), 1-20.

MacCallum, K., Day, S., Skelton, D., & Verhaart, M. (2017). Mobile affordances and learning theories in supporting and enhancing learning. *International Journal of Mobile and Blended Learning (IJMBL), 9*(2), 61-73.

Martinez, M., (2016). *Flint, Michigan: Did race and poverty factor into water crisis?* Retrieved from https://www.cnn.com/2016/01/26/us/flint-michigan-water-crisis-race-poverty/index.html

McCright, A. M., Charters, M., Dentzman, K., & Dietz, T. (2016). Examining the effectiveness of climate change frames in the face of a climate change denial counter frame. *Topics in Cognitive Science, 8*(1), 76-97.

McCright, A. M., & Dunlap, R. E. (2011). The politicization of climate change and polarization in the American public's views of global warming, 2001–2010. *The Sociological Quarterly, 52*(2), 155-194.

McCright, A. M., O'Shea, B. W., Sweeder, R. D., Urquhart, G. R., & Zeleke, A. (2013). Promoting interdisciplinarity through climate change education. *Nature Climate Change, 3*(8), 713-716.

McCune, V. (2009). Final year biosciences students' willingness to engage: Teaching-learning environments, authentic learning experiences and identities. *Studies in Higher Education, 34*(3), 347-361

McDermott, P., & Mack, K. M. (2014). The twenty-first-century case for inclusive excellence in STEM. *Peer Review, 16*(2), 4-5.

Mele, C. (2017, March 18). Ice Bends, Doesn't Break, Cherry Blossoms. *New York Times*, p. A10.

Memmott, J., Craze, P. G., Waser, N. M., & Price, M. V. (2007). Global warming and the disruption of plant–pollinator interactions. *Ecology Letters, 10*(8), 710-717.

Merlin, M., (2017, October 13). Fall foliage coming, just delayed, experts say. *Morning Call*. Retrieved from http://www.mcall.com/news/breaking/mc-nws-lehigh-valley-foliage-20171011-story.html

Metcalf, D., Milrad, M., Cheek, D., Raasch, S., & Hamilton, A. (2008). My sports pulse: Increasing student interest in STEM disciplines through sports themes, games and mobile technologies. *Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education (wmute 2008)*. doi:10.1109/wmute.2008.38

Meyer, N. J., Scott, S., Strauss, A. L., Nippolt, P. L., Oberhauser, K. S., & Blair, R. B. (2014). Citizen science as a REAL environment for authentic scientific inquiry. *Journal of Extension, 52*(4), 1-6.

Mezirow, J. (1978). Perspective transformation. *Adult Education Quarterly, 28*(2), 100-110.

Mezirow, J. (2009). An overview on transformative learning. In: Knud Illeris (ed.) Contemporary theories of learning. *Learning theorists... in their own words* (pp. 90-105). London: Routledge.

Miller, J. D., & Kimmer, L. G. (2012). Pathways to a STEM profession. *Peabody Journal of Education, 87*(1), 26-46.

Milfont, T. L., Wilson, M. S., & Sibley, C. G. (2017). The public's belief in climate change and its human cause are increasing over time. *PloS one, 12*(3), 1-9.

Min, P. G., & Jang, S. H. (2015). The concentration of Asian Americans in STEM and health-care occupations: An intergenerational comparison. *Ethnic and Racial Studies, 38*(6), 841-859. doi:10.1080/01419870.2014.941891

Moakler, M. W., & Kim, M. M. (2014). College major choice in STEM: Revisiting confidence and demographic factors. *The Career Development Quarterly, 62*(2), 128-142. doi:10.1002/j.2161-0045.2014.00075.x

Mocombe, P. C. (2016). The death of Imhotep a hermeneutical framework for understanding the lack of black males in STEM fields. *Education and Urban Society*, *2016*(1)1-18. doi: 10.1177/0013124516677080.

Mohr-Schroeder, M. J., Jackson, C., Miller, M., Walcott, B., Little, D. L., Speler, L., . . . Schroeder, D. C. (2014). Developing middle school students' interests in STEM via summer learning experiences: See blue STEM camp. *School Science and Mathematics, 114*(6), 291-301. doi:10.1111/ssm.12079

Møller, A. P., Rubolini, D., & Lehikoinen, E. (2008). Populations of migratory bird species that did not show a phenological response to climate change are declining. *Proceedings of the National Academy of Sciences, 105*(42), 16195-16200.

Monteith, K. L., Bleich, V. C., Stephenson, T. R., Pierce, B. M., Conner, M. M., Klaver, R. W., & Bowyer, R. T. (2011). Timing of seasonal migration in mule deer: Effects of climate, plant phenology, and life- history characteristics. *Ecosphere, 2*(4), 1-34.

Moodley, T., & Aronstam, S. (2016). Authentic learning for teaching reading: Foundation phase pre-service student teachers' learning experiences of creating and using digital stories in real classrooms. *Reading & Writing, 7*(1), 1-10.

Moore, J. C. (2012). Transitional to formal operational: Using authentic research experiences to get non-science students to think more like scientists. *European Journal of Physics Education, 3*(4), 1-12.

Morrison, J., Roth McDuffie, A., & French, B. (2015). Identifying key components of teaching and learning in a STEM school. *School Science and Mathematics, 115*(5), 244-255.

Morrison, M., Duncan, R., & Parton, K. (2015). Religion does matter for climate change attitudes and behavior. *PloS one*, *10*(8), 1-16.

Mullich, J. (2013). Rising to the challenge: America's math and science curriculum is key to future competitiveness. *Wall Street Journal*. Retrieved from http://online.wsj.com/ad/article/mathscience-rising

Murphy, P., Lunn, S., & Jones, H. (2006). The impact of authentic learning on students' engagement with physics. *The Curriculum Journal, 17*(3), 229-246.

Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011). Special issue: Racial and ethnic minority students' success in STEM education. *ASHE Higher Education Report, 36*(6), 1-140.

Nadelson, L. S., Seifert, A., Moll, A. J., & Coats, B. (2012). i-STEM summer institute: An integrated approach to teacher professional development in STEM. *Journal of STEM Education: Innovations and Research, 13*(2), 69-83.

NASA. (2016a). *ESTEEM project history*. Retrieved from https://www.nasa.gov/education/esteem/history

NASA. (2016b). *S'cool* Retrieved from https://scool.larc.nasa.gov/rover.html

NASA. (2017a). *NASA ESTEEM cohort*. Retrieved from http://www.nasa.gov/education/esteem/cohort

NASA. (2017b). *Scientific consensus: Earth's climate is warming*. Retrieved from https://climate. nasa.gov/scientific-consensus/

NASA's Jet Propulsion Laboratory. (2016). *Global temperature*. Retrieved from http://climate.nasa.gov/vital-signs/global-temperature/.

National Action Council for Minorities in Engineering. (2013). *Underrepresented minorities in*

STEM. Retrieved from http://www.nacme.org/underrepresented-minorities

National Alliance for Partnerships in Equity. (2018). *STEM equity*. Retrieved from https://www.napequity.org/stem/

National Centers for Environmental Information. (2017). *Monthly summaries map*. Retrieved from https://gis.ncdc.noaa.gov/maps/clim/summaries/monthly

National Institute of Environmental Health Sciences. (2017). *Environmental stewardship*. Retrieved from https://www.niehs.nih.gov/about/stewardship/

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: Government Printing Office.

National Science Board (US). (2007). *A national action plan for addressing the critical needs of the US science, technology, engineering, and mathematics education system*. National Science Foundation.

The National Wildlife Federation (2012, September 25). *2012 national survey of hunters and anglers*. Retrieved from https://www.nwf.org/en/Educational-Resources/Scientific-Reports/2012/09-25-2012-Durvey-of-Sportsmen

Nature Conservancy. 2011. *Connecting America's youth to nature*. Retrieved from https://www.nature.org/newsfeatures/kids-in-nature/kids-in-nature-poll.xml

Neuhauser, A. (2015, June 29). 2015 STEM index shows gender, racial gaps widen. *U.S. New & World Report*. Retrieved from http://www.usnews.com/news/stem-index/articles/2015/06/29/gender-racial-gaps-widen-in-stem-fields

Ng, W. (2011). *Mobile technologies and handheld devices for ubiquitous learning: Research and pedagogy*. Hershey, PA: Information Science Reference.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Nielsen, J. (2008, February 6). *Americans spending less time in nature.* Retrieved from http://www.npr.org/templates/story/story.php?storyId=18698731

Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2009). The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behaviour. *Environment and Behavior, 41*(5), 715-740. doi: 10.1177/0013916508318748

Northeast Climate Science Center. (2014). *2014 annual report*. Retrieved from https://necsc.umass.edu/sites/default/files/NECSC-AR2014-web-4mb_0_0.pdf

Nov, O., Arazy, O., & Anderson, D. (2014). Scientists @ home: What drives the quantity and quality of online citizen science participation? *PLoS One, 9*(4), 1-11. doi: 10.1371/ journal.pone.0090375

Ockwell, D. Whitmarsh, L., & O'Neill, S. (2009). Reorienting climate change communication for effective mitigation: Forcing people to be green or fostering grass-roots engagement? *Science Communication, 30*(3), 305-327. doi: 10.1177/1075547008328969

Oonk, D., Leckey, E., Gold, A. U., Margo-Schneider, J., Littrell-Baez, M., Smith, L., & Lynds, S. (2017). Lens on climate change: Using place-based learning to explore climate change effects. *Science Scope, 41*(2), 86.

Organisation for Economic Co-operation and Development (OECD). (2010). *PISA 2009 results: What students know and can do: Student performance in reading, mathematics and science (Volume I)*. OECD, Paris, France.

Ormrod, J. E. (2004). *Human learning* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change, 20*(4), 550-557. doi: 10.1016/j. gloenvcha.2010.07.004

Pachauri, R. K., & Reisinger, A. (2007). Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change. *IPCC*, Geneva, Switzerland.

Pacheco-Vega, R. (2015). Transnational environmental activism in North America: Wielding soft power through knowledge sharing? *Review of Policy Research, 32*(1), 146-162. doi: 10.1111/ropr.12111

Paço, A., & Gouveia Rodrigues, R. (2016). Environmental activism and consumers' perceived responsibility. *International Journal of Consumer Studies, 40*(4), 466-474. doi:10.1111/ijcs.12272

Palermo, E., Laut, J., Nov, O., Cappa, P., & Porfiri, M. (2017). A natural user interface to integrate citizen science and physical exercise. *PLoS ONE, 12*(2), 1-21. doi: 10.1371 /journal.pone.0172587

Pandve, H. (2007). Global warming: Need to sensitize general population. *Indian Journal of Occupational and Environmental Medicine, 11*(2), 86-87.

Pandve, H., Chawla, P., Fernandez, K., Singru, S., Khismatrao, D., & Pawar, S. (2011). Assessment of awareness regarding climate change in an urban community. *Indian Journal of Occupational and Environmental Medicine, 15*(3), 109-112.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology, 13*(2), 299-307.

Parant, A., Pacual, A., Jugel, M., Kerroume, M., Felonneau, M., & Guéguen, N. (2017). Raising students awareness to climate change: An illustration with binding communication. *Environment and Behavior, 49*(3), 339-353. doi: 10.1177/0013916516629191

Partnership for 21st Century Skills. (2007). *The road to the 21st century: A policymakers guide to 21st century skills*. Retrieved from http://web.archive.org/web/20130117111652/p21.org/tools-and-resources/publications/925

Pecor, K. W., & Batko, K. A. (2017). Phenology: From natural history to climate change. *American Biology Teacher, 79*(5), 412-416. doi: 10.1525/abt.2017.79.5.412

Peng, H., Su, Y., Chou, C., & Tsai, C. (2009). Ubiquitous knowledge construction: Mobile learning redefined and a conceptual framework. *Innovations in Education and Teaching International, 46*(2), 171-183. doi: 10.1080/14703290902843828

Pennsylvania Department of Conservation and Natural Resources, 2017. *DCNR fall foliage report*. Retrieved from http://www.dcnr.pa.gov/Conservation/ForestsAndTrees/FallFoliageReports/Pages/default.aspx

Pettit, J., & Kukulska-Hulme, A. (2011). Mobile 2.0: crossing the border into formal learning? In M.J. Lee & C. McLoughlin (Eds.), *Web 2.0-based E-Learning: Applying social informatics for tertiary teaching* (pp. 192–208). Hershey PA: Information Science Reference.

Powell, G. N. (2011). The gender and leadership wars. *Organizational Dynamics, 40*(1), 1–9. doi:10.1016/j.orgdyn.2010.10.009

Powell, J. L. (2016, March 28). Climate scientists virtually unanimous: Anthropogenic global warming is true. *Bulletin of Science, Technology & Society, 35*(5-6), 121-124. doi: 10.1177/0270467616634958

Price, C. A., & Lee, H. S. (2013). Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching, 50*(7), 773-801.

Priest, S. (2013). Critical science literacy what citizens and journalists need to know to make sense of science. *Bulletin of Science, Technology & Society*, *33*(5), 138-145.

Prins, G. T., Bulte, A. M., Van Driel, J. H., & Pilot, A. (2009). Students' involvement in authentic modelling practices as contexts in chemistry education. *Research in Science Education, 39*(5), 681-700.

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future*. Retrieved from https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf

Pu, Y. H., Wu, T. T., Chiu, P. S., & Huang, Y. M. (2016). The design and implementation of authentic learning with mobile technology in vocational nursing practice course. *British Journal of Educational Technology, 47*(3), 494-509.

Pureswaran, D. S., De Grandpre, L., Pare, D., Taylor, A., Barrette, M., Morin, H., . . . Kneeshaw, D. D. (2015). Climate-induced changes in host-tree-insect phenology may drive ecological state-shift in boreal forests. *Ecology, 96*(6), 1480-1491.

Qian, K., Yang, M., Guo, M., Bhattacharya, P., & Tao, L. (2013, July). Mobile device based authentic learning for computer network and security. *In Proceedings of the 18th ACM Conference on Innovation and Technology in Computer Science Education* (pp. 335-335). ACM.

Quigley, C. (2014). Expanding our view of authentic learning: Bridging in and out-of-school experiences. *Cultural Studies of Science Education, 9*(1), 115-122.

Quimby, J. L., Seyala, N. D., & Wolfson, J. L. (2007). Social cognitive predictors of interest in environmental science: Recommendations for environmental educators. *The Journal of Environmental Education, 38*(3), 43-52.

Raines, J. M. (2012). FirstSTEP: A preliminary review of the effects of a summer bridge program on pre-college stem majors. *Journal of STEM Education: Innovations & Research, 13*(1), 22-29.

Ranieri, M., & Pachler, N. (2014). Inventing and re-inventing identity: Exploring the potential of mobile learning in adult education. *Prospects, 44*(1), 61-79. doi: 10.1007/s11125-014-9294-1

Rathburn, B., (2017, October 25). 2017 World Series: Record heat to persist for game 2 in Los Angeles. *Accuweather*. Retrieved from https://www.accuweather.com/en/weather-news/2017-world-series-record-challenging-heat-to-kick-off-opening-games-in-los-angeles/70003072

Reardon, S. F., & Bischoff, K. (2011). Income inequality and income segregation. *American Journal of Sociology, 116*(4), 1092-1153.

Richardson, A. d., Keenan, T. F., Migliavacca, M., Ryu, Y., Sonnentag, O., & Toomey, M. (2013). Climate change, phenology, and phenological control of vegetation feedbacks to the climate system. *Agricultural and Forest Meteorology, 169*(1), 156-173. doi: 10.1016/j. agrformet.2012.09.012

Rideout, V. (2015). *The common sense census: Media use by tweens and teens.* Retrieved from https://www.commonsensemedia.org/research/the-common-sense-census-media-use-by-tweens-and-teens.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458-476.

Robinson, C. F., & Kakela, P. J. (2006). Creating a space to learn: A classroom of fun, interaction, and trust. *College Teaching, 54*(1), 202-206. doi:10.3200/CTCH.54.1.202-207

Rogers-Chapman, M. F. (2014). Accessing STEM-focused education: Factors that contribute to the opportunity to attend STEM high schools across the United States. *Education and Urban Society, 46*(6), 716-737.

Romine, W., Sadler, T. D., Presley, M., & Klosterman, M. L. (2014). Student interest in technology and science (SITS) survey: Development, validation, and use of a new instrument. *International Journal of Science and Mathematics Education*, *12*(2), 261-283.

Ruiz-Mallén, I., Riboli-Sasco, L., Ribrault, C., Heras, M., Laguna, D., & Perié, L. (2016). Citizen science: Toward transformative learning. *Science Communication, 38*(4), 523-534. doi: 10.1177/1075547016642241

Rust, M. J., Richardson, B. D., Davis, K. C., Soled, S. W., & Heckel, P. (2006). *Work in progress: Introducing electrical and computer engineering to high school math and science students.* Paper presented at the 36th ASEE/IEEE Frontiers in Education Conference, San Diego, CA.

Rydin, Y., & Pennington, M. (2000). Public participation and local environmental planning: The collective action problem and the potential of social capital. *Local environment, 5*(2), 153-169. doi: 10.1080/13549830050009328

Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), 411-427.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Thousand Oaks, CA: Sage.

Sastry, N., & Pebley, A. R. (2010). Family and neighborhood sources of socioeconomic inequality in children's achievement. *Demography, 47*(3), 777-800.

Schlobohm, T. L. (2016). *Creating a learning continuum: A critical look at the intersection of prior knowledge, outdoor education, and next generation science standards disciplinary core ideas and practices* (Doctoral dissertation). Retrieved from https://pdxscholar.library.pdx.edu/open_access_etds/2749/

Schmader, T. (2010). Stereotype threat deconstructed. *Current Directions in Psychological Science, 19*(1), 14-18.

Schuster, C., & Martiny, S. E. (2017). Not feeling good in STEM: Effects of stereotype activation and anticipated affect on women's career aspirations. *Sex Roles, 76*(1-2), 40-55.

Science for Citizens LLC. (2017) *SciStarter*. Retrieved from https://scistarter.com/.

Semenza, J. C., Ploubidia, G. B., & George, L. A. (2011). Climate change and climate variability: Personal motivation for adaptation and mitigation. *Environmental Health*, *10*(1), 1-12.

Settles, I. H., Cortina, L., M., Buchanan, N. T., & Miner, K. N. (2013). Derogation, discrimination, and (dis)satisfaction with jobs in science: A gendered analysis. *Psychology of Women Quarterly, 37*(1), 179-191. doi: 10.1177/0361684312468727

Settles, I. H., Cortina, L. M., Malley, J., & Stewart, A. J. (2006). The climate for women in academic science: The good, the bad, and the changeable. *Psychology of Women*

Quarterly, 30(1), 47-58. doi: 10.1111/j.1471-6402.2006.00261.x

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Shah, H. R., & Martinez, L. R. (2016). Current approaches in implementing citizen science in the classroom. *Journal of Microbiology & Biology Education, 17*(1), 17-22. doi: 10.1128/ jmbe.v17i1.1032

Sha, L., Looi, C. K., Chen, W., Seow, P., & Wong, L. H. (2012). Recognizing and measuring self-regulated learning in a mobile learning environment. *Computers in Human Behavior, 28*(2), 718-728.

Sharma, A. (2012). Global climate change: What has science education got to do with it? *Science & Education, 21*(1), 33-53.

Sharkey, P., & Elwert, F. (2011). The legacy of disadvantage: Multigenerational neighborhood effects on cognitive ability. *American Journal of Sociology, 116*(6), 1934-1981.

Shepardson, D. P., Niyogi, D., Roychoudhury, A., & Hirsch, A. (2012). Conceptualizing climate change in the context of a climate system: Implications for climate and environmental education. *Environmental Education Research, 18*(3), 323-352.

Sherry, R. A., Zhou, X., Gu, S., Arnone, J. A., Schimel, D. S., Verburg, P. S., ... & Luo, Y. (2007). Divergence of reproductive phenology under climate warming. *Proceedings of the National Academy of Sciences, 104*(1), 198-202.

Shin, W. S., Shin, C. S., Yeoun, P. S., & Kim, J. J. (2011). The influence of interaction with forest on cognitive function. *Scandinavian Journal of Forest Research, 26*(6), 595-598.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., . . . Krasny, M. E. (2012). Public participation in scientific research: A framework for deliberate design. *Ecology and Society, 17*(2), 1-20. doi: 10.5751/ES-04705-170229

Slavit, D., Nelson, T. H., & Lesseig, K. (2016). The teacher's role in developing, opening, and nurturing an inclusive STEM-focused school. *International Journal of STEM Education, 3*(1), 1-17.

Southeast Regional Climate Center. (2017). *Quarterly climate impacts and outlook - Southeast region*. Retrieved from http://www.sercc.com/SERCC_quarterly_report_winter_2016_2017.pdf

Stald, G. (2008). *Mobile identity: Youth, identity, and mobile communication media*. Cambridge, MA: The MIT Press.

Stenseth, N. C., & Mysterud, A. (2002). Climate, changing phenology, and other life history and traits: Nonlinearity and match-mismatch to the environment. *Proceedings of the National Academy of Sciences, 99*(21), 13379- 13381. doi: 10.1073/pnas.212519399

Stepich, D. A., Ertmer, P. A., & Lane, M. M. (2001). Problem-solving in a case-based course: Strategies for facilitating coached expertise. *Educational Technology Research and Development, 49*(3), 53-69.

Sternberg, R. J., (1998). Abilities are forms of developing expertise. *Educational Researcher, 27*(3), 11-20.

Stevenson, K. T., Peterson, M. N., Bondell, H. D., Moore, S. E., & Carrier, S. J. (2014). Overcoming skepticism with education: Interacting influences of worldview and climate change knowledge on perceived climate change risk among adolescents. *Climatic change, 126*(3), 293-304.

Stout, J. G., Dasgupta, N., Hunsinger, M., & McManus, M. A. (2011). STEMing the tide: Using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology, 100*(2), 255-270.

Struzik, E. (2010, September 23). *A troubling decline in the caribou herds of the Arcti*c. Retrieved from http://e360.yale.edu/features/a_troubling_decline_in_the_caribou_herds_of_the_arctic

Stumpf, H., & Stanley, J. C. (1998). Standardized tests: Still gender biased? *Current Directions in Psychological Science, 7*(1), 335-344.

Subramaniam, M. M., Ahn, J., Fleischmann, K. R., & Druin, A. (2012). Reimagining the role of school libraries in STEM education: Creating hybrid spaces for exploration. *The Library Quarterly, 82*(2), 161-182.

Taylor, E. W. (2007). An update of transformative learning theory: A critical review of the empirical research (1999–2005). *International Journal of Lifelong Education, 26*(2), 173-191.

Terkowsky, C., Haertel, T., Bielski, E., & May, D. (2013). Creativity @ school: Mobile learning environments involving remote labs and E-Portfolios. A conceptual framework to foster the inquiring mind in secondary STEM education. In J. G. Zubía and O. Dziabenko (Eds.), *IT innovative practices in secondary schools: remote experiments* (pp. 255-280). Spain: University of Deusto Bilbao

Terras, M. M., & Ramsay, J. (2012). The five central psychological challenges facing effective mobile learning. *British Journal of Educational Technology, 43*(5), 820-832.

The White House, Office of the Press Secretary. (2011, January 25). *Remarks by the President in State of Union Address*. Retrieved from https://obamawhitehouse.archives.gov/the-press-office/2011/01/25/remarks-president-state-union-address

The White House, Office of the Press Secretary. (2017, February 17). *Remarks by President Trump at Signing of H.R. 321 and H.R. 255*. Retrieved from https://www.whitehouse.gov/the-press-office/2017/02/28/remarks-president-trump-signing-hr-321-and-hr-255

Thierfelder, C., & Wall, P. C. (2010). Investigating conservation agriculture (CA) systems in Zambia and Zimbabwe to mitigate future effects of climate change. *Journal of Crop Improvement, 24*(2), 113-121.

Thoman, D. B., Arizaga, J. A., Smith, J. L., Story, T. S., & Soncuya, G. (2014). The grass is greener in non-science, technology, engineering, and math classes: Examining the role of competing belonging to undergraduate women's vulnerability to being pulled away from science. *Psychology of Women Quarterly, 38*(2), 246-258. doi: 10.1177/0361684313499 899

Thrumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education, 84*(2), 265-275.

Toomey, A. H., & Domroese, M. C. (2013). Can citizen science lead to positive conservation attitudes and behaviors? *Human Ecology Review, 20*(1), 50.

Trueman, R. J. (2014). Productive failure in STEM education. *Journal of Educational Technology Systems, 42*(3), 199-214.

University of Washington College of Engineering. (2017). *STEM Bridge program*. Retrieved from https://www.engr.washington.edu/curr_students/studentprogs/bridge. html

USA National Phenology Network. (2017). *Nature's notebook*. Retrieved from https://www.usanpn.org/

U.S. Census Bureau. (2016). *QuickFacts – United States*. Retrieved from https://www.census.gov/quickfacts/fact/table/US/PST045216

U.S. Department of Education, National Center for Education Statistics. (2015). *Degrees in engineering and engineering technologies conferred by postsecondary institutions, by level of degree and sex of student: Selected years, 1949-50 through 2013-14* [Data file]. Retrieved from https://nces.ed.gov/programs/digest/d15/tables/dt15_325.45.asp

U.S. Department of Energy. (2017). *Mentoring café: Overview of STEM mentoring cafés.* Office of Economic Impact and Diversity. Retrieved from https://energy.gov/diversity/stem-mentoring-caf

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. (2007). *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.* Retrieved from https://www.census.gov/prod/2008pubs/fhw06-nat.pdf

U.S. Geological Survey. (2017, February 17). *When timing is everything: Migratory bird phenology in a changing climate.* Retrieved from https://nccwsc.usgs.gov.content/when-timing-everything-migratory-bird-phenology-changing-climate

Van Asch, M., Julkunen-Tiito, R., & Visser, M. E. (2010). Maternal effects in an insect herbivore as a mechanism to adapt to host plant phenology. *Functional Ecology, 24*(5), 1103-1109.

VanMeter-Adams, A., Frankenfeld, C. L., Bases, J., Espina, V., & Liotta, L. A. (2014). Students who demonstrate strong talent and interest in STEM are initially attracted to STEM through extracurricular experiences. *CBE-Life Sciences Education, 13*(4), 687-697.

van Tuijl, C., & van der Molen, J. H. W. (2016). Study choice and career development in STEM fields: An overview and integration of the research. *International Journal of Technology* *and Design Education, 26*(2), 159-183. doi:10.1007/s10798-015-9308-1

Versprille, A. N., & Towns, M. H. (2014). General chemistry students' understanding of climate change and the chemistry related to climate change. *Journal of Chemical Education, 92*(4), 603-609.

Vilorio, D. (2014). STEM 101: Intro to tomorrow's jobs. *Occupational Outlook Quarterly, 58*(1), 2-12.

Visser, M. E., & Both, C. (2005). Shifts in phenology due to global climate change: The need for a yardstick. *Proceedings of the Royal Society B*. *272*(1), 2561-2569. doi: 10.1098/rspb.2005.3356

Visser, M. E., Both, C., & Lambrechts, M. M. (2004). Global climate change leads to mistimed avian reproduction. *Advances in Ecological Research, 35*(1), 89-110.

Walker, S. L., & McNeal, K. S. (2013). Development and validation of an instrument for assessing climate change knowledge and perceptions: The climate stewardship survey (CSS). *International Electronic Journal of Environmental Education, 3*(1), 57-73.

Walker, T., & Molnar, T. (2014). Can experiences of authentic scientific inquiry result in transformational learning? *Journal of Transformative Education, 11*(4), 229-245.

Wallace, D. E., & Bodzin, A. M. (2017). Developing scientific citizenship identity using mobile learning and authentic practice. *Electronic Journal of Science Education, 21*(6), 46-71.

Wallace III, J., D'Aleo, J., & Idso, C., (2017). *On the validity of NOAA, NASA and Hadley CRU global average surface temperature data & the validity of EPA's CO2 endangerment finding.* Retrieved from https://thsresearch.files.wordpress.com/2017/05/ef-gast-data-research-report-062717.pdf

Wals, A. E., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science, 344*(1), 583-584. doi: 10.1126/science.1250515

Watagodakumbura, C. (2013). Authentic learning experience: Subtle but useful ways to provide it in practice. *Contemporary Issues in Education Research, 6*(3), 299-304.

Watts, M. T. (1963). *Tree Finder: A manual for the identification of trees by their leaves*. Rochester, NY: Nature Study Guild Publishers.

Weis, L., Eisenhart, M. Cipollone, K., Stich, A. E., Nikischer, A. B., Hanson, J., . . . Dominguez, R. (2015). In the guise of STEM education reform: Opportunity structures and outcomes in inclusive STEM-focuses high schools. *American Educational Research Journal, 52*(6), 1024-1059. doi: 10.3102/0002831215604045

Wildlife Management Institute. (2008). *Seasons' end: Global warming's threat to hunting and fishing.* Retrieved from http://www.tu.org/sites/default/files/offline/science/Seasons%20End.pdf

Willemse, J. J., & Bozalek, V. (2015). Exploration of the affordances of mobile devices in integrating theory and clinical practice in an undergraduate nursing program. *Curationis, 38*(2), 1-10. doi: 10.4102/curationis.v38i2. 1510

Williams, J. P. (2014, April 24). The crucial role of mentors in STEM. *U.S. News & World Report*. Retrieved from https://www.usnews.com/news/stem-solutions/articles/2014/04/24/the-crucial-role-of-mentors-in-stem

Witecki, G., & Nonnecke, B. (2015). Engagement in digital lecture halls: A study of student course engagement and mobile device use during lecture. *Journal of Information Technology Education: Research, 14*(1), 73-90.

Wolfram, (2017). *STEM – Science, technology, engineering, and mathematics*. Retrieved from https://www.wolfram.com/solutions/stem/

Wolkovich, E. M., & Cleland, E. E. (2014). Phenological niches and the future of invaded ecosystems with climate change. *AoB Plants, 6*(13), 1-16. https://doi.org/10.1093/aobpla/plu013

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual review of sociology, 41*(1), 331-357.

Xie, Y., & Killewald, A. A. (2012). *Is American science in decline?* Cambridge, MA: Harvard University Press.

Xie, Y., & Shauman, K. A. (2003). *Women in science: Career processes and outcomes*. Cambridge, MA: Harvard University Press.

Yoho, R. A., & Vanmali, B. H. (2016). Controversy in biology classrooms-citizen science approaches to evolution and applications to climate change discussions. *Journal of Microbiology & Biology Education, 17*(1), 110-114.

Yoon, S. Y., Dyehouse, M., Lucietto, A. M., Diefes- Dux, H. A., & Capobianco, B. M. (2014). The effects of integrated science, technology, and engineering education on elementary students' knowledge and identity development. *School Science and Mathematics, 114*(8), 380-391.

Young, J., Ortiz, N., & Young, J. (2017). STEMulating interest: A meta-analysis of the effects of out-of-school time on student STEM interest. *International Journal of Education in Mathematics, Science and Technology, 5*(1), 62-74.

Zbinden, A., Souchet, L., Girandola, F., Bourg, G. (2011). Binding communication and social representations: An application for the environment protection and recycling. *Pratiques Psychologiques, 17*(3), 285-299.

Zhang, X., Mclnerney, J., & Frechtling, J. (2010). Engaging STEM faculty in K-20 reforms-implications for policies and practices. *Science Educator, 19*(1), 1-13.

Zhe, J., Doverspike, D., Zhao, J., Lam, P., & Menzemer, C. (2010). High school bridge program: A multidisciplinary STEM research program. *Journal of STEM education, 11*(1), 61-68.

Zooniverse. (2017). *Galaxy Zoo*. Retrieved from https://www.galaxyzoo.org/

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APPENDIX A: The Citizen Science Identity, Mobile Learning and Conservation and Environmentally-minded STEM Interest Survey (CSI-CEmSTEM)

The Citizen Science Identity, Mobile Learning and Conservation and Environmentally-minded

STEM Interest Survey (CSI-CEmSTEM)

In this survey, you will be asked to share your ideas about STEM (science, technology, engineering and math), citizen science, mobile learning, environmental activism, climate change and conservation. For the purpose of this survey, we use these terms in the following ways.

STEM represents fields of study and careers related to science, technology, engineering and mathematics.

CEmSTEM refers to a type of STEM that is founded in conservation and environmental-mindedness.

Citizen Science represents the collection and analysis of data relating to the natural world by members of the general public (often collaborating with professional scientists and contributing to research).

Mobile Learning represents the use of mobile technologies (such as smartphones, apps, iPads, etc.) to increase learning.

Climate Change is the long-term change in the earth's temperature. This often relates to global warming, specifically warming temperatures cause by humans.

Environmental Stewardship refers to individuals or groups of people that have a sense of responsibility for the environment and may take part in activities that help the environment (such as a group of volunteers that takes part in monthly beach cleanup events or recycling activities).

For each of the items on the following pages, you will be asked to indicate the extent to which you agree or disagree with a statement.

Section I: STEM Interest. Items in this section present ideas related to your interest in STEM education and careers. Indicate the extent to which you agree or disagree with the following statements. Please read each sentence and MARK THE CIRCLE that best describes your opinion for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
1. I enjoy learning science.	○	○	○	○	○
2. School science has improved my decision-making.	○	○	○	○	○

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
3. I enjoy using technology to solve science problems.	○	○	○	○	○
4. I plan to take more science classes in high school.	○	○	○	○	○
5. Technology does NOT help me learn science.	○	○	○	○	○
6. More time in the school day should be devoted to science.	○	○	○	○	○
7. Computers make learning science more interesting.	○	○	○	○	○
8. Learning science is NOT interesting.	○	○	○	○	○
9. I enjoy using technology to learn science.	○	○	○	○	○
10. More time in science classes should involve the use of technology.	○	○	○	○	○
11. I would be more likely to take a job if I knew it involved working with technology.	○	○	○	○	○
12. Working in technology would be interesting.	○	○	○	○	○
13. I would like to become a scientist.	○	○	○	○	○
14. I would like to get a job in technology.	○	○	○	○	○
15. I would NOT enjoy a job in technology.	○	○	○	○	○
16. I will probably choose a job that involves using technology.	○	○	○	○	○
17. I would like to work in a science laboratory	○	○	○	○	○
18. I would like to contribute additional data to scientific research.	○	○	○	○	○

Section II: CEmSTEM Perceptions. Items in this section present ideas related to interest in conservation and environmentally-minded types of STEM. Indicate the extent to which you agree or disagree with the following statements. Please read each sentence and MARK THE CIRCLE that best describes your opinion for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
19. STEM is useful if it can help conservation efforts.	○	○	○	○	○
20. One of the most important uses of STEM is to improve/solve issues such as climate change.	○	○	○	○	○
21. I am interested in a STEM career that will help the environment.	○	○	○	○	○
22. I am only interested in a STEM career if I can help the environment.	○	○	○	○	○
23. STEM innovations are important even if they harm the planet.	○	○	○	○	○
24. STEM careers are interesting because they have the potential to positively impact the environmental problems in our world.	○	○	○	○	○
25. I am NOT interested in the conservation and environmental aspects of STEM.	○	○	○	○	○
26. I am interested in careers that use engineering to help the environment.	○	○	○	○	○
27. I am interested in careers that use science to help the environment.	○	○	○	○	○
28. I am interested in careers that use technology to help the environment.	○	○	○	○	○

Section III: Ideas about Citizen Science. Items in this section present ideas related to citizen science. Indicate the extent to which you agree or disagree with the following statements. Please read each sentence and MARK THE CIRCLE that best describes your opinion for EACH item. *An example of citizen science may include fishermen concerned about the population of a certain species of fish. In this example, they may submit data when they catch this type of fish (such as size weight, gender, condition, season, etc.) to scientists that will use the information in a global study. This information may be used to understand and protect fish populations.*

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
29. Citizen Science helps me better understand the world I live in.	○	○	○	○	○
30. More people should take part in Citizen Science.	○	○	○	○	○
31. Contributing data/information to Citizen Science is important for the planet.	○	○	○	○	○
32. Taking part in Citizen Science does NOT help the environment.	○	○	○	○	○
33. Anyone can be a Citizen Scientist.	○	○	○	○	○
34. I want to be a Citizen Scientist.	○	○	○	○	○
35. I want to participate in Citizen Science projects in the future.	○	○	○	○	○
36. Citizen Science helps me understand climate change.	○	○	○	○	○
37. I feel like a Citizen Scientist.	○	○	○	○	○
38. Citizen Science is fun.	○	○	○	○	○
39. I can help my local environment by taking part in Citizen Science.	○	○	○	○	○
40. I am a Citizen Scientist.	○	○	○	○	○
41. Citizen Science makes science seem more real.	○	○	○	○	○

Section IV: Ideas about Mobile Learning. Items in this section present ideas related to mobile learning. Indicate the extent to which you agree or disagree with the following statements. Please read each sentence and MARK THE CIRCLE that best describes your opinion for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
42. Using my smartphone/mobile device helps me learn.	○	○	○	○	○
43. My smartphone/mobile device makes it easier to communicate with classmates and teachers.	○	○	○	○	○
44. I use my smartphone/mobile device for schoolwork.	○	○	○	○	○
45. I use my smartphone/mobile device for schoolwork while I'm outside of the normal classroom.	○	○	○	○	○
46. I do NOT feel connected because of my smartphone/mobile device.	○	○	○	○	○
47. My smartphone/mobile device makes learning easier.	○	○	○	○	○
48. My smartphone/mobile device helps me understand the world around me.	○	○	○	○	○
49. Using my smartphone/mobile device can help the environment.	○	○	○	○	○
50. I can use my smartphone/mobile device for important projects.	○	○	○	○	○
51. Using my smartphone/mobile device helps my work as a citizen scientist.	○	○	○	○	○

Section V: Ideas about Climate Change. Items in this section present ideas related to climate change. Indicate the extent to which you agree or disagree with the following statements. Please read each sentence and MARK THE CIRCLE that best describes your opinion for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
52. I am concerned about climate change.	○	○	○	○	○
53. I understand what causes climate change.	○	○	○	○	○
54. I am well informed about the consequences of climate change.	○	○	○	○	○
55. I understand what is necessary to reduce climate change.	○	○	○	○	○
56. Climate change is caused mostly by human activities.	○	○	○	○	○
57. Climate change is caused by both human activities and natural changes.	○	○	○	○	○
58. The issue of climate change is important to me personally.	○	○	○	○	○

Section VI: Ideas about Environmental Stewardship. Items in this section present ideas related to environmental stewardship. Indicate the extent to which you agree or disagree with the following statements. Please read each sentence and MARK THE CIRCLE that best describes your opinion for EACH item.

	Indicate how you feel about each statement.				
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
59. Environmental protection starts with me.	○	○	○	○	○
60. I'm willing to take up responsibility to protect the environment in the United States.	○	○	○	○	○
61. Behaving responsibly toward the Earth – living a sustainable life-style– is part of my moral code.	○	○	○	○	○
62. Engaging in environmental behaviors is	○	○	○	○	○

important to me.					
63. If I had enough time or money, I would certainly devote some of it to working for environmental causes.	○	○	○	○	○
64. I have a lot in common with environmentalists as a group.	○	○	○	○	○
65. Learning about the natural world should be an important part of every child's upbringing.	○	○	○	○	○
66. My own interests usually seem to coincide with the position advocated by environmentalists.	○	○	○	○	○

APPENDIX B: Open Ended Survey (Mobile Technology Group)

Open Ended Survey (Mobile Technology Group)

1. How might using mobile technologies to gather environmental data change your future career path, course of study or interest in STEM?

2. How important is it to consider the environment when creating STEM innovations?

3. How have your feelings toward climate change been effected by taking part in this citizen science project?

4. How has this project influenced how you think about citizen science?

5. How has using a smartphone for this project to identify trees, plot location, conduct research and take photos impacted your thoughts on learning with your smartphone/mobile device?

6. How has this citizen science project changed the way you think about humankind's impact on climate change?

7. How has taking part in this project impacted your thoughts on caring for the environment?

8. Did using your smartphone for this project make you feel like a citizen scientist? If so, how?

9. Did using your smartphone for this project make you more interested in any STEM fields? If so, how?

10. Would you like to provide any additional feedback about this project? If so, please respond.

APPENDIX C: Open Ended Survey (Non-Mobile Technology Group)

Open Ended Survey (Non-Mobile Technology Group)

1. How might taking part in this citizen science project change your future career path, course of study or interest in STEM?

2. How important is it to consider the environment when creating STEM innovations?

3. How have your feelings toward climate change been effected by taking part in this citizen science project?

4. How has this project influenced how you think about citizen science?

5. How might your feelings about this project have changed if you were able to use your smartphone to identify trees, plot location, conduct research and take photos?

6. How has this project changed the way you think about humankind's impact on climate change?

7. How has taking part in this project impacted your thoughts on caring for the environment?

8. Would using your smartphone for this project make you feel like a citizen scientist? If so, how?

9. Would using your smartphone for this project make you more interested in any STEM fields? If so, how?

10. Would you like to provide any additional feedback about this project? If so, please respond.

APPENDIX D: Initial a Priori Codes

Initial a Priori Codes

Code	Description
STEM Interest	Participants respond with affirmations of interest in STEM or science
STEM Career	Participants respond with positive feelings related to careers in STEM
No STEM Interest Gained	Participants reported that they did not have any increased interest in STEM
CEmSTEM Perceptions	Participants note an understanding of the relationship between STEM and the environment.
Affordances of Citizen Science	Participants stated several attributes related to taking part in citizen science
CS Identity	Participants responded with feeling like or being a citizen scientist.
Mobile Tech Affordances	Participants record opportunities for learning and working with mobile technologies.
Climate Change Awareness	Participants responded with obtaining an increased awareness or understanding of climate change after taking part in the study.
Environmental Stewardship	Participants discuss a need or desire to care for the environment.

APPENDIX E: Revised Codes with Member Check

Revised Codes with Member Check

Code	Description	Example
STEM Interest	Participants respond with affirmations of interest in STEM or science	"Yes, because the science and technology helping us understand what type of tree the leaf came from. So I would be more interested in doing more science and technology projects in school."
STEM Career	Participants respond with positive feelings related to careers in STEM	"Citizen science has made me consider different careers. It has increased my interest in STEM and how it could help the environment."
No STEM Interest Gained	Participants reported that they did not have any increased interest in STEM	"I don't believe it will change my career path or course of study but it could be a hobby for me"
CEmSTEM Perceptions	Participants note an understanding of the relationship between STEM and the environment.	"It is very important, because some of the most pressing issues in our nation and world are climate change and pollution, so we should make extra effort to not contribute to those problems, but instead create STEM innovations that help the environment."
CS Affordances	Participants comment on the attributes related to taking part in citizen science.	"I feel very happy to have helped scientists and the environment by collecting information that may help slow down climate change."
CS Promotes Pro-environmental Ethos	Participants identify citizen science as a method that is benefiting the environment and creating a pro-environmental ethos.	"This project opened up my eyes to how citizen science can actually be used to better the Earth's situation and how everyday citizens, who are not scientists, can still get involved in helping the environment."

CS Promotes CC Understandings	Participants identified citizen science as a way to better understand climate change.	"Taking part in this project has taught me that climate change may be more serious than some people consider it to be and even the slightest concepts such as tree phenology can demonstrate the effects of climate change."
CS Identity	Participants responded with feeling like or stating that they actually are a citizen scientist.	"It has made me notice that climate change is real and by being a citizen scientist, I can help scientists research on how to fix all the issues we are facing."
CS Anyone	Participants stated that anyone is able to be a citizen scientist.	"It makes me realize that citizen science is something anyone can do and take part in, and it really makes a difference."
Mobile Learning Affordances	Participants record opportunities for learning and working with mobile technologies.	"It would have been a lot easier. I feel that smartphones and technology have become efficient. They could show me easily which species, the location and everything which would have made my study easier."
Mobile Fosters CS Identity	Participants state that the use of mobile technologies make them feel like citizen scientists.	"It did, because I was able to use my own phone to be a citizen scientist. It made me feel like being a citizen scientist is easier than I thought, so I can benefit the environment in the future."
Mobile Generates STEM Interest	Participants point to the use of mobile technologies as a contributing factor in generating STEM interest.	"Using technology to gather data may make you have a stronger connection to the subject. Using technology like phones may make you more interested in STEM since its a daily item you use and can relate it to the subject."

Personally Experience CC	Participants make statements regarding personally experiencing climate change as a result of the citizen science project.	“This project gave me a new approach on how to help it. Seeing the trees delay their change because of the climate change is real proof that we need to change.”
Climate Change Awareness	Participants responded with obtaining an increased awareness or understanding of climate change after taking part in the study.	“Taking part in this project has taught me that climate change may be more serious than some people consider it to be and even the slightest concepts such as tree phenology can demonstrate the effects of climate change.”
Moving toward action-oriented Environmentalism	Participants discuss a need or desire to care for the environment.	“Before I never really paid attention to the trees and didn’t really observe what was happening to our community in terms of the landscape, but this citizen science project has allowed me to see what I could do to help raise awareness about climate change.”

APPENDIX F: Means and Standard Deviations of the pre and posttest Scores for Each Item from the CSI-CEmSTEM Instrument by the Type of Intervention

Means and Standard Deviations of the pre and posttest Scores for Each Item from the CSI-CEmSTEM Instrument by the Type of Intervention.

Scale of Measurement	Control Group Mean (SD)		Non-mobile Technology Group Mean (SD)		MobiLAP Group Mean (SD)	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Section 1: STEM interest (18 items)	58.64 (9.75)	55.84 (11.68)	57.84 (12.56)	61.69 (14.48)	57.44 (12.75)	61.15 (10.22)
Item 1	3.80 (0.55)	3.59 (0.90)	3.53 (1.04)	3.91 (1.14)	3.42 (1.09)	3.63 (0.96)
Item 2	3.02 (0.90)	3.25 (0.84)	2.82 (0.83)	3.31 (1.16)	2.83 (1.08)	3.08 (1.07)
Item 3	3.73 (0.92)	3.57 (0.90)	3.87 (0.94)	3.82 (0.94)	3.85 (0.85)	3.69 (0.88)
Item 4	3.45 (0.90)	3.16 (1.01)	3.16 (1.02)	3.91 (1.12)	3.08 (1.15)	3.35 (1.00)
Item 5	3.80 (0.93)	3.57 (0.93)	3.96 (0.98)	3.80 (0.94)	3.94 (0.73)	3.69 (0.99)
Item 6	2.50 (0.90)	2.48 (1.02)	2.60 (0.94)	2.80 (0.94)	2.42 (1.13)	2.67 (1.12)
Item 7	3.41 (0.87)	3.23 (1.03)	3.58 (0.92)	3.69 (0.95)	3.67 (0.91)	3.83 (0.83)
Item 8	3.80 (0.95)	3.52 (1.09)	3.47 (1.01)	3.91 (1.08)	3.35 (1.19)	3.33 (1.23)
Item 9	3.48 (0.88)	3.48 (0.93)	3.56 (0.89)	3.87 (0.79)	3.69 (0.85)	3.81 (0.70)
Item 10	3.11 (0.99)	3.27 (1.06)	3.33 (1.02)	3.44 (1.12)	3.40 (0.87)	3.67 (0.83)
Item 11	3.30 (0.95)	3.00 (1.10)	3.24 (1.21)	3.31 (1.10)	3.23 (1.08)	3.54 (0.94)

Item 12	3.25 (1.10)	3.05 (1.22)	3.49 (1.24)	3.47 (1.16)	3.50 (1.03)	3.71 (0.90)
Item 13	2.43 (1.02)	2.32 (0.91)	2.29 (0.97)	2.69 (1.29)	2.21 (1.34)	2.63 (1.23)
Item 14	3.09 (1.10)	2.89 (1.19)	2.93 (1.39)	3.00 (1.26)	2.94 (1.21)	3.42 (0.92)
Item 15	3.48 (1.05)	3.16 (0.99)	3.20 (1.34)	3.20 (1.24)	3.25 (1.12)	3.38 (1.00)
Item 16	3.45 (0.95)	3.09 (1.05)	3.40 (1.29)	3.47 (1.12)	3.31 (1.06)	3.73 (0.74)
Item 17	2.45 (1.00)	2.48 (0.90)	2.40 (0.99)	2.73 (1.21)	2.29 (1.30)	2.71 (1.05)
Item 18	3.09 (1.01)	2.75 (0.94)	3.02 (1.22)	3.36 (1.28)	3.06 (1.21)	3.29 (0.90)
Section 2: CEmSTEM perceptions (10 items)	30.91 (5.94)	29.84 (6.02)	30.69 (3.15)	33.96 (5.39)	29.96 (5.57)	32.63 (5.25)
Item 1	3.48 (0.82)	3.34 (0.83)	3.78 (0.74)	4.13 (0.87)	3.67 (0.86)	3.90 (0.75)
Item 2	3.59 (0.87)	3.34 (0.89)	3.71 (0.89)	3.96 (0.85)	3.58 (0.85)	3.85 (0.77)
Item 3	2.89 (0.89)	2.73 (0.85)	2.78 (0.70)	3.22 (0.88)	2.67 (0.95)	3.02 (0.98)
Item 4	2.82 (0.87)	2.64 (0.89)	2.69 (0.79)	2.84 (0.82)	2.69 (0.95)	2.96 (0.90)
Item 5	2.59 (0.76)	2.80 (0.79)	2.38 (0.91)	2.40 (0.75)	2.56 (0.90)	2.73 (1.07)
Item 6	3.57 (0.87)	3.32 (0.74)	3.56 (0.62)	3.84 (0.77)	3.56 (0.85)	3.63 (0.84)
Item 7	3.05 (0.91)	3.11 (0.95)	3.07 (0.89)	3.69 (0.97)	2.96 (1.11)	3.25 (0.89)
Item 8	3.07 (0.90)	2.82 (0.81)	2.82 (0.89)	3.18 (1.01)	2.63 (0.94)	2.92 (0.94)

Item 9	2.91 (0.86)	2.84 (0.75)	2.93 (0.96)	3.42 (1.08)	2.81 (0.98)	3.10 (1.02)
Item 10	2.95 (1.03)	2.91 (0.91)	2.98 (0.81)	3.27 (1.16)	2.83 (0.93)	3.27 (0.89)
Section 3: Ideas about citizen science (13 items)	39.84 (6.90)	39.18 (8.51)	40.20 (6.51)	47.64 (9.53)	40.06 (8.74)	46.90 (6.07)
Item 1	3.30 (0.79)	3.09 (0.91)	3.22 (0.74)	3.80 (0.81)	3.27 (0.87)	3.69 (0.75)
Item 2	3.30 (0.63)	3.20 (0.90)	3.31 (0.70)	3.84 (0.80)	3.35 (0.79)	3.54 (0.68)
Item 3	3.41 (0.76)	3.39 (0.84)	3.53 (0.76)	4.02 (0.84)	3.73 (0.82)	3.81 (0.79)
Item 4	3.41 (0.73)	3.18 (0.81)	3.44 (0.76)	3.91 (0.82)	3.65 (0.76)	3.96 (0.71)
Item 5	3.34 (0.83)	3.36 (0.87)	3.47 (0.73)	3.98 (0.81)	3.38 (0.98)	3.94 (0.60)
Item 6	2.59 (0.87)	2.64 (0.84)	2.69 (0.95)	3.24 (0.98)	2.58 (1.03)	3.06 (0.76)
Item 7	2.95 (0.83)	2.84 (0.86)	2.80 (0.84)	3.40 (1.03)	2.67 (1.02)	3.46 (0.82)
Item 8	3.09 (0.83)	3.09 (0.74)	3.16 (0.93)	3.71 (0.82)	3.21 (0.94)	3.73 (0.76)
Item 9	2.66 (0.75)	2.70 (0.79)	2.56 (0.78)	3.33 (0.93)	2.48 (1.01)	3.38 (0.76)
Item 10	2.91 (0.68)	2.89 (0.75)	3.04 (0.98)	3.58 (0.94)	2.90 (0.86)	3.48 (0.74)
Item 11	3.27 (0.85)	3.14 (0.85)	3.24 (0.77)	3.76 (0.86)	3.25 (0.89)	3.75 (0.67)
Item 12	2.50 (0.76)	2.57 (0.87)	2.56 (0.81)	3.33 (0.95)	2.44 (0.92)	3.38 (0.61)
Item 13	3.11 (0.65)	3.09 (0.77)	3.18 (0.83)	3.73 (0.96)	3.17 (0.95)	3.73 (0.76)
Section 4: Ideas	36.66	36.02	39.67	39.53	39.00	38.92

about mobile learning (10 items)	(6.65)	(8.53)	(5.99)	(7.67)	(6.87)	(6.39)
Item 1	3.86 (0.93)	3.73 (1.00)	4.04 (0.80)	4.02 (0.97)	4.02 (0.93)	3.94 (0.95)
Item 2	4.16 (0.78)	3.86 (0.98)	4.31 (0.73)	4.22 (0.74)	4.23 (0.81)	4.00 (0.92)
Item 3	4.05 (0.94)	3.68 (0.96)	4.07 (0.89)	4.04 (0.98)	3.98 (0.89)	4.02 (0.79)
Item 4	3.98 (1.05)	3.77 (0.99)	4.11 (0.91)	4.07 (0.94)	4.00 (0.77)	4.04 (0.85)
Item 5	2.43 (1.09)	3.34 (1.12)	3.87 (0.97)	3.91 (1.02)	3.79 (0.90)	3.77 (0.86)
Item 6	3.55 (1.09)	3.41 (1.04)	3.80 (0.92)	3.89 (0.98)	3.69 (0.80)	3.90 (0.75)
Item 7	3.73 (1.04)	3.55 (1.07)	3.78 (0.88)	3.89 (0.96)	3.71 (0.99)	3.83 (0.78)
Item 8	3.52 (1.17)	3.41 (1.11)	3.78 (1.13	3.78 (1.17)	3.73 (0.98)	3.79 (0.97)
Item 9	3.73 (1.04)	3.57 (1.09)	3.93 (0.89	3.93 (0.96)	3.88 (1.06)	3.92 (0.82)
Item 10	3.66 (1.06)	3.70 (1.00)	3.98 (0.75)	3.78 (0.95)	3.98 (0.86)	3.71 (0.97)
Section 5: Ideas about climate change (7 items)	25.18 (4.28)	25.34 (4.06)	26.09 (2.95)	27.93 (5.06)	25.60 (4.59)	26.71 (3.99)
Item 1	3.41 (1.15)	3.55 (0.79)	3.73 (0.91)	4.11 (0.96)	3.56 (1.29)	3.81 (0.91)
Item 2	3.73 (0.92)	3.77 (0.64)	3.98 (0.69)	4.09 (0.90)	3.94 (0.73)	3.90 (0.66)
Item 3	3.75 (0.97)	3.64 (0.72)	3.89 (0.75)	3.98 (0.99)	3.85 (0.92)	3.96 (0.65)
Item 4	3.50 (0.95)	3.68 (0.74)	3.82 (0.89)	3.91 (1.06)	3.79 (0.90)	3.77 (0.69)

Item 8	4.00 (0.81)	3.80 (0.93)	3.64 (0.91)	4.18 (0.83)	3.65 (1.00)	3.75 (0.81)
Item 9	3.80 (0.95)	3.75 (0.89)	3.73 (0.75)	4.02 (0.87)	3.69 (0.97)	3.96 (0.90)
Item 12	3.00 (0.99)	3.16 (0.78)	3.29 (0.89)	3.64 (0.93)	3.13 (1.18)	3.56 (0.82)
Section 6: Ideas about environmental stewardship (8 items)	25.20 (4.99)	25.32 (4.53)	26.40 (3.69)	28.47 (5.70)	25.40 (5.83)	27.42 (4.10)
Item 1	3.34 (0.83)	3.16 (0.71)	3.29 (0.82)	3.64 (0.77)	3.17 (0.95)	3.56 (0.80)
Item 2	3.11 (0.87)	3.20 (0.70)	3.36 (0.74)	3.47 (0.87)	3.25 (0.84)	3.52 (0.71)
Item 3	3.18 (0.87)	3.05 (0.86)	3.56 (0.78)	3.67 (0.83)	3.52 (0.95)	3.58 (0.77)
Item 4	3.16 (0.83)	3.18 (0.69)	3.33 (0.64)	3.64 (0.77)	3.21 (0.85)	3.38 (0.76)
Item 5	3.41 (0.90)	3.39 (0.84)	3.42 (0.81)	3.64 (0.77)	3.33 (1.06)	3.65 (0.84)
Item 6	2.80 (0.67)	2.80 (0.70)	2.76 (0.65)	3.20 (0.84)	2.52 (0.77)	2.81 (0.73)
Item 7	3.43 (0.95)	3.55 (0.63)	3.58 (0.78)	3.87 (0.84)	3.50 (0.97)	3.85 (0.68)
Item 8	2.77 (0.77)	3.00 (0.68)	3.87 (0.84)	3.33 (0.93)	2.90 (0.81)	3.06 (0.78)

APPENDIX G: Informed Consent Form

Informed Consent Form

Dear Parents or Guardians,

My name is Duane Wallace and I am a doctoral student in the Teaching, Learning and Technology program at Lehigh University. I am working under the guidance of Dr. Alec Bodzin, professor of science and environmental education, on my dissertation study. I also work full time at SCVTS as the Supervisor of Learning and Technology.

I will be conducting a research project at your child's school to investigate student learning and attitudes toward science while using mobile learning technology in a citizen science project (citizen science is scientific research conducted, in whole or in part, by amateur or nonprofessional scientists). The objective is to see if participating in citizen science affects attitudes toward and interest in citizen science, STEM (science, technology, engineering and math) and the environment. Students will learn about phenology (the study of plant and animal life cycles due to climate change) while using various technologies such as smartphones, iPads, apps and Google Earth. The program will use a "bring your own device" (BYOD) approach where students use their own smartphones to learn. Students will be observing the growth patterns of several plant species and contributing their findings to a national citizen science project called Project Budburst (www.budburst.org).

This form is to request your permission to examine and analyze your child's responses to surveys and questionnaires prior to and after completing this course of study. Your child's response to these surveys will not count towards his or her grade. Also, I request permission to observe your student during the activities and analyze those observations as well. Some photographs may be taken for documentation purposes, presentations and for use in peer-reviewed research articles. If photos are used in presentations, names of the students will not be used.

By granting me permission to examine your child's activity in the project and responses to surveys, your child will be helping me to understand whether we can raise the level of engagement in scientific citizenship through authentic practice and mobile learning technologies.

Any responses to surveys and other activities will remain confidential with regard to your child's identity. Your decision about your child's participation in this study is voluntary. This research project coincides with your child's course of study in science and will not take away from regular class instruction. Several benefits of participating in this project include: an alignment with the Next Generation Science Standards, critical thinking, using technology to solve real-world issues, learning about their local environment and experiences with STEM. While some of the project activities take place outside of the classroom, there are a few minimal risks involved including: completing a survey, walking outdoors (on campus), taking leaf samples from trees and the potential for insect bites and stings. Students may withdraw from the project at any time without repercussions.

If you have any questions about this study, you may email me at dew310@lehigh.edu. You may direct questions in regard to your child's rights pertaining to the use of the data in this study to the Naomi Coll in the Office of Research and Sponsored Programs, Lehigh University, 610-758-3021. All reports or correspondence will be kept confidential.

To confirm your consent of your child's participation in this study and your permission for me to take and use photographs of your child as described above, please sign below. Thank you.

Student name: _______________________________ Date:______________

Signature of minor participant's parent or guardian __________________________

Signature if you also consent to the use of your child’s photo______________________

Investigator’s signature______________________ Date:______________

APPENDIX H: Child Written Assent Form

Child Written Assent

This form is to request your agreement to participate as a subject in the research project on Citizen Science Identity and STEM interest called Creating Citizen Science Identity: Growing Conservation and Environmentally-minded STEM interest through Mobile Learning and Authentic Practice conducted by Duane Wallace (under the supervision of) Dr. Alec Bodzin at Lehigh University.

As part of developing the Somerset County Vocational and Technical Schools science curriculum, we will be conducting a study to investigate the use of new materials. We would like to find out what you currently know about citizen science, what you think about mobile learning, science, technology, engineering and math and how you feel about climate change and the environment. We would like you to complete a citizen science, STEM and environmental survey and a questionnaire on citizen science, STEM and the environment as well as take part in a real citizen science project. Keep in mind, this is not a test. You will not get a grade, but your answers are very important because we need to understand what your whole class knows and thinks about these topics. Please answer the questions truthfully and to the best of your ability. You can stop taking the survey and stop participating in the activities at any time if you wish without repercussion.

This research project coincides with your course of study in science and will not take away from regular class instruction. Several benefits of participating in this project include: an alignment with the Next Generation Science Standards, critical thinking, using technology to solve real-world issues, learning about their local environment and experiences with STEM (science, technology, engineering and math). While some of the project activities take place outside of the classroom, there are a few minimal risks involved including: completing a survey, walking outdoors (on campus), taking leaf samples from trees and the potential of insect bites and stings.

We would like to request your permission to examine and analyze your responses to the assessment and survey. We would also like to request permission to take photographs of you while you participate in some of the project activities. If we use any of these photos in presentations or publications about this project, we will not use your names.

By granting us permission to examine your responses, you will be helping us learn how to improve the school's teaching and learning activities.

I agree to take part in this research study and give the researchers permission to use the data I provide to better understand citizen science, mobile learning, STEM, climate change and the environment.

____

Print Name

____

Sign Name

____

Date

APPENDIX I: Support Letter

SOMERSET COUNTY VOCATIONAL & TECHNICAL SCHOOLS
P.O. Box 6350 • 14 Vogt Drive • Bridgewater, NJ 08807-0350 • (908) 526-8900 • www.scvths.org

LETTER OF SUPPORT

August 9, 2017

Office of Vice President and Associate Provost for Research and Graduate Studies
Lehigh University
7 Asa Drive
Bethlehem, PA 18015

RE: IRB Letter of Support

Dear Lehigh University Institutional Review Board Chair and Members:

I am writing this letter of support for one of our colleagues, Duane Wallace. It is our intention to support Duane's research (described below) which is being conducted under primary investigator Dr. Alec Bodzin.

Research Overview

Title: Creating Citizen Science Identity: Growing Conservation and Environmentally-Minded STEM Interest through Mobile Learning and Authentic Practice

1. Project Summary: This study will take place over a six-week period during Biology class at SCVTS. Students will be arranged in teams of three and will learn how to use various technologies (such as smartphone apps, Google Earth and digital forms). They will also learn about plant life cycles, climate change and tree species. Students will explore the local environment in order to identify tree species and collect data which will be submitted to Project BudBurst. Using a BYOD (bring your own device) approach, students will be able to use their own smartphones so they can continue to learn and collect information when not in class (if they choose).

2. Objectives:
This study aims to determine how the mobile learning and authentic practice (MobiLAP) approach affects student interest in STEM as well as how it may develop citizen science identity within participants, increase climate awareness and enhance engagement in environmental activities.

Our school supports this project, including recruitment of participants and data collection, through our institution.

Sincerely,
Dr. Chrys Harttraft

Dr. Chrys Harttraft
Superintendent of Schools
Somerset County Vocational & Technical Schools
14 Vogt Drive
Bridgewater, NJ 08807
908.526.8900

Duane Wallace

duane@duanew.com | www.linkedin.com/in/duanewallace | www.duanew.com

INSTRUCTIONAL TECHNOLOGIST AND EDUCATOR PROFILE SUMMARY

- An educational technology leader with 13+ years' experience in higher education.
- Proficient in web based learning (synchronous and asynchronous), traditional instruction, and blended teaching approaches.
- A developer of sound pedagogical processes specifically designed for adult learning.
- A successful manager of projects and people, able to prioritize and multitask complex initiatives.
- Analyzes new educational technology, adapts to industry trends and contributes to the application of technology in education.
- An exceptional communicator who is skilled in engaging a diverse population of learners.
- A lifelong learner that obtained a PhD in Teaching, Learning and Technology in May, 2018.
- A team player that contributes to the success of the organization.
- Created State Board test simulation which more than tripled pass-rates (from 20% passing to 64% passing) and raised average scores over seven percentage points.

EDUCATIONAL TECHNOLOGY MANAGEMENT & INSTRUCTIONAL EXPERIENCE

Supervisor of Technology-based Learning and Communications — August 2007 - Present
Somerset County Vocational & Technical School District (SCVTS), Bridgewater, NJ

- Educate faculty and staff on the integration of technology within the classroom and workplace.
- Implemented and manages Moodle Learning Management System.
- Train faculty, staff and students on the use of distance learning platforms.
- Create, manages and delivers online courses for faculty, staff and students.
- Manage social media presence and completed three redesigns and implementations of district websites.
- Supervise technology and communications personnel and serve on multiple committees.
- Create marketing campaigns and publicity materials for the district.
- Provide visionary and fiscal oversight for educational technology and communications.
- Created and developed the Mechatronics, Engineering and Advanced Manufacturing Program.
- Deliver presentations and reports to the Board of Education and district administrators.

Instructional Technology Specialist — April 2005 - July 2007
Lackawanna College, Scranton, PA

- Implemented and educated faculty on the Jenzabar Internet Campus Solution (LMS).
- Collaborated with faculty to develop online courses.
- Coordinated the Lehigh University distance education satellite location at Lackawanna College.
- Managed the redesign and maintenance of college websites.
- Coordinated the Lehigh University distance education satellite location at Lackawanna College

Adjunct Professor, Theatre/Communications Program — April 2005 - July 2007
Lackawanna College, Scranton, PA

- Developed curriculum and taught classes for the Theatre/Communications Program.
- Directed and managed student theatre performances.
- Provided academic advising to students in the Communications Program.

Faculty — January 2010 - Present
University of Phoenix (online)

- Facilitate Online Courses in web design and web systems.
- Remains current with university trainings and LMS changes including proprietary and third party systems.

EDUCATION

Lehigh University, Bethlehem, Pennsylvania — Anticipated: May 2018
Ph.D. Teaching, Learning and Technology – 3.92 GPA

Bloomsburg University, Bloomsburg, Pennsylvania — Graduation: May 2005
Master of Science, Instructional Technology – 3.55 GPA

Bloomsburg University, Bloomsburg, Pennsylvania — Graduation: May 2003
Bachelor of Arts, Theatre Arts/Communication Studies

Luzerne County Community College, Nanticoke, Pennsylvania — Graduation: May 2000
Associate of Science, Education

CONFERENCE PRESENTATIONS

- ASTE 2018, Baltimore, MD. January 3-6. *"Developing Scientific Citizenship Identity Using Mobile Learning and Authentic Practice."*
- ISTE 2015, Philadelphia Pennsylvania. June 28 – July 1, 2015. *"OhSnap: Using Mobile Learning Technologies and Authentic Tasks to Foster Scientific Citizenship"*
- ISTE 2015 VILS Virtual Conference. February 10. *"Transformative Learning: Using Mobile Technologies and Authentic Tasks to Foster Scientific Citizenship"*
- ASTE 2014, Columbia University, NYC. October 16-17. *"Affordances of Mobile Learning Technologies in the Environmental Sciences"*
- PETE&C 2013, Hershey, PA. February 10-13. *"Project-Based Grad Class Pushes Tech's Limits"*.
- TECHSPO 2010, Atlantic City, NJ. Sponsored by the New Jersey Association of School Administrators (NJASA) - January 28-29. *"Developing Technological Literacy Among Faculty and Staff"*
- Capital Region Society for Technology in Education (CRSTE) CyberConference 2010, February 28. *"Developing Technological Literacy Among Faculty and Staff - On the Fly"*

PUBLICATIONS

"Creating Citizen Science Identity: Growing Conservation and Environmentally-Minded Stem Interest through Mobile Learning and Authentic Practice.” *Dissertation* (2018).

"Developing Scientific Citizenship Identity Using Mobile Learning and Authentic Practice." *Electronic Journal of Science Education* 21, no. 6 (2017).

AWARDS & HONORS

- $380,000.00 competitive grant award – 2018 County Vocational School Partnership Grant
- $650,000.00 competitive grant award – 2016 County Vocational School Partnership Grant.
- First place in Newsletter Category – NJSPRA 2015 School Communications Awards.
- “Excellence in Action Award” 2007 – Lackawanna College.

TECHNICAL SKILLS

Standard: Microsoft Office, Adobe Acrobat

Creative Tools: Adobe (Image Ready, Director, Premiere, Breeze, Captivate, Illustrator, Photoshop, Fireworks, Authorware), Sonic Foudry Sound Forge, Saba Centra

Software: Adobe CS3: Adobe Image Ready, Adobe Director, Adobe Premiere, Adobe Breeze, Adobe Captivate, Camtasia

Webdesign: Adobe Dreamweaver, Adobe Flash, Content Management Systems

Coding: HTML, FTP, CSS, JavaScript

Learning Management Systems: Blackboard, WebCT, Google Classroom, Jenzabar, Moodle, Phoenix LMS

CERTIFICATIONS & CORPORATE TRAINING

- Somerset County Government Employee Training - Adobe Acrobat Professional XI implementation
- University of Phoenix – Faculty Certification – Core Materials
- University of Phoenix – Faculty Certification – Axia College Materials
- University of Phoenix – Faculty Certification – New Classroom Facilitator

PROFESSIONAL AFFILIATIONS

International Society for Technology in Education
New Jersey Principals and Supervisors Association
New Jersey Association for Educational Technology
Association for Science Teacher Education

RESEARCH INTERESTS

- Educational technology

- Mobile learning
- Distance learning
- Citizen science