ECOLOGICAL LITERACY, URBAN GREEN SPACE, AND MOBILE TECHNOLOGY: EXPLORING THE IMPACTS OF AN ARBORETUM CURRICULUM DESIGNED FOR UNDERGRADUATE BIOLOGY COURSES

by

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I lovingly dedicate this dissertation to my family, who supported me throughout this challenging process. A special thank you is due to my wife, Vena, and my loving daughters, Zooecia and Sophia, who bore the largest burden. Despite the many challenges my work presented, they continually offered me a level of unwavering support and unconditional love that only those most close can offer. I am eternally indebted to them for their patience and understanding.

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ABSTRACT

Increasing individual ecological literacy levels may help citizens make informed choices about the environmental challenges facing society. The purpose of this study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers during a summer course.

Using a convergent parallel mixed-methods design, both quantitative and qualitative data were collected, analyzed, and later merged to create an enhanced understanding of the impact of the curriculum on the environmental attitudes and beliefs of the participants. Quantitative results revealed a significant difference between pre- and post-survey scores for ecological knowledge, with no significant differences between pre- and post-scores for the other variables measured. However, no significant difference in scores was found between experimental and comparison groups for any of the three variables.

When the two data sets were compared, results from the quantitative and qualitative components were found to converge and diverge. Quantitative data indicated the environmental attitudes and beliefs of participants were unaffected by the arboretum curriculum. Similarly, qualitative data indicated participants' perceived environmental attitudes and beliefs about the importance of nature remained unchanged throughout the course of the study. However, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum helped participants develop an appreciation for trees and nature and led them to believe they increased their knowledge about trees.

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CHAPTER 1: INTRODUCTION

For the first time in history, most people live in urban areas (United Nations Department of Economic and Social Affairs, Population Division [UNDESA], 2014), including an estimated 84% of North Americans (United States Census Bureau [USCB], 2010a). As one of the many human activities that alter habitats, urban development poses an escalating threat to biological diversity (McKinney, 2002). Urban areas diminish and degrade habitats (Marzluff, 2001), while contributing to the homogenization of distinctive ecosystems by facilitating the establishment of non-native species (Blair & Launer, 1997). They may also increase the separation people feel from natural environments, isolate them from natural systems, and decrease the quantity and quality of human interactions with nature (Lin, Fuller, Bush, Gaston, & Shanahan, 2014; Turner, Nakamura, & Dinetti, 2004).

Along with urban development, other human activities such as agriculture and energy and material extraction have led to the disruption of many natural systems and a reduction in ecological and biological diversity (Trombulak et al., 2004; Wilson, 1989). As a result, many ecosystems have experienced significant changes in their fire regimes, geomorphology, hydrology, productivity, and nutrient cycling (Dukes & Mooney, 2004). Coupled with these profound changes in natural systems is a staggering decline in biological diversity. The global rate of species loss is conservatively 1,000 times the rate of pre-human intervention, and in this century the scale of species loss may become the largest in the last 65 million years (Barnosky et al., 2011).

However, urban green infrastructure, such as green spaces, help conserve biological diversity and offer other human health benefits (Brown & Grant, 2005; Shwartz, Turbé, Simon, & Julliard, 2014). Urban green spaces also provide the opportunity for people in urban environments to interact with intact local natural and semi-natural areas, which has been shown to increase individual levels of ecological literacy (Cooper, 2008; Lindemann-Matthies, 2005; Parker, 2009; Pilgrim, Cullen, Smith, & Pretty, 2008). Additionally, widely available mobile technologies like smart phones and tablets foster collaboration and communication (Gikas & Grant, 2013). By combining the use of urban green spaces and mobile technology, it may be possible to enhance individual ecological literacy levels by providing direct experience with nature and creating a more collaborative learning environment (Looi et al., 2011).

Statement of the Problem

Preserving biological and ecological diversity is an essential goal for continued human survival, because humans are inseparably linked to the environments humans are transforming. To address the environmental problems that confront us, there is a need for an ecologically literate citizenry that can make well-informed decisions (Hsu, 2004; United Nations Educational, Scientific and Cultural Organization [UNESCO], 1980). Ecological literacy can be broadly defined as the ability to understand environmental problems in order to make reasonable and informed decisions at a citizen's level (Nair, Jones, & White, 2002; Orr, 1991).

Although the ecological literacy of the average American is unknown, it is widely believed that it is not developed enough to facilitate the development of effective solutions to our current environmental problems (Jordan, Singer, Vaughan, & Berkowitz, 2008). In fact despite

the widely recognized need for ecological literacy among citizens to make informed decisions regarding the environmental problems facing society, basic knowledge of our natural surroundings is decreasing (Atran, Medin, & Ross, 2004). Importantly, direct experience with nature has been widely noted as a critical factor affecting individual ecological literacy levels (Cooper, 2008; Eaton, 1998; Parker, 2009; Preston & Griffiths, 1995; Wagner, 2008).

Purpose of the Study

The purpose of this study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers. The quantitative component of the study sought to answer several questions. First, were there significant differences among the groups and the comparison group on ecological knowledge, environmental attitudes and beliefs, and environmental behaviors? Next, were there significant differences between the pre- and post-survey scores for ecological knowledge, environmental attitudes and beliefs, and environmental behaviors? Finally, were there significant interaction effects between the group and survey factors on ecological knowledge, environmental attitudes and beliefs, and environmental behaviors?

Although the quantitative portion of the study focused on three different variables, the qualitative component focused solely on environmental attitudes and beliefs. The qualitative research question was: How does participation in the arboretum curriculum influence the perceived environmental attitudes and beliefs of undergraduate students, if at all? Though the qualitative instruments and analysis focused on environmental attitudes and beliefs, any ideas

that emerged related to ecological knowledge and environmental behavior were noted. Results that emerged from the exploratory qualitative data about students' environmental attitudes and beliefs were compared to results from the quantitative data.

Significance of Study

Although many factors such as resource dependency and urbanization have been shown to affect ecological literacy levels, the primary reason for the decline in ecological literacy can be attributed to the diminishing amount of time people spend in natural environments (Pilgrim, Smith, & Pretty, 2007). The literature is also clear on the benefits provided by urban green infrastructure such as green spaces in terms of human health, biological diversity, and ecological services (Brown & Grant, 2005; Cornelis & Hermy, 2004). Because of their critical role in mitigating stormwater runoff and improving urban air quality (McPhearson, Maddox, Gunther, & Bragdon, 2013), urban trees are particularly important elements of urban green infrastructure. However, studies evaluating the ability of urban green spaces to increase ecological literacy (e.g., Shwartz et al., 2012; Shwartz et al., 2014) are not widespread in the literature (Lin et al., 2014; Standish, Hobbs, & Miller, 2013).

Additionally, although studies evaluating the use of mobile technology to enhance non-specific domain learning are numerous (Martin & Ertzberger, 2013; Wu et al., 2012), studies investigating the combined use of direct experience with nature and mobile technologies to enhance ecological literacy are less prevalent (e.g., Liu, Peng, Wu, & Lin, 2009; Ruchter, Klar, & Geiger, 2010; Zimmerman & Land, 2014). Given the ability of mobile technologies to foster

communication, collaboration, and help create a more student-centered learning environment (Gikas & Grant, 2013; Looi et al., 2011), the need for further research in this area is clear.

There is national support for improving individual ecological literacy levels among K-12 students that is illustrated in the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). The NGSS explicitly address several aspects of ecological literacy in the Disciplinary Core Ideas (DCI) that form an integral part of the standards. The DCIs were designed to connect to the experiences and interests of students that involve scientific knowledge and connect to societal concerns (National Science Teacher's Association [NSTA], 2015). DCI LS2 Ecosystems: Interactions, Energy, and Dynamics; DCI LS4 Biological Evolution: Unity and Diversity; and DCI ETS1.B: Developing Possible Solutions address aspects of ecological literacy as defined in the study (NGSS Lead States, 2013).

At the undergraduate level, support for improving individual ecological literacy can be found in *Vision and Change in Undergraduate Biology Education: A Call to Action* (American Association for the Advancement of Science [AAAS], 2011). The report provides five recommended core concepts and six core competencies for biological literacy (AAAS, 2011). Of the five core concepts, learning about the connectedness of living systems and how those systems change and grow over time relates directly to ecological literacy. Finally, understanding and evaluating the role that science plays in society and how science can be used to solve the problems facing society is part of the definition of ecological literacy and is also a core competency in the *Vision and Change* report (AAAS, 2011).

Framework

The ecological literacy framework that guided this study is based on the work of Jordan, et al. (2008). Their framework consists of three elements that are critical features of ecological literacy. First, this framework recognizes that ecological literacy by necessity combines an understanding of the connections between human activities and human impacts on the environment. Second, it emphasizes the importance of understanding key ecological concepts such as the connectivity of ecosystems, biological diversity, and energy transfer. Third, it realizes the fundamental importance of skills such as critical thinking and reasoning as they pertain to the science of ecology and the issues surrounding it. A more thorough discussion of the framework outlined by Jordan et al. (2008) has been provided in Chapter Two.

Definition of Terms

To support the reader's interpretation of this study, the following definitions of ecological literacy, urban green infrastructure, urban green spaces, and mobile technology have been provided.

Ecological Literacy

One of the first to use the term ecological literacy was David Orr (1991). Orr did not offer an explicit definition of ecological literacy but instead provided a list of topics students needed to master to be ecologically literate that included economics, ecology, thermodynamics, agriculture, technology, and ethics. However, an explicit definition of ecological literacy was offered by Nair et al. (2002). They defined ecological literacy as the ability to have a context-based understanding of environmental issues that enables individuals to analyze, synthesize,

evaluate, and make decisions about environmental issues at a citizen's level. Thus, ecological literacy can be broadly defined as the ability to understand environmental problems in order to make reasonable and informed decisions at a citizen's level (Nair et al., 2002; Orr, 1991).

Urban Green Infrastructure

The definition of urban green infrastructure used in this study is adapted from the United States Environmental Protection Agency (2014), which describes it as urban open space that uses natural water features and flow patterns to mitigate water flow and at the same time provide environmental benefits to a community. For the purposes of this study, this definition has been combined with a broader interpretation of urban green infrastructure that includes any natural or semi-natural network of functioning ecological systems of varying scales that are located in or around urban areas (Tzoulas et al., 2007). Therefore, the definition of urban green infrastructure used here includes urban networks and other environmental features such as parks, which is largely the same definition used by Shwartz et al. (2014).

Urban Green Space

The definition of urban green space used in this study is adapted from the United States Environmental Protection Agency (2016), which defines urban green space as urban land that is completely or partially covered with vegetation. This includes community gardens, cemeteries, parks, schoolyards, and public plazas. This definition is combined with that used by James et al. (2009), which further defines urban green space as largely permeable surfaces such as soil, trees, grass, and shrubs. The green space used in this study was a university arboretum.

Mobile Technology

For the purposes of this study, mobile technology is defined as wirelessly networked, portable, and personal electronic devices such as mobile phones and tablets (Crompton, 2014; Crompton & Keane, 2012; Looi et al., 2011). Mobile technologies such as phones and tablets can be used to make calls, access the internet, share photos and videos, find locations, and participate in social media. They are essential tools of modern life that enable communication, sharing, collaboration, and learning that also minimize temporal and locational restraints (Looi et al., 2011). Mobile technology such as mobile phones and tablets also have the potential to make learning more personalized and learner-centered, while providing a context for learning (Crompton, 2014).

Chapter Summary

Human activities such as urbanization pose an increasing threat to biological diversity (McKinney, 2002). Preserving biological diversity is a necessity, and increasing individual ecological literacy levels may help citizens make informed choices about the environmental challenges confronting society (Hsu, 2004; UNESCO, 1980). Unfortunately, basic knowledge of our natural surroundings is diminishing (Atran et al., 2004).

However, urban green infrastructure and urban green space help conserve biological diversity and may help people develop and maintain connections with natural spaces (Brown & Grant, 2005; Shwartz et al., 2014). Furthermore, mobile technology has the potential to facilitate collaboration and cooperation among peers that is not limited by time and space (Looi et al., 2011) and make learning more student-centered (Gikas & Grant, 2013). Because studies

investigating the effects of urban green space on ecological literacy (e.g., Shwartz et al., 2012; Shwartz et al., 2014) are not widespread in the literature (Lin et al., 2014; Standish et al., 2013), this study seeks to contribute to that understanding. Moreover, studies exploring the combined use of mobile technology and place-based environmental education (e.g., Liu, Peng, Wu, & Lin, 2009; Ruchter, Klar, & Geiger, 2010; Zimmerman & Land, 2014) are also not widespread in the literature and this study also seeks to advance this area of inquiry.

CHAPTER 2: REVIEW OF LITERATURE

The purpose of this study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers. The intent of this chapter is to provide a review of the relevant literature regarding the impact of urban green spaces and mobile technology on individual levels of ecological literacy. The chapter is organized into several sections, beginning with a critique of the research relevant to the study. Next, a summary of the research is offered, followed by a synthesis of ideas, concepts, and inferences for the current study. The critique itself is divided into four sections, with each addressing one of four areas of interest. The first section examines articles that attempt to define ecological literacy or develop a framework to guide researchers and practitioners interested in promoting this. The second section surveys articles that attempt to identify factors affecting individual levels of ecological literacy. The third section investigates articles detailing the effects of urban green infrastructure and urban green spaces. Finally, the fourth section examines articles that involved the use of mobile technology to enhance ecological literacy.

Critique of Research

The critique of the research is organized into four categories. The first category includes studies that attempted to define and develop a framework for ecological literacy. Next, the second category focuses on studies that illustrated factors affecting individual levels of ecological literacy. Then, the third category is comprised of studies that explored the effects of

urban green infrastructure. Finally, the fourth category examines studies that incorporated the use of mobile technology to enhance ecological literacy.

Defining Ecological Literacy and Developing a Framework

Both the definitions of ecological literacy and the theoretical frameworks developed to guide practitioners and researchers in promoting it varied in the literature (Jordan et al., 2008; McBride, Brewer, Berkowitz & Borrie, 2013). Ecological literacy has often been used interchangeably with the terms ecoliteracy and environmental literacy, and the theoretical frameworks for ecological literacy have varied widely in terms of the number of components deemed critical and the emphasis placed on these various elements (McBride et al., 2013). The prevalence in the literature of discussions regarding the exact meaning of ecological literacy and the frameworks used to address it, along with the importance of operationalizing these concepts for future research, led to the selection of this topic for the review.

One of the first to use the term ecological literacy was David Orr (1991). His article has served as a foundational resource for the topic of ecological literacy and helped illustrate the connection between education and human cultural practice (our modern drive to dominate nature). Orr (1991) contended that environmental destruction placed human prosperity and health at risk and noted that the destruction has been a result of the actions of highly educated people. He argued that the education they received was the culprit and named six myths that underlie its foundation: ignorance is a solvable problem; the earth can be managed with more technology and knowledge; increasing human knowledge equates with increasing human

goodness; humans can restore what they have destroyed; human culture is the zenith of human achievement; and the purpose of education is upward mobility and success (Orr, 1991).

With these misconceptions in mind, Orr (1991) suggested six education principles to promote human survival through sustainability: all education is environmental education; the goal of education is self-mastery not subject mastery; with knowledge comes the responsibility to use it wisely; humans only know something when they understand its effects on real communities and the people in them; examples are more powerful than words; and the way that learning occurs is as important as the content. Although Orr (1991) did not offer an explicit definition of ecological literacy, he did provide a list of topics students needed to master to be ecologically literate that included economics, ecology, thermodynamics, agriculture, technology, and ethics. However, an explicit definition of ecological literacy was offered by Nair et al. (2002). They defined ecological literacy as the ability to have a context-based understanding of environmental issues that enables individuals to analyze, synthesize, evaluate, and make decisions about environmental issues at a citizen's level.

In a further effort to more specifically define ecological literacy, Jordan et al. (2008) reviewed the literature and presented a discussion of the efforts to develop a theoretical framework for ecological literacy. Their paper brought together ideas from a wide range of social sciences with content deemed critical by ecologists. The proposed framework had three components: appreciating the links between the environment and human actions; understanding key ecological concepts; and advocating the development of skills that help individuals reason about ecological sciences and issues.

Included in their understanding of key ecological concepts was a list of essential ideas that related the distribution of species to both biotic and abiotic factors in an environment that included biological diversity, nutrient cycles, evolutionary concepts, population dynamics, organisms, and species. Critically, Jordan et al. (2008) also indicated that an understanding of the relationship between human actions and the resultant impacts on ecosystems was a fundamental factor in defining ecological literacy.

The third component of the framework advanced by the authors illustrated their belief that a definition of ecological literacy must include the ability to discern between scientific evidence and evaluation based on beliefs (Jordan et al., 2008). Finally, Jordan et al. (2008) concluded by calling for professional input to further refine the framework (e.g., outlining the role of values, defining sustainability in the context of education, and exploring the psychosocial aspects of ecological literacy).

Similarly, McBride et al. (2013) also reviewed the research to better define ecological literacy and the theoretical frameworks used to guide researchers and practitioners. Their study first discussed the differences between ecological literacy (i.e., critical ecological knowledge necessary for making informed decisions), environmental literacy (i.e., awareness of the environment, its problems, and the knowledge and skills to work towards solutions), and ecoliteracy (i.e., focusing on sustainable communities and society) (McBride et al., 2013). The authors then compared various frameworks proposed for research in these fields and provided an overview of past, present, and future research in these areas.

The environmental literacy frameworks reviewed shared these themes: knowledge of ecological concepts; awareness of environmental problems and issues; environmental appreciation; and the actions and skills necessary to prevent or improve environmental issues (McBride et al., 2013). The ecological literacy frameworks reviewed varied in the number of components deemed critical (from four to twenty), with an emphasis on explicit ecological knowledge, scientific-inquiry skills, and human dependence on ecological systems (McBride et al., 2013). The authors found more recent ecological frameworks focused on the components of the scientific method and systems thinking (environmental context). The ecoliteracy frameworks shared most themes with the environmental literacy frameworks, with the major difference being an emphasis on sustainability and spirituality (reverence for the earth) (McBride et al., 2013).

Likewise, Berkowitz, Ford, and Brewer (2005) provided an overview of the various definitions of ecological literacy and some of the terms associated with it in their chapter on developing a framework for integrating ecological literacy, environmental education, environmental citizenship, and civics literacy. However, their analysis also included additional information on environmental citizenship (i.e., having the motivation, awareness, and ability to use ecological knowledge and engage in civic duties) and civics literacy (i.e., understanding and participating in social systems) (Berkowitz et al., 2005). The authors additionally illustrated the relationships between these concepts, presented a framework for ecological literacy (to guide theory, research, and practice), and identified several pathways to integrating ecological literacy into environmental education. The framework consisted of three dimensions: key ecological systems, ecological thinking skills, and the place of ecological science in society. The pathways

identified were pedagogy, education research, materials and curriculum, standards and assessments, institutions, and academics. Finally, the authors identified two themes in education research as in need of investigation: how do individuals learn ecological concepts and what do they already know about ecological systems.

A thorough examination of the literature led to the realization that the characterizations of ecological literacy and the theoretical frameworks developed to guide both researchers and practitioners have varied widely in the literature (Jordan et al., 2008; McBride et al., 2013). This has occurred from nearly the beginning of the usage of the term, with Orr (1991) having provided only a list of topics students needed to master to be ecologically literate (e.g., economics, ecology, thermodynamics, agriculture, technology, and ethics) rather than an explicit definition. Nair et al. (2002) took a quite different approach and explicitly defined it as the ability to have a context-based understanding of environmental issues that enables individuals to analyze, synthesize, evaluate, and make decisions about environmental issues at a citizen's level. In comparison, McBride et al. (2013) defined it solely as critical ecological knowledge necessary for making informed decisions. Thus, there were many varying definitions of ecological literacy found in the literature.

Similarly, the elements for the frameworks to address ecological literacy varied widely and were the subject of frequent debate. Berkowitz et al. (2005) presented a framework for ecological literacy that consisted of three dimensions: key ecological systems, ecological thinking skills, and the place of ecological science in society. After reviewing the literature, Jordan et al. (2008) proposed a different framework that also had three components:

appreciating the links between the environment and human actions, understanding key ecological concepts, and advocating the development of skills that help individuals reason about ecological sciences and issues. Although many shared an emphasis on explicit ecological knowledge, scientific-inquiry skills, and human dependence on ecological systems, in fact the ecological frameworks in the literature varied widely in the number of components that were deemed critical (McBride et al., 2013). Furthermore, the components of more recent ecological frameworks have shifted again and focused on the scientific method and environmental systems thinking (McBride et al., 2013).

Factors Affecting Individual Levels of Ecological Literacy

Understanding the factors causing the decline in ecological literacy was also a central theme in the literature examined. A decline in individual levels of ecological literacy was noted across cultures, economic levels, and gender (Atran et al., 2004; Pilgrim et al., 2007; Cooper, 2008; Jordan et al., 2008; Parker 2009). Documenting the decline in ecological literacy and the factors responsible for this decline was an essential first step in developing strategies for reversing the trend, and therefore much of the foundational work done in the field of ecological literacy was done with the intent of establishing the levels of individual ecological literacy and identifying the factors affecting those levels.

Parker's study (2009) surveyed over 400 New Zealand households to explore predictors of ecological knowledge. Data collected consisted of photo identification of species, free-listing of species, and knowledge of local avifauna. The study of New Zealand residents found that participants with more education who visited local natural areas, lived in less urbanized areas,

and had larger yards exhibited greater levels of ecological literacy (Parker, 2009). The paper concluded with a call for more research to develop a better understanding of urban ecological knowledge, generational loss of ecological knowledge, and a more detailed understanding of the factors that predicted levels of ecological knowledge.

Pilgrim, Smith, and Pretty (2007) sought to develop a better understanding of these factors by measuring the ecological knowledge of 504 Ohio adults and collecting their demographic information using a telephone survey. The results indicated that individuals with low ecological literacy levels differed significantly from individuals with high ecological literacy in several ways. For example, the individuals with the lowest ecological literacy levels were generally less educated, had a lower than median household income level, were older, were minorities, and were female (Mancl et al., 1999). Furthermore, individuals with low levels of ecological literacy were also less likely to obtain information from environmental groups, more likely to obtain information from television, and less likely to participate in outdoor activities (Mancl et al., 1999).

Unlike the previous two studies which focused solely on non-resource-dependent communities, Pilgrim et al.'s (2007) study compared resource-dependent and non-resource-dependent communities. The study examined the factors affecting ecological literacy of individuals (n = 1250 interviews) in rural, suburban, urban, and coastal sites in the United Kingdom (non-resource-dependent), India (resource-dependent), and Indonesia (resource-dependent). In the United Kingdom, participants with the highest levels of ecological literacy resided or were raised in rural areas, visited the countryside often, and obtained their knowledge

from informal sources (family, friends, and hobbies) (Pilgrim et al., 2007). In India and Indonesia, ecological literacy differed by gender (men higher in India; animal husbandry higher in Indonesian men and ethnobotanical knowledge higher in Indonesian women) and wealth status (least wealthy had higher levels) (Pilgrim et al., 2007). The importance of oral transfer and direct experience in maintaining ecological literacy was evident at all study sites. Pilgrim et al. (2007) emphasized the importance of direct experience in developing and maintaining ecological literacy and suggested informal learning environments situated in natural settings were more effective when they emphasized oral transmission of ecological knowledge and collaborative interaction between learners (which may mimic the interactions in a family setting).

In a subsequent study that further investigated these cross-cultural themes, the results suggested that as the wealth of a society increased, ecological knowledge tended to become more concentrated in individuals with a particular interest (e.g., people who study the environment) (Pilgrim et al., 2008). Conversely, in societies that were dependent on the natural environment for resources, ecological knowledge was equally shared by members of the community involved in day-to-day activities involving meeting the needs of families (Pilgrim et al., 2008). Pilgrim et al. (2008) attributed this general decline in ecological knowledge among members to an overall decreased amount of time spent interacting with natural environments.

Relatedly, Wagner (2008) examined the botanical knowledge of South Carolina college students and found similar results although the sample size was small (n = 31). The participants were asked to free-list different categories of plants (such as local crops, grasses, wildflowers, trees, etc.). The results indicated that students had a poor understanding of plant morphology

and local ecology, and the few plants they could correctly name were crop plants and came largely from human-managed landscapes not natural wild landscapes (Wagner, 2008). The author attributed the lack of local botanical knowledge to the limited or non-existent interaction of the participants with natural ecosystems, which are rare or non-existent for many urban residents (Wagner, 2008). Wagner (2008) also added that crop plants were much more likely to be correctly categorized and listed because they had more cultural salience or more cultural significance than the wild plants.

While many factors were associated with various levels of ecological literacy such as location (urban vs. rural), race, gender, age, income, and level of education (Mancl et al., 1999; Parker, 2009; Pilgrim et al., 2007; Pilgrim et al., 2008), direct experience with nature was noted among nearly all studies examining factors affecting individual levels of ecological literacy (Cooper, 2008; Eaton, 1998; Goldman, Assaraf, & Shaharabani, 2013; Luksa et al., 2009; Mancl et al., 1999; Parker, 2009; Pilgrim et al., 2007; Pilgrim et al., 2008; Preston & Griffiths, 1995; Prokop, Tuncer, & Kvasničák, 2007; Wagner, 2008). Thus, the research examined has provided strong evidence that direct experience is a critical factor affecting individual ecological literacy levels across many demographic and socioeconomic factors.

For example, Parker's (2009) study found that New Zealand residents who visited local natural areas exhibited greater levels of ecological literacy. Additionally, Pilgrim et al.'s (2007) study comparing resource-dependent and non-resource-dependent communities in the U.K., India, and Indonesia also emphasized the importance of direct experience in developing and maintaining ecological literacy and found direct experience in maintaining ecological literacy

was evident at all study sites. Moreover, a subsequent study by Pilgrim et al. (2008) attributed a general decline in ecological knowledge among community members to an overall decreased amount of time spent interacting with natural resources. Furthermore, Mancl et al. (1999) reported that individuals with lower levels of ecological literacy were less likely to participate in outdoor activities.

However, it is important to note that although direct experience with nature may be a determining factor in individual levels of ecological literacy, it has been argued that there may be an underlying cause for the decline in ecological literacy as measured by knowledge of local organisms such as plants. Wagner (2008) acknowledged that the lack of local botanical knowledge was likely attributed to the limited or non-existent interaction of individuals with natural ecosystems, which are rare or non-existent for many urban residents. More importantly, she attributed this lack of ecological knowledge of wild plants to a general lack of cultural salience or cultural significance associated with these organisms (Wagner, 2008). While this idea was limited to one study, it raised important questions about the underlying causes of the decline in ecology literacy related to the role of local environments as cultural resources and suggested further study in this area is needed.

Effects of Urban Green Infrastructure

An examination of the literature on the effects of urban green infrastructure revealed two recurring themes. The first theme to emerge concerned the ecosystem and human health benefits of urban green infrastructure. The second theme involved the potential for urban green infrastructure to increase the appreciation and awareness among urban inhabitants for native

wildlife and intact ecosystems. In the remainder of this section, the articles reviewed on urban green infrastructure are discussed as they relate to these two themes.

Ecosystem and human health benefits of urban green infrastructure. Among the most widely discussed ecosystem benefits of urban green infrastructure were improved water quality and flood prevention (Ravit, Obropta, & Kallin, 2008), air quality (Brown & Grant, 2005), and habitat and biodiversity conservation (Brown & Grant, 2005; Shwartz et al., 2012; Shwartz et al., 2014). Urban green infrastructure such as restored urban wetlands and riparian areas were found to reduce runoff from stormwater and remove pollutants such as nitrates (Ravit et al., 2008). In addition to the hydrological benefits of urban green infrastructure, both Ravit et al. (2008) and Shwartz et al. (2012) noted that preserving diminishing open space contributed to habitat preservation. As an additional benefit of conserving habitat, urban green infrastructure was also found to preserve or even enhance existing biodiversity (Cornelis & Hermy, 2004; Shwartz et al., 2012; Shwartz et al., 2014). Furthermore, Cornelis and Hermy (2004) showed that urban green infrastructure can function as biodiversity hotspots in urban areas.

Along with the ecosystem services provided by urban green infrastructure, a review of the literature also revealed the human health benefits of urban green infrastructure. Brown and Grant (2005) performed a thorough review of studies examining the effects of interacting with natural areas on human health. In addition to improving air quality and ameliorating temperature extremes, the authors reported interactions with natural areas resulted in reduced heart rates, lower blood pressure, and a reduction in stress levels (Brown & Grant, 2005). These effects were particularly evident in urban areas (Brown & Grant, 2005). Luck, Davidson, Boxall, and

Smallbone (2011) also found that human well-being was a function of the natural features found in neighborhoods but cautioned that demographic characteristics such as activity level and age explained more variance among their participants.

Urban green infrastructure's potential to increase environmental awareness. As mentioned previously, the second theme involved the potential for urban green infrastructure to increase the appreciation and awareness among urban inhabitants for native wildlife and intact ecosystems. Noss (2004) maintained having urban green spaces provided opportunities for individuals to retain their intrinsic appreciation of nature, resulting in citizens willing to support conservation initiatives. Standish et al. (2013) examined several options for enhancing biodiversity in urban landscapes, focusing on ways to increase human interaction with nature. The authors argued that increasing opportunities to interact with natural areas might help researchers understand the perception urban residents have about biodiversity and the need to protect natural landscapes (Standish et al., 2013).

Relatedly, Shwartz et al. (2012) found a strong positive correlation between the amount of participation of individuals in urban natural activities and their interest in the local urban biodiversity. However, Lin et al. (2014) found that orientation was more important than opportunity for using urban green space. They suggested efforts to increase an individual's appreciation of nature would be more effective than increasing the amount of urban green space available (Lin et al., 2014).

Summary. The analysis of the literature reviewed concerning urban green infrastructure revealed two themes. The first theme to emerge was associated with the benefits to human and

ecosystem health offered by urban green infrastructure. The second theme encompassed the potential for urban green infrastructure to positively affect the ecological literacy and appreciation for native wildlife and healthy ecosystems of urban inhabitants. These two themes are summarized in the remainder of this section.

A review of the literature revealed that urban green infrastructure provided benefits in terms of both ecosystem services and human health (Brown & Grant, 2005; Ravit et al., 2008). Benefits to ecosystems included improvements in water quality and flood prevention (Ravit et al., 200, habitat preservation, and conservation of biodiversity (Ravit et al., 2008; Shwartz et al., 2012; Shwartz et al., 2014). Human health benefits provided by urban green infrastructure included improved air quality, reduced heart rates, and faster healing rates (Brown & Grant, 2005). General human well-being was also correlated with the presence of natural features in neighborhoods, but was found to be less predictive of human health than demographic factors such as age or level of activity (Luck et al., 2011).

The second theme to emerge in the review of the urban green infrastructure literature consisted of the potential for urban green infrastructure to increase the individual ecological literacy and appreciation for native wildlife and healthy ecosystems of urban residents. Noss (2004) argued urban green spaces increased contact with nature and resulted in citizens more likely to support biodiversity conservation. Standish et al. (2013) maintained that urban green infrastructure increased the contact urban residents had with natural areas, which may provide researchers the opportunity to better understand how people in highly urbanized areas perceive and value natural landscapes.

Shwartz et al. (2012) also argued that participating in activities in natural settings had a positive impact on urban residents' interest in biodiversity, citing a strong positive correlation between the two revealed by their study. However, Lin et al. (2014) cautioned that pre-existing orientation may be a more important factor than availability when examining the likelihood that an individual may use urban green spaces. Next, a summary of the literature reviewed concerning the use of mobile technology to enhance ecological literacy is offered.

Using Mobile Technology to Enhance Ecological Literacy

An examination of the literature regarding the use of mobile technology to enhance individual ecological literacy levels revealed both the rapidly changing nature of research in this area and the two general areas of research interest: assessing the usefulness of using mobile technology to enhance learning in this content area and designing ecological and environmental learning activities incorporating mobile technology. These general research trends are similar to those found by Wu et al. (2012) during their meta-analysis of studies incorporating mobile learning across a variety of content areas.

Importantly, none of the studies examined explicitly mentioned ecological literacy as the content area. Instead the studies used terms like outdoor natural science learning (Chen, Hwang, & Tsai, 2014; Liu, Peng, Wu, & Lin, 2009; Liu, Tan, & Chu, 2009), environmental knowledge and awareness (Uzunboylu, Cavus, & Ercag, 2009), biological diversity and life cycles (Land, Zimmerman, Choi, Seely, & Mohney, 2015; Looi et al., 2011; Song, Wong, & Looi, 2012; Zimmerman et al., 2015), ecological system relationships (Hung, Lin, & Hwang, 2010), ecological concepts (Hwang, Wu, & Ke, 2011; Zimmerman, & Land, 2014), and environmental

literacy (Hougham, 2015; Ruchter, Klar, & Geiger, 2010). However, the definition of ecological literacy used in this study (Nair et al., 2002; Orr, 1991) includes these topics. What follows next is a more in-depth discussion of the relevant literature regarding the rapidly changing nature of research in using mobile technology to enhance ecological literacy, assessing the usefulness of using mobile technology to enhance learning in this content area, and designing ecological and environmental learning activities incorporating mobile technology.

The rapidly changing nature of research using mobile technology to enhance ecological literacy. The mobile technology employed in the studies reviewed included personal digital assistants (PDAs), radio frequency identification (RFID) tags and readers, tablet computers, mobile phones, global positioning system (GPS) receivers, and Moving Picture Experts Group (MPEG) Audio Layer 3 (MP3) players. Generally, older studies involved the use of PDAs and RFID technology and newer studies used mobile phones and tablet computers. Studies employing the use of PDAs included Hung et al. (2010), Hwang et al. (2011), Ruchter et al. (2010), and T.Y. Liu et al. (2009). Hung et al. (2010) used PDAs as a stand-alone mobile technology, while Ruchter et al. (2010) employed PDAs connected to GPS receivers. Similarly, Hwang et al. (2011) equipped the PDAs used in their study with RFID readers and RFID tags. Finally, T.Y. Liu et al. (2009) combined the use of personal digital assistants (PDAs), a mobile server station, RFID readers and tags, and separate cameras.

Unlike the previous studies, the more contemporary studies abandoned the use of PDAs for the more recently adopted technologies of mobile phones and tablet computers. For example, T. C. Liu et al. (2009) used internet-enabled tablet computers in their study examining the

effectiveness of using mobile technology to learn about aquatic plants. Hougham (2015) also used tablet computers with internet access, but combined them with the use of computer applications that supported digital microscopes. Similarly, Chen et al. (2014) used internet-enabled tablets combined with a computer application that scanned quick response (QR) codes. Each of the remaining studies incorporated mobile phones as an element of the mobile technology employed.

For example, Uzunboylu et al. (2009) used mobile phones and their built-in technology as stand-alone devices for their study. Looi et al. (2011) and Looi et al. (2014) went a step further, incorporating mobile phones and computer applications designed for use on mobile devices. Similarly, Song et al. (2012) also used mobile phones and mobile computer applications. However, Song et al. (2012) included more extensive use of these applications to offer students support in completing worksheets, developing presentations, and making sketches. Finally, the studies by Land et al. (2015), Zimmerman & Land (2014), and Zimmerman et al. (2015) also incorporated the use of mobile computer applications. However, unlike the previous studies, these employed a broader selection of mobile technologies that included tablet computers, mobile phones, and internet-enabled MP3 players.

Designing and assessing ecological and environmental learning activities incorporating mobile technology. Although the purpose of some of the studies was solely to design (Land et al., 2015; Zimmerman & Land, 2014) or evaluate (Zimmerman et al., 2015) ecological and environmental learning activities, most of the studies reviewed were designed to do both. For example, Hung et al. (2010) designed and evaluated a formative assessment that

integrated PDAs into ecology observations for fifth and sixth graders studying ecological relationships in wetland and mangrove ecosystems in Taiwan. The PDAs provided instant feedback for student responses solicited during field observations, while also offering students opportunities for extended learning through electronic journals for observation and description (Hung et al., 2010). The authors reported that most of the students exhibited considerable improvements in their observation abilities and increased their inquiry skills.

Similarly, Hwang et al. (2011) designed and evaluated an approach to learning about butterfly ecology that incorporated the use of PDAs. However, the authors also included wireless communication networks that incorporated the use of RFID readers and tags. The sample consisted of 30 elementary students that were divided into control and experimental groups, with both groups subsequently receiving detailed instruction about the ecology of the butterfly *Idea leuconoe* (Hwang et al., 2011). The students then used the technology to navigate through a butterfly garden and complete a series of learning tasks that resulted in individual concept maps describing the ecology of the selected species (Hwang et al., 2011). Although both groups created concept maps, only the experimental group created interactive maps using the technology provided (Hwang et al., 2011). Pre- and post-tests were administered to measure their knowledge of butterfly ecology, while pre-and post-questionnaires were administered to measure their attitudes toward butterfly ecology (Hwang et al., 2011). The results indicated that relative to the control group, the experimental group had significantly higher gains in both learning attitudes and learning achievements regarding butterfly ecology.

Like the previous studies examined, Ruchter et al. (2010) also designed and evaluated an ecological learning activity that incorporated the use of mobile technology. Instead of focusing solely on students, their study included 185 school children and 76 adults that participated in a guided nature walk using PDAs and GPS receivers to deliver images and texts of trees and activities based on location (Ruchter et al., 2010). The results indicated similar gains in environmental literacy compared to traditional methods (human guides accompanying visitors), prompting the authors to state that the activity showed potential for increasing engagement and motivation for the school children.

In comparison to the other studies examined, T.Y. Liu et al. (2009) arguably designed the most elaborate assemblage of mobile technology evaluated. Their technology included their own mobile server station, PDAs, separate cameras, and RFID readers and tags (T.Y. Liu et al., 2009). The mobile server station alone consisted of a laptop computer, a wireless router, and a separate rechargeable battery (T.Y. Liu et al., 2009). The sample consisted of a group of fifth-grade students doing field work in a wetland ecosystem, with the experimental group using PDAs with internet access and the control group using more traditional methods (T.Y. Liu et al., 2009). The pre- and post-test comparisons revealed significantly higher student learning for the experimental group when compared to the control group, while a post-survey administered to the experimental group revealed that most of the students found the mobile technology easy to use and believed that it could help their learning.

Like most of the studies reviewed, T. C. Liu et al. (2009) also had the stated purpose of designing and evaluating ecological learning activities. Using fourth-grade students (n = 46)

equipped with tablet computers, T. C. Liu et al.'s (2009) activity was developed to enhance student learning about aquatic plants in an ecological pool at their school. Results from the quantitative and qualitative data collected indicated that the activities incorporating mobile technology enhanced student knowledge, student understanding, and student perception about aquatic plants.

As in this study, Hougham (2015) chose to have students investigate various ecological aspects of trees growing on school grounds. The author's stated purpose for this case study was to evaluate the implementation of an integrated mobile technology program designed to enhance the environmental literacy of underserved youth in the community (Hougham, 2015). In addition to using field guides and hand lenses to identify trees, the students used tablet computers supported by a mobile computer application and digital microscopes to examine tree leaves at the cellular and sub-cellular levels (Hougham, 2015). Data collected from pre- and post-assessments designed to measure environmental knowledge, awareness, and attitudes revealed significant improvements in student interest in using technology outdoors, learning about plants, and learning about birds.

Chen et al. (2014) also evaluated the use of mobile technology to investigate student learning of plant ecology, with a study design that incorporated the use of tablet computers and QR codes to assist students in learning flower characteristics in an elementary school plant garden. Two classes of students ($n = 31$ and $n = 29$) taught by the same instructor received either traditional instruction in identifying flower characteristics or instruction incorporating the use of the mobile technology discussed (Chen et al., 2014). Pre- and post-content assessments were

administered, along with pre- and post-questionnaires measuring learning attitudes and motivation (Chen et al., 2014). Results indicated that the experimental group using the newly developed prompting approach had significantly higher learning achievements than the control group.

In contrast to other studies, Uzunboylu et al. (2009) used mobile phones as the mobile technology employed to design and evaluate learning activities intended to increase environmental awareness. As part of a six-week undergraduate instructional technology and computer education course, 41 students used mobile phones to take and share photos of local environmental problems, make observations about the photos of the environmental problems at those sites, and participate in discussion boards designed to facilitate solutions to these problems (Uzunboylu et al., 2009). Results from the comparison of the pre- and post-questionnaires indicated that there was significant improvement in student perceptions of the usefulness of mobile technology to enhance awareness of environmental concerns (Uzunboylu et al., 2009). Additionally, a comparison of the results from the pre-questionnaires revealed a significant difference based on gender, with females having significantly lower initial environmental awareness and attitudes toward the environment than males (Uzunboylu et al., 2009). However, results from the post-questionnaires indicated no statistical difference based on gender.

Similarly, Looi et al. (2011) selected mobile phones as the mobile technology used in their design for ecological learning activities. In a further step, the authors combined mobile phone technology with the use of a mobile computer application in a two-year longitudinal study of six classes of third graders engaged in biodiversity and systems learning in the classroom, at

home, and in the field (Looi et al., 2011). Data was collected from both pre- and post-surveys on attitude and engagement and end-of-course science exam scores. Results showed that students engaged in using the mobile technology performed better, were more engaged, and had more positive attitudes toward the use of mobile technology for learning.

In a subsequent study, Looi et al. (2014) focused on an examination of the effects of incorporating mobile technology during ecological investigations in formal and informal settings with both students and teachers. The data sources included information gathered from teacher professional development sessions, weekly teacher meetings, student work in both the classroom and in the field, and end-of-course science achievement test scores (Looi et al., 2014). The results of the study indicated gains in overall student performance for all four years of the study, as well as a move toward an increase in the use of constructivist pedagogical approaches by teachers (Looi et al., 2014).

In another instance in which the researchers designed and evaluated ecological and environmental learning activities, Song et al. (2012) conducted a study using mobile phones to support student inquiry into the life cycles of butterflies and spinach plants. With a sample of 27 primary students from the same class, the activities included working with documents on the phone, taking pictures of organisms, making sketches using a mobile computer application, and creating presentations (Song et al., 2012). The results of the study revealed evidence that the personalized learning of the students was supported by the mobile technology employed during the investigation (Song et al., 2012).

Among the studies that focused solely on the design of ecological and environmental learning activities incorporating mobile technology, Land et al. (2015) revised an existing application to focus on the life cycles of trees. Intended to be used in conjunction with on-site naturalist guides, the researchers were guided by five design principles: the computer application would be part of a learning environment (not stand alone), prompts from both the naturalist and the mobile technology would enhance visitor observations, content from both the naturalist and mobile technology would help visitors draw connections between site observations and scientific concepts, visitors should use digital photography to observe and reflect on their learning, and all family members should be engaged (Land et al., 2015). The authors argued that their previous study (Zimmerman & Land, 2014) provided support for the efficacy of the five guidelines (Land et al., 2015).

In their previous study, Zimmerman and Land (2014) combined the use of a tree identification mobile computer application, mobile phones, tablet computers, internet-enabled MP3 players, and QR codes to support the learning of important ecological concepts in local environments. Fourth grade students on field trips and families participated in the learning activity, which involved using the application and scanning QR codes to facilitate comparisons between native and non-native tree species (Zimmerman & Land, 2014). The authors developed this learning activity based on three guidelines they deemed critical for designing ecological and environmental learning activities incorporating mobile technology: facilitating dialogue and practices in relevant places, enhance observations and connect content to local environments, and

broaden experiences by employing new depictions and investigating new perspectives (Zimmerman & Land, 2014).

In keeping with their previous studies discussed here, Zimmerman et al. (2015) again examined a learning activity incorporating mobile technology designed to enhance ecological and environmental learning. In contrast to their previous studies, Zimmerman et al. (2015) chose to focus solely on evaluating the effects of the activity. The authors analyzed video recordings of ten separate families taken as they accompanied naturalists and used mobile technologies at the Penn State Arboretum (Zimmerman et al., 2015). The results of their analysis indicated that the families engaged in high levels of description and identification while using the mobile technology (Zimmerman et al., 2015). Additionally, prompts provided by the mobile computers helped the families make connections between the content and their everyday lives (Zimmerman et al., 2015). The authors argued that their results emphasized the importance of providing localized, on-demand, mobile support for outdoor ecological and environmental learning activities (Zimmerman et al., 2015). In the next section, a summary of the relevant literature reviewed has been provided.

Summary of Research

The review of the literature was organized into four categories. The first category included studies that attempted to define and develop a framework for ecological literacy. The second category focused on studies that illustrated factors affecting individual levels of ecological literacy. The third category was comprised of studies that explored the effects of urban green infrastructure. The fourth category examined studies that incorporated the use of

mobile technology to enhance ecological literacy. An examination of the literature revealed the continuing struggle to define ecological literacy and develop a framework to facilitate its implementation, the importance of direct experience with natural environments in developing and maintaining ecological literacy, and the realized and potential benefits for humans and ecosystems from urban green infrastructure. The review of relevant literature also illustrated the rapidly changing nature of mobile technology research and the positive effects ecological and environmental learning activities incorporating mobile technology have on learning, attitudes, and awareness. In the final section of this chapter, a synthesis of the literature reviewed and support for the current study is provided.

Synthesis/Inferences for Current Study

A review of the literature indicated that discussion about the exact meaning of ecological literacy and the appropriate theoretical framework necessary for its successful implementation continues (Jordan et al., 2008; McBride et al., 2013). Nevertheless, the literature has shown that a critical factor in individual levels of ecological literacy is direct experience with nature (Cooper, 2008; Eaton, 1998; Goldman et al., 2013; Luksa et al., 2009; Mancl et al., 1999; Parker, 2009; Pilgrim et al., 2007; Pilgrim et al., 2008; Preston & Griffiths, 1995; Prokop et al., 2007; Wagner, 2008).

Also importantly, the literature was clear on the benefits provided by urban green infrastructure in terms of human health, biological diversity, and ecological services (Brown & Grant, 2005; Cornelis & Hermy, 2004). However, studies evaluating the effectiveness of the ability of urban green infrastructure to increase ecological literacy were not widespread in the

literature (Lin et al., 2014; Shwartz et al., 2012; Shwartz et al., 2014; Standish et al., 2013). Although many studies suggested experiences urban residents have in natural settings may make them more inclined to appreciate nature and support conservation (Noss, 2004; Novacek, 2008; Standish et al., 2013), there was little or no empirical evidence offered. Indeed, while both Shwartz et al. (2012) and Shwartz et al. (2014) offered limited empirical evidence for the positive effects urban green infrastructure experiences had on urban residents' individual ecological literacy levels, they also cited the need for more research in this area.

Lastly, a review of the literature revealed the rapidly changing nature of research using mobile technology to enhance ecological literacy. The review also highlighted the two major themes of research in this area: designing and assessing ecological and environmental learning activities incorporating mobile technology. Additionally, an analysis of the literature illustrated the positive effects ecological and environmental learning activities incorporating mobile technology have on learning, attitudes, and awareness. Importantly, most of the participants in the research examined were either elementary students or elementary students and their families. In fact, only one of the studies examined focused on undergraduate students (Uzunboylu et al., 2009), indicating a need for more research in this area.

CHAPTER 3: METHODOLOGY

Individual ecological literacy levels are declining (Atran et al., 2004), probably in part due to the diminishing amount of time people spend in natural environments (Pilgrim et al., 2007). Urban green infrastructure and urban green spaces offer the potential for urban dwellers to interact with intact local natural areas (Noss, 2004; Shwartz et al., 2014; Standish et al., 2013), which has been shown to increase individual levels of ecological literacy (Cooper, 2008; Lindemann-Matthies, 2005; Parker, 2009; Pilgrim et al., 2008). Additionally, environmental and ecological learning activities incorporating mobile technology have positive effects on learning, attitudes, and awareness (Chen et al., 2014; Hougham, 2015; Hung et al., 2010; Hwang et al., 2011; Land et al., 2015; T. C. Liu et al., 2009; T. Y. Liu et al., 2009; Looi et al., 2011; Ruchter et al., 2010; Song et al., 2012; Uzunboylu et al., 2009; Zimmerman & Land, 2014; Zimmerman et al., 2015). The purpose of this study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers.

The intent of this chapter is to provide an overview of the methodology of the study. The chapter is organized into several sections, beginning with an overview of the research that includes a description of the interactive online campus arboretum guide developed for the study. Next, a description of the context of the research is provided. Then, a section describing the sample and the participants for the respective quantitative and qualitative components of the study is included. Afterward, the instruments and data sources for the quantitative and

qualitative components of the study are discussed separately. Then, a section describing the curriculum development and procedures is included. Subsequently, a section detailing the data analysis is offered. Lastly, a discussion of the limitations and delimitations of the study is presented.

Research Overview

The purpose of this study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers. A new interactive online guide for the campus arboretum designed to enhance ecological literacy was employed, in conjunction with a series of ecological activities designed to promote student exploration of the trees in the campus arboretum. After receiving protocol approval from the Institutional Review Board (IRB) (see Appendix A), students enrolled in two undergraduate biology classes participated in ecological and environmental activities designed to enhance ecological literacy. Students enrolled in a third undergraduate biology class served as a comparison group and did not participate in the ecological and environmental activities.

Using a convergent parallel mixed methods design, both qualitative and quantitative data were collected and analyzed separately and concurrently (Creswell & Plano Clark, 2011). The convergent parallel design offers several strengths important to this study. First, it provides an opportunity to collect and synthesize both quantitative and qualitative data to develop an enhanced understanding of the chosen topics (Creswell & Plano Clark, 2011). It is also an

efficient design, because both quantitative and qualitative data can be collected at approximately the same time (Creswell & Plano Clark, 2011). Quantitative data were collected using three separate instruments that measured student ecological knowledge, ecological attitudes and beliefs, and environmental behaviors. Qualitative data were collected using open-ended written reflections gathered from the K-W-L tree activities, interviews with participants, and observations.

Quantitative data were analyzed using three separate 3(between -subjects) x 2(within -subjects) mixed design ANOVAs conducted through the MANOVA approach to test for statistical significance. Qualitative data analysis consisted of audio recording and transcription of the participants' interviews, exploring and coding the data by dissecting and labeling the text obtained from the three separate qualitative sources, combining similar codes to form themes, and exploring the relationship between the various themes as suggested by Creswell and Plano Clark (2011). Results that emerged from the exploratory qualitative data concerning students' environmental attitudes and beliefs were used to support an enhanced understanding of results from the quantitative data collected measuring these same constructs.

Curriculum Development

The researcher designed the curriculum in part to enhance access to the 34 tree specimens in the pre-existing campus arboretum, which received Level 1 Certified Arboreta Status from the Tennessee Urban Forestry Council (TUFC) in 2015 (TUFC, 2017). The researcher first constructed an interactive online guide for the campus arboretum, using the cross-platform and open-source software Bioimages Collection Manager (BCM) (Polzin, 2014) to add images of

living organisms and associated metadata to the Bioimages website database (Baskauf, 2015). Bioimages is a biodiversity database of high quality images of living organisms, a group of online tools for learning about ecoregions and plants, and an illustration of biodiversity informatics recommended practices (Baskauf, 2015).

Metadata collected using BCM follows biodiversity informatics recommended practices. BCM uses terms from the Biodiversity Information Standards (Taxonomic Databases Working Group, 2013), the Dublin Core Metadata Initiative (DCvb I) (DCMI, 2012), and the Darwin-SW Ontology (DSW) (Baskauf & Webb, 2014; Polzin, 2014). In addition to being submitted to the Bioimages website, the data submitted using this software is also distributed to biodiversity aggregators such as the Encyclopedia of Life and the Global Biodiversity Information Facility.

After taking more than 1,000 images of the 34 tree specimens in the campus arboretum, the researcher submitted several hundred to the Biomages database (Baskauf, 2015) using the BCM software (Polzin, 2014). The BCM software generated web pages for each of the 34 tree specimens in the arboretum that provide multiple images of the individual organisms, taxonomic information, and geospatial data. In addition, the researcher added detailed information from the United Stated Department of Agriculture Natural Resources Conservation Service (USDANRCS) Plants Database (USDANRCS, 2016) on species descriptions, distribution, habitat, adaptation, commercial and historical uses, and environmental concerns to the web pages for each tree specimen. Subsequently, the researcher generated QR codes linked to the web pages for each tree in the arboretum and attached the identifying tags to each organism. This enabled students to access the tree websites by scanning the codes using mobile phones or

tablets. Then, 25 trees were selected by the researcher and added to one of three separate tree walks that link individual tree web pages (see Figure 1) and guide students along predetermined routes in the campus arboretum.

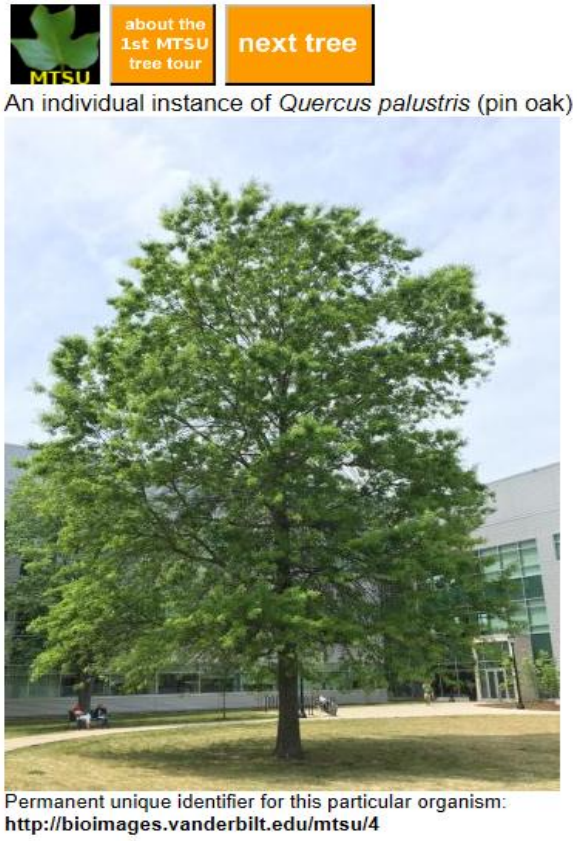

Figure 1. Screen Shot of Tree Tour Page for *Quercus palustris.*

Next, the researcher created a series of ecological activities intended to promote student exploration of the trees in the campus arboretum. The researcher designed the activities to enhance student understanding of eight ecological principles measured by an instrument

developed by Morron, Mancl, and Carr (2001). The design was also intended to provide the researcher with qualitative data regarding student learning, engagement, and perceptions in the form of student reflections and responses. The ecological activities consisted of three separate arboretum tree tour K-W-L reflection activities and three corresponding sets of ecological literacy questions to be used in conjunction with the campus tree tours developed for the interactive online campus arboretum guide (see Appendix B).

The researcher designed the K-W-L reflection activities to provide students with opportunities for open-ended reflections regarding their knowledge of arboretum tree species both before and after participating in each of the campus tree tours. The K-W-L technique is a widely used three-step procedure designed to facilitate student learning and comprehension by encouraging them to access and apply previous content-specific knowledge (Ogle, 1986). A typical K-W-L activity incorporates three steps for the students: they recall what they know about the topic and write it down, then think about what they want to know about the topic and write that down, and finally after the activity they think about what they have learned about the topic and write that down as well (Ogle, 1986). Each K-W-L reflection developed for this study provided students with a list of the arboretum tree species they encountered during one of three separate tree walks that link individual tree web pages and guide students along predetermined routes in the campus arboretum. Each K-W-L activity prompted students to reflect on their knowledge of the selected tree species and record what they know and what they would like to learn during the activity. To complete each activity, students reflected and recorded what they

had learned about the selected tree species during the campus tree tour conducted that day and responded to a writing prompt exploring their environmental attitudes and beliefs.

The ecological literacy questions represented summative components for each of the daily activities promoting student exploration of the trees in the campus arboretum. To support an enhanced understanding of the eight ecological principles measured by the instrument from Morrone et al. (2001), the ecological literacy questions provided students with an opportunity to reflect on their experiences and apply what they learned during the tree walks and the associated activities. The eight ecological principles that guided the development of the questions were biogeography, the earth as a biosphere, carrying capacity, ecological succession, biodiversity, ecological energetics, materials cycling, and biotic interactions (Morrone et al., 2001). Consisting of three separate assignments, each set of ecological literacy questions was comprised of a group of short response questions that required students to apply their understanding of two to three selected ecological principles.

Research Context

Located in the southeastern United States, the urban area where the study was located had approximately 120,000 inhabitants (USCB, 2010b) at the time of the study. Approximately 76% of the residents were non-Hispanic white, 15% were African-American, 6% were Hispanic, 3% were Asian, and less than 1% were Native American (USCB, 2010b). The median age of the city inhabitants was 29 years, with more than a third of residents over the age of 25 having a bachelor's degree or higher (UCSB, 2010b). In terms of gender, the inhabitants of the city were comprised of nearly equal amounts of males and females (UCSB, 2010b). Finally, the per capita

income for the city was just over $25,000, with approximately 17% (UCSB, 2010b) of individuals living below the 2014 Federal Poverty Level (FPL) guidelines (United States Department of Health and Human Services, 2014).

Situated in the heart of the urban area described above, the public university serving as the location for the study reported a student population in excess of 22,000. During the fall of 2015, approximately 75% of the students were enrolled full-time and 25% of the students were enrolled half-time, with 90% of the students enrolled in undergraduate studies and 10% of the students enrolled in graduate studies. Additionally, the average ACT composite of incoming freshman was listed as 22.3 and the average undergraduate student age was listed as 23 years. Furthermore, approximately 91% of the students were permanent residents of the state in which the school is located, 5% were permanent residents of other states, and 4% were permanent residents from areas outside the United States.

For the fall semester of 2015, female students at the university comprised approximately 54% of the student body and male students comprised approximately 45% of the student body. Approximately 67% of the students were white, 20% were African-American, 4% were Hispanic, 4% were Asian, and less than 1% were Native American.

Sample

The quantitative sample for the study consisted of 32 undergraduate students enrolled in one of two different biology courses: an introductory biology course for non-majors and an upper division life science course for pre-service elementary teachers. The average age of the sample was 24 and the median age was 23. The sample of students was 28% African-American,

69% white, and 3% other. Additionally, 56% of the students were education majors, 19% were behavioral health science majors, 16% were mass communication majors, 3% were basic and applied sciences majors, 3% were language arts majors, and 3% did not report a specific major.

The biology class for non-majors emphasized a broad selection of topics that help students make informed choices on societal issues involving biology. It included the nature of science, the diversity and characteristics of life, cells, genetics, environmental concerns, biotechnology, and ecological principles. The instructor for the non-majors biology course had taught in the university biology department for 23 years. His research focused primarily on the effects of environmental toxins in aquatic environments. The life science course for pre-service elementary teachers emphasized the implementation and analysis of activities designed for the study of life in elementary classrooms. The instructor for the life science course had taught in the university biology department for 23 years. Her research interests focused on teaching and learning as they relate to environmental and life sciences. As summer courses, the classes met four days a week between two and four hours a day.

Participants

For the qualitative component of the study, the researcher selected four participants from the quantitative sample. After the pre-surveys for environmental attitudes and beliefs were scored, the researcher selected potential participants from the second quartile of the inter-quartile range. Subsequently, the researcher narrowed the pool of potential participants to two participants from each experimental section based on student attendance during the first week of the semester. A description of each participant follows.

Angelica (Pseudonym)

Angelica had recently transferred to the university from another school close to her home in a rural community in the eastern part of the state. She was a 21-year-old white female education major enrolled in the life science course for pre-service elementary teachers. Her responses on the pre-interview indicated that she believed humans were more important than other species, that preserving the environment was important so that humans could continue using it, and that human impacts on the environment were mostly negative.

Eliza (Pseudonym)

As another education major, Eliza had also enrolled in the life science course for pre-service elementary teachers. She was a white 23-year-old from a rural area in the central part of the state, working a part-time job at a make-up counter in a local shopping mall. During her pre-interview she expressed a general affinity for nature, cited the importance of the environment as a source for natural resources, and expressed concerns about littering.

Peggy (Pseudonym)

Peggy was a 23-year-old white education major enrolled in the biology class for non-majors. Unlike the other two female participants, Peggy was raised in an urban area in the central part of the state. During her pre-interview she expressed pessimism about the future of the environment, explaining that she believed humans were not doing enough to protect it and that it would be destroyed as a natural consequence of human action.

Alexander (Pseudonym)

Like Peggy, Alexander was also enrolled in the biology class for non-majors. Raised in an urban area, he was a 23-year-old African-American majoring in behavioral and health sciences. During his pre-interview Alexander indicated that he believed nature was important for intrinsic reasons, that animals and plans were often treated dismissively, and that he believed humans should treat nature with more respect.

Instruments and Data Sources

Pre- and post-treatment data were collected on individual student ecological knowledge, environmental attitudes and beliefs, and environmental behaviors using three survey instruments. Additionally, demographic information was collected on age, gender, ethnicity, parents' level of education, hometown (i.e., urban or rural), and college major (see Appendix C). As part of the convergent parallel mixed methods design, qualitative data were also collected and concurrently analyzed.

Ecological Knowledge Instrument

The survey instrument used to collect data on individual ecological knowledge (see Appendix D) was an instrument adapted from Morrone, Mancl, and Carr's (2001) Questions to Measure the Knowledge of Ecological Principles of Ohio Adults. An iterative process was used to determine eight ecological principles that formed the basis for the ecological knowledge survey developed by Morrone et al. (2001). Subsequently, the principles were validated for content by a panel of experts and the reliability of the instrument was then tested with the use of focus groups and pretesting (Morrone et al., 2001). The pretesting resulted in the revision of

certain test questions and the elimination of terminology perceived as confusing (Morrone et al., 2001). The instrument consists of 32 multiple-response questions. Because the instrument was developed for use in Ohio, some questions used the name of the state. To eliminate confusion, the researcher substituted the name of the state where the study was conducted in place of Ohio.

Environmental Attitudes and Beliefs Instrument

To provide information on the environmental attitudes and beliefs of the sample, the researcher selected the revised New Ecological Paradigm (NEP) Scale (see Appendix E) developed by Dunlap, Van Liere, Mertig, and Jones (2000) as an additional instrument for the study. The original NEP has been extensively used to measure attitudes and beliefs about the environment, with its validity having been widely tested and accepted (Dunlap et al., 2000). The revised instrument offers a more complete treatment of critical components of an ecological worldview, while also removing outdated terminology used in the original instrument (Dunlap et al., 2000).

The instrument consists of fifteen items, with three items each for one of five key attributes chosen to represent an ecological worldview: an understanding of the fragile balance of nature, the realization of the potential of an ecological crisis as a result of anthropogenic disturbance, the finite nature of many natural resources that limit growth, a rejection of anthropocentrism, and an understanding that humans are not exempt from the limits of nature (Dunlap et al., 2000). An indication of agreement with certain items indicates a pro-ecological worldview, whereas indicating agreement with other items denotes an anti-ecological worldview (Dunlap et al., 2000).

Environmental Behaviors Instrument

The final quantitative instrument selected for the study was an instrument developed by Hsu and Roth (1998) (see Appendix F) that was designed to assess responsible environmental behaviors. The five types of environmental behavior categories were defined as behaviors involving political actions, behaviors involving legal action, behaviors intended to persuade others to help solve environmental problems, physical behaviors intended to directly ameliorate environmental problems, and individual behaviors by consumers intended to solve or prevent environmental problems (Hsu & Roth, 1998). The initial questions regarding responsible environmental behavior were drawn from existing scales after a review of the literature (Hsu & Roth, 1998).

After being reviewed by a panel of experts in responsible environmental behaviors and piloted with a sample of 30 graduate students, the instrument emerged with a list of 30 questions (Hsu & Roth, 1998). The instrument was tested for reliability using both test-retest reliability and coefficient alpha measures, resulting in a test-retest coefficient of 0.89 and a coefficient alpha of 0.90 (Hsu & Roth, 1998). Subsequently, the instrument was tested for validity using a panel of four environmental educators, who found it to have content and face validity (Hsu & Roth, 1998).

Qualitative Data Sources

As part of the convergent parallel mixed methods design, the researcher also collected qualitative data to compare to the quantitative data generated by the survey instruments (Creswell & Plano Clark, 2011). The data were collected from several sources to offer depth and

fullness to the results of the study and establish validity of the analysis procedures (Creswell & Plano Clark, 2011). The qualitative data were collected from ecological literacy questions (See Appendix G), open-ended written reflections obtained from the K-W-L writing prompts (see Appendix H), semi-structured pre- and post-interviews with participants (see Appendix I and Appendix J), and observations (see Appendix K).

Providing students with valuable opportunities for open-ended reflections, the researcher designed the K-W-L activities to elicit information regarding student knowledge of arboretum tree species both before and after participating in each of the campus tree tours. Students were first prompted to reflect on their knowledge of the selected tree species and record what they know and what they would like to learn during the activity. After the tree tour activity, students were then prompted to reflect on and record what they had learned about the selected tree species during the campus tree tour conducted that day. To complete the K-W-L activities, the students responded to a writing prompt designed to explore their environmental attitudes and beliefs.

Like the writing prompts, the researcher also designed the pre- and post-activities semi-structured interview protocols to explore student environmental attitudes and beliefs. The pre-activity interview protocol consisted of five questions. Each question either explored general student environmental attitudes and beliefs or specific student responses from the quantitative instrument measuring these same constructs. The post-activity interview protocol consisted of five questions. Each question followed up on previous student responses from the pre-activity interviews, explored student tree activity experiences, or provided students with an opportunity for open reflection.

As the third and final source of qualitative data for the study, the researcher designed the observation protocol (see Appendix K) to facilitate collection of qualitative data from participants engaged in the tree activities. The observation protocol consisted of three columns to collect data on positive student statements or actions, negative student statements or actions, and personal connections mentioned by the students. An additional area provided the researcher with an opportunity to note student off-task behavior.

Researcher as Instrument

Because this study contains a qualitative component, the researcher must also be acknowledged as an instrument. The processes that the qualitative researcher uses to analyze and interpret data are mediated by their cultural experiences (Arzubiaga, Artiles, King, & Harris-Murri, 2008). The values and experiences of the researcher may influence aspects of the study such as its design, the researcher's interpretation of participants' statements, or the way that the researcher and participants interact (Arzubiaga et al., 2008). The researcher is a bilingual white male in his mid-forties. Before becoming a K-12 science teacher 15 years ago, he worked as a field biologist and environmental educator in the southwestern United States and northwestern Mexico. In addition, as a doctoral student the researcher completed coursework on qualitative research methods, which provided a foundation of the experience and knowledge necessary to conduct the qualitative component of the study.

Procedures

As part of the design of the study, one class served as a comparison group and did not participate in the arboretum curriculum study activities. The comparison class consisted of

undergraduate students enrolled in a biology class designed for pre-service K-8 teachers. The comparison class began before the treatment group classes. Therefore, both the pre- and post-surveys were administered first to this group. For the comparison group, the researcher administered paper copies of the pre-surveys to students who indicated on the consent form (see Appendix L) that they were willing to participate in the study during the first week of class. After allowing sufficient time, the researcher collected the completed surveys and stored them in a secure location for further analysis. During the fifth week of class, the researcher administered the post-surveys. After allowing sufficient time, the researcher collected the completed surveys and stored them in a secure location for further analysis.

The two treatment groups consisted of 24 undergraduate students enrolled in one of two different biology courses: an introductory biology course for non-majors and an upper division life science course for pre-service elementary teachers. For the treatment groups, the researcher administered paper copies of the surveys to students willing to participate in the study on the first day of week one. The researcher collected the surveys and stored them in a secure location for further analysis. After selecting the qualitative participants, the researcher conducted the initial interviews on the fifth day of week one.

During week two, the students engaged in the arboretum curriculum activities designed for the first campus tree tour. The researcher observed the class during the activities using the observation protocol. First, the instructor for each class provided students with the K-W-L exercise for arboretum tree tour one. The instructor then prompted the students to complete the first two sections of the K-W-L activity, by having the students reflect on what they knew and

what they would like to know about the tree species they would encounter during the first campus tree tour. After providing approximately twenty minutes for students to complete the first two sections of the K-W-L activity, the instructor prepared to lead the students on arboretum tree tour one.

Importantly, students in the experimental groups needed to have a QR reader computer application installed on their phone or tablet. Each instructor informed students that they needed a QR reader computer application installed on their mobile device. Many students already had these applications installed on their mobile devices. Those that did not downloaded free QR applications in a matter of moments. In the rare instance that a student did not have their own personal mobile device, the instructor paired that student with a student that did have their own personal mobile device. After ensuring each student had a QR reader installed or had access to a classmates QR reader, the instructor led students on arboretum tree tour one.

Following the prompts for the guided online arboretum tree tour one, the instructor for each class asked students to scan the QR code for each tree in the tour to access the images and information. The instructor encouraged students to examine the trees and explore the images and information available for each specimen in the online campus arboretum. The instructor also provided information about each tree species that students encountered. This information included identifying characteristics, taxonomy, distribution, habitat, adaptation, commercial and historical uses, environmental concerns, and specimen history. The instructor for each class alternately answered student questions directly, solicited answers through group discussion, or

encouraged students to explore the information available on the online campus arboretum to enhance their understanding.

At the completion of arboretum tree tour one, the instructor returned with the students to the classroom and instructed the students to finish the K-W-L activity by reflecting on what they had learned about the trees they examined during arboretum tree tour one. After providing approximately twenty minutes for students to complete the final section of the K-W-L activity for arboretum tree tour one, the instructor collected the completed K-W-L activities and explained to the students that their next activity was to answer a set of short response questions that required them to reflect on their experiences during the arboretum tree tour and apply their understanding of various ecological principles.

To align with the guiding principles used in the ecological knowledge survey instrument, the ecological literacy questions for the first arboretum tree tour addressed three specific ecological principles: biogeography, ecosystem succession, and biotic interactions. The instructor then distributed the questions to each student and provided time for them to reflect on their experiences and respond to the ecological literacy questions. After all students had completed the ecological literacy questions, the instructor collected them and stored them in a secure place.

During week three, each instructor conducted the second arboretum tree tour featuring a different group of trees. Each tree tour lasted approximately one hour. The researcher observed each class during the activities using the observation protocol. As before, students in each class participated in a K-W-L activity and responded to a separate set of ecological literacy questions.

The ecological literacy questions for the second arboretum tree tour were designed to address a separate set of ecological principles: ecological energetics, biodiversity, and the earth as a biosphere. During week four, each instructor conducted the third arboretum tree tour with a distinctive set of trees. The researcher again observed the class during the activities using the observation protocol. Once more, the students took part in another K-W-L activity and responded to a unique set of ecological questions. The questions for the third arboretum tree tour addressed a different set of ecological principles: materials cycling and carrying capacity.

During the fifth week after all activities were completed, the researcher collected the K-W-L activities and the ecological literacy questions of the students that consented to participate in the study and administered the post-surveys in class. The researcher also conducted the follow-up interviews at this time. The researcher subsequently stored the documents and completed post-surveys in a secure location for subsequent analysis.

Data Analysis

Both quantitative and qualitative data collected were concurrently analyzed as part of the convergent parallel mixed methods design (Creswell & Plano Clark, 2011). Quantitative data were collected using three separate instruments that measured student ecological knowledge, environmental attitudes and beliefs, and environmental behaviors. Qualitative data were collected using writing prompts from the K-W-L activities, interviews with participants, and observations.

Three separate 3(between -subjects) x 2(within -subjects) mixed design ANOVAs were conducted through the MANOVA approach to analyze the quantitative data for statistical

significance. Nine separate hypotheses were tested: (1) There is a significant difference among the three groups on ecological knowledge; (2) There is a significant difference between pre- and post-survey scores on ecological knowledge; (3) There is a significant interaction effect between the group and survey factors on ecological knowledge; (4) There is a significant difference among the three groups on environmental attitudes and beliefs; (5) There is a significant difference between pre- and post-survey scores on environmental attitudes and beliefs; (6) There is a significant interaction effect between the group and survey factors on environmental attitudes and beliefs; (7) There is a significant difference among the three groups on environmental behaviors; (8) There is a significant difference between pre- and post-survey scores on environmental behaviors; and (9)There is a significant interaction effect between the group and survey factors on environmental behaviors.

In contrast, the qualitative component of the study sought to answer a single research question: How does participation in the arboretum curriculum influence the environmental attitudes and beliefs of undergraduate students, if at all? As suggested by Braun and Clarke (2006), Creswell and Plano Clark (2011), and Vaismoradi, Jones, Turunen, and Snelgrove (2016), the qualitative data analysis involved several steps. First, the audio recordings of the participant interviews were transcribed. Next, the researcher began the process of becoming familiar with the data by carefully reading through the interview transcriptions, the reflections from the K-W-L activities, and the notes from the student observations repeatedly.

During this process and throughout the remainder of the qualitative data analysis process, reflective notes were recorded in the form of memos to facilitate the dissection, labeling, coding,

and thematic analysis of the data using the ATLAS.ti qualitative data analysis software (Muhr, 2017). The reflective journaling was critical, because it helped diagram the data analysis process, reveal the perspectives of the researcher, and strengthen data collection (Yin, 2016). Using an open-coding process, initial codes were then generated and defined.

After redundant codes were consolidated, the reliability of the remaining codes (see Table 1) was verified by having a separate individual review and code a subset of the qualitative data as recommended by Creswell and Plano Clark (2011). The second individual was a mathematics and science education doctoral student who had received training in qualitative analysis and was currently conducting a separate qualitative study. An analysis comparing the coded subsets of data resulted in a Cohen's kappa value of 0.83, indicating an almost perfect strength of agreement between the two coders (Landis & Koch, 1977). Next, the codes were examined to identify patterns or themes between them (Braun & Clarke, 2006). Similar codes were then combined to elicit themes from the data.

Table 1

Codes Elicited from Data

Answering prompts or asking questions during activities
Childhood experiences
Collecting tree artifacts
Curriculum informative/interesting
Discussing trees
Nature as human resource
Human life/needs most important
Humans should respect nature
Perceived learning about trees
Making observations during activities
Other organisms have a right to exist
Playing Pokémon go
Previous knowledge
Quality of life and future generations
Taking notes during activities
Using QR codes/websites
Using social media

Because of the cyclical nature of qualitative analysis, the coding and thematic analysis process was lengthy and required the researcher to continually return to the data during the course of the analysis (Vaismoradi et al., 2016). As noted by Aronson (1994), subthemes may be present in the data and may be useful in acquiring a better understanding of participants' perspectives. The researcher found that subthemes were indeed present in the data and any relationship between the various themes and subthemes was explored. Finally, results that emerged from the exploratory qualitative data about students' environmental attitudes and beliefs were compared to results from the quantitative data collected measuring these same constructs to better understand how the data from both diverge or converge (Creswell & Plano Clark, 2011).

Limitations and Delimitations

Unfortunately, some factors may be beyond the control of the researcher. Additionally, some choices are made by the researcher that may potentially impact the results of the study. An important potential limitation affecting this study was the non-random nature of the quantitative sample. The researcher did not randomly assign each student into different groups. This resulted in a quasi-experimental design. Another important potential limitation that may have affected the results of the study was having multiple instructors. The comparison group, treatment group one, and treatment group two each had a different instructor. Additionally, the limited skill level of the researcher may represent a potential constraint. As a novice scholar, the researcher had limited experience with designing and conducting a mixed-methods study.

Among the study's most significant delimitations was choosing to conduct the study during the summer semester. In contrast to the fall and spring semesters, during the summer the

trees have their leaves the entire semester. Additionally, summer classes are smaller and more easily managed during outdoor activities. However, this decision resulted in a smaller sample size that may have affected the generalizability of the quantitative results from the study. Additionally, the generalizability of the study may be affected by choosing to conduct the study during a summer session. The structure of summer courses and the sample of students enrolled in summer courses may differ from those of courses offered during the fall and spring semesters, both of which may potentially affect the generalizability of the results from the study.

Chapter Summary

The intent of this chapter was to provide an overview of the methodology of the study. Undergraduate students enrolled in the two different biology courses participated in a series of ecological activities incorporating mobile technology designed to promote student exploration of the trees in the campus arboretum. Undergraduate students enrolled in one additional biology class served as a comparison group and did not participate in the ecological activities. Using a convergent parallel mixed methods approach, both qualitative and quantitative data were collected and analyzed separately and concurrently (Creswell & Plano Clark, 2011).

For the quantitative component of the study, pre- and post-treatment data was collected on individual student ecological literacy levels, environmental attitudes and beliefs, and environmental behaviors using three survey instruments. Additionally, demographic information was collected on age, gender, ethnicity, parents' level of education, hometown (i.e., urban or rural), and college major. Quantitative data were analyzed using three separate 3(between-

subjects) x 2(within-subjects) mixed design ANOVAs conducted through the MANOVA approach to test for statistical significance. Nine separate hypotheses were tested.

Qualitative data were collected using open-ended written reflections, pre- and post-interviews with participants, and observations. Qualitative data analyses included audio recording and transcription of the participants' interviews, exploring and coding the data by dissecting and labeling the text obtained from the three separate qualitative sources, combining similar codes to form themes, and exploring the relationship between the various themes (Creswell & Plano Clark, 2011).

Importantly, there are potential limitations and delimitations associated with the design of the study. The lack of individual randomization is an important limitation that resulted in a quasi-experimental design. Additionally, the limited skill level of the researcher and having multiple instructors may represent important potential limitations. Finally, choosing to conduct the study during the summer semester resulted in a smaller sample size that may have affected the generalizability of the quantitative results.

CHAPTER 4: RESULTS

The intent of this chapter is to report the results from the analysis of both the quantitative and qualitative sets of data, as well as an analysis of the merged results from both sets of data concerning environmental attitudes and beliefs. The quantitative analysis results are reported first, followed by the results from the qualitative analysis. Finally, the analysis of the merged results is presented. The quantitative analysis results consist of descriptive statistics for the sample, as well as results from the three separate 3(between-subjects) x 2(within-subjects) mixed design ANOVAs conducted through the MANOVA approach to test for statistical significance. The qualitative analysis results consist of the codes and emergent themes elicited from the three qualitative data sources, as well as an analysis of inter-coder agreement. Using a technique suggested by Creswell and Plano Clark (2011), the analysis of the merged results examines the differences and similarities between the two data sets within the overarching dimension of environmental attitudes and beliefs.

Quantitative Results

In all, 37 students consented to participate in the quantitative component of the study. Five students either dropped the class from their schedules or did not complete both pre- and post-surveys and were, therefore, removed from the study. Thus, data from 32 students were collected for analysis. Pre- and post-survey scores for the comparison group, treatment group 1, and treatment group 2 are provided in Table 2. The means and standard deviations for the pre- and post-survey scores from each group are included.

Table 2

Pre- and Post-Survey Scores for Comparison and Treatment Groups

	Comparison Group (n = 8)		Treatment Group 1 (n = 15)		Treatment Group 2 (n = 9)	
Variable	Pre-	Post-	Pre-	Post-	Pre-	Post-
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Ecological Knowledge[a]	21.38 (2.88)	21.88 (3.80)	20.60 (3.60)	22.47 (3.60)	23.22 (3.03)	24.33 (3.71)
Environmental Attitudes and Beliefs[b]	3.64 (0.43)	3.72 (0.45)	3.28 (0.52)	3.28 (0.45)	3.33 (0.48)	3.64 (0.37)
Environmental Behaviors[c]	1.99 (0.32)	1.91 (0.47)	2.45 (0.84)	2.48 (0.46)	2.67 (1.25)	2.85 (1.20)

[a]The instrument used to assess ecological knowledge consisted of 32 multiple choice questions. [b]The instrument used to assess environmental attitudes and beliefs consisted of 15 Likert-type items rated on a scale of 1-5. [c]The instrument used to assess environmental behaviors consisted of 30 Likert-type items rated on a scale of 1-6.

To test the three hypotheses related to the variable ecological knowledge (See Table 3), a 3 (between) x 2 (within) mixed design ANOVA using the MANOVA approach was conducted. The results showed a significant difference between the pre- and post-survey scores for ecological knowledge, F (1, 29) = 5.72, p = .0235, Wilk's Λ = 0.835. The mean score from the pre- to post-survey increased from 21.53 to 22.84. However, there was no significant difference among the groups, F (2, 29) = 5.72, $p > .05$. In addition, there was no significant interaction effect between the group and survey factors for ecological knowledge, F (2, 29) = 5.72, $p > .05$.

Another 3 (between) x 2 (within) mixed design ANOVA using the MANOVA approach was conducted, to test the three hypotheses concerning environmental attitudes and beliefs (see Table 3). The results for differences between the pre- and post-survey scores for environmental attitudes and beliefs were approaching significance, F (1, 29) = 3.97, p = .0559, Wilk's Λ = 0.880. The mean score for the pre- and post- surveys increased from 3.38 to 3.49. Additionally, there was no significant difference among the groups, F (2, 29) = 2.37, $p > .05$. Finally, there was no significant interaction effect between the group and survey factors for environmental attitudes and beliefs, F (2, 29) = 2.02, $p > .05$.

To test the three hypotheses related to the final variable of environmental behaviors (See Table 3), a third 3 (between) x 2 (within) mixed design ANOVA using the MANOVA approach was conducted. The results showed no significant difference between the pre- and post-survey scores for environmental behaviors, F (1, 29) = 0.12, $p > .05$, Wilk's Λ = 0.996. The mean score for the pre- and post-surveys increased only slightly from 2.40 to 2.44. As with the other variables, there was no significant difference among the groups, F (2, 29) = 2.26, $p > .05$.

Additionally, there was no significant interaction effect between the group and survey factors for environmental behaviors, F (2, 29) = 0.33, $p > .05$.

Table 3

List of Quantitative Hypotheses

Hypothesis	Reject HO	Fail to Reject HO
There is a significant difference among the three groups on ecological knowledge.		X
There is a significant difference between pre- and post-survey scores on ecological knowledge. [a]	X	
There is a significant interaction effect between the group and survey factors on ecological knowledge.		X
There is a significant difference among the three groups on environmental attitudes and beliefs.		X
There is a significant difference between pre- and post-survey scores on environmental attitudes and beliefs. [b]		X
There is a significant interaction effect between the group and survey factors on environmental attitudes and beliefs.		X
There is a significant difference among the three groups on environmental behaviors.		X
There is a significant difference between pre- and post-survey scores on environmental behaviors.		X
There is a significant interaction effect between the group and survey factors on environmental behaviors.		X

[a] There was a significant difference between the combined pre- and post-survey scores for ecological knowledge ($p = .0235$).
[b] The difference between the combined pre- and post-survey scores for environmental attitudes and beliefs was approaching significance ($p = .0559$).

Qualitative Results

In contrast to the quantitative component, the qualitative analysis focused on the variable environmental attitudes and beliefs. The qualitative research question was: How does participation in the arboretum curriculum influence the perceived environmental attitudes and beliefs of undergraduate students, if at all? Qualitative data were collected from four participants: two individuals in each experimental section. The data consisted of open-ended written reflections, transcribed pre- and post-interviews with participants, and observations.

Following an open coding process, four themes emerged from the data: (1) *Engagement*; (2*) Disengagement*; (3) *Connecting with the curriculum*; and (4) *Nature is important*. The theme *connecting with the curriculum* was found to consist of two subthemes: (1) *Prior experiences* and (2) *Participant perceptions.* Additionally, the theme *nature is important* was found to consist of two subthemes: (1) *Human-centered reasons* and (2) *Intrinsic value*. Of the four emergent themes, the *connecting with the curriculum* and *nature is important* themes were most closely associated with the qualitative research question. In the remainder of this section, a list of the themes and subthemes elicited from the data will be presented with supporting examples. Immediately following the qualitative results section, the merged results from the quantitative and qualitative components are compared using the overarching dimension of environmental attitudes and beliefs.

Themes

Following thematic analysis, four themes emerged from the data: (1) *Engagement*; (2) *Disengagement*; (3) *Connecting with the curriculum*; and (4) *Nature is important.* As noted by

Aronson (1994), individual themes may be comprised of subdivisions (subthemes) that enable the researcher to develop a better understanding of the perspectives of the participants. Accordingly, the theme *connecting with the curriculum* consisted of two subthemes: (1) *Prior experiences* and (2) *Participant perceptions.* Additionally, the theme *nature is important* was found to consist of two subthemes: (1) *Human-centered reasons* and (2) *Intrinsic value*. In the remainder of this section, evidence for each theme will be provided by citing various sources of data (e.g., quotations from pre- and post-interviews, open-ended written reflections, and student observations). In addition, several figures have been included to illustrate the relationships among the emergent themes, subthemes, and the codes elicited from the data.

Engagement. One of the primary goals when creating curricula is to promote learning by keeping students interested and engaged. A broad theme of *engagement* emerged from analysis of participant observations collected during this study. This theme was defined as participants being actively engaged with the curriculum by doing things such as accessing the online arboretum, taking notes, collecting artifacts, making observations, and discussing relevant topics. Although this theme provided evidence that the participants engaged in the arboretum curriculum, its importance was limited because it did not address the research question. A graphical display of this theme and its supporting codes drawn from the four participants can be found in Figure 2. Supporting examples of occurrences from the study with accompanying quotes from the observation protocol have been provided in the following paragraphs.

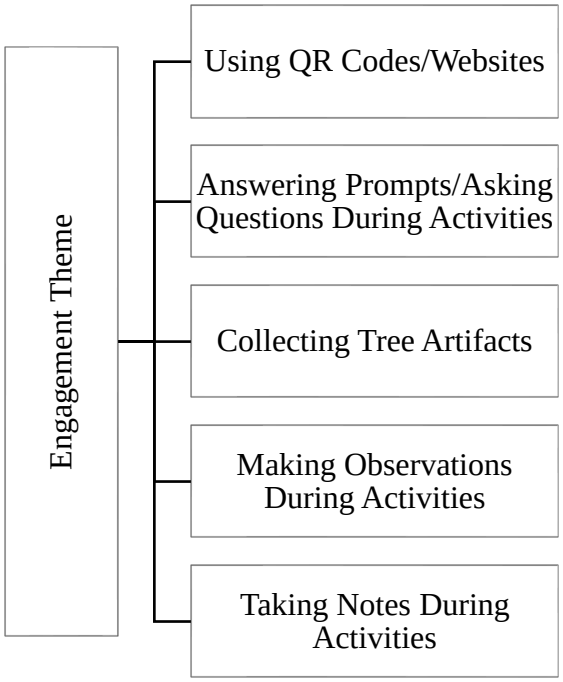

Figure 2. Engagement Theme with Supporting Codes.

On the first tree tour, Alexander displayed behavior interpreted as engaging with the curriculum. He collected tree artifacts, scanned the QR codes and accessed the tree websites, and responded to the instructor's prompts (Alexander, Observation protocol, 7/12/16). During the second tree tour, Alexander was observed using the QR codes to access the arboretum curriculum, taking notes he later used in class to complete the K-W-L activity, and making observations of redbud tree leaves (Alexander, Observation protocol, 7/19/16).

Later that afternoon the class visited a *Catalpa* tree on the tour, where he was observed discussing the tree with several classmates. Referring to the large trunk of the tree he said, "That's some fat trunkage" (Alexander, Observation protocol, 7/19/16). Alexander also engaged with the curriculum during the third tree tour. He was observed taking pictures of tree

specimens, taking notes, and again accessing the tree websites via the QR codes attached to the individual trees (Alexander, Observation protocol, 7/26/16).

Angelica also engaged with the curriculum throughout the course of the study. During the first tree tour she was observed sketching the trees, feeling the bark and branches, and using the QR codes and websites (Angelica, Observation protocol, 7/11/16). The following week Angelica was observed using a hand lens to examine leaves and insect galls, collecting beech tree leaves, and discussing trees on the tour with a partner (Angelica, Observation protocol, 7/18/16). On the last tree tour she led a discussion on the cedar tree specimen, asked about the effects of pine straw on soil, and collected juniper berries from one of the arboretum specimens (Angelica, Observation protocol, 7/25/16). Angelica also used the QR codes and websites on this occasion (Angelica, Observation protocol, 7/25/16).

During the study, Eliza was also engaged with the curriculum. On the first tree tour she was observed taking pictures of trees, using the QR codes and websites, and comparing her photos to the online photos of the tree specimen (Eliza, Observation protocol, 7/11/16). Eliza was also observed collecting tree artifacts, asking questions about an injured elm tree specimen, and making suggestions about future educational activities involving the arboretum curriculum (Eliza, Observation protocol, 7/11/16). She also engaged with the curriculum during the last tree tour. At that time Eliza was observed posting tree specimen photos on Instagram, examining hackberry leaves and hickory nuts, and discussing trees on the tour with fellow students (Eliza, Observation protocol, 7/25/16).

Similarly, Peggy was observed engaging with the curriculum during the study. Unlike the other participants, Peggy was only observed twice during two of the tree walks and the accompanying activities. This was because she missed class during one of the scheduled activities. She was observed taking notes about the tree specimens on her phone and later discussing the tree specimens with her classmates (Peggy, Observation protocol, 7/26/16). Additionally, Peggy was observed smelling juniper berries during the tour and later working intently on her reflective questions in the classroom (Peggy, Observation protocol, 7/26/16).

Disengagement. Although one of the primary goals of curricula development is engaging students, that engagement can be transitory. Despite repeated evidence of participant engagement, at times participants displayed evidence of disengagement. Disengagement was defined as off-topic conversation, phone use not related to activities (i.e., phone call, texting, social media, and email), or participating in other activities not related to the curriculum. Evidence for the *disengagement* theme was limited. During the first and third tree tour activity, Peggy was observed using her phone for an unrelated activity (Peggy, Observation protocol, 7/19/16, 7/26/16). Alexander also briefly left the group on two separate occasions to collect Pokémon Go avatars (Alexander, Observation protocol, 7/12/16, 7/19/19). A visual presentation of this theme and its supporting codes is illustrated in Figure 3.

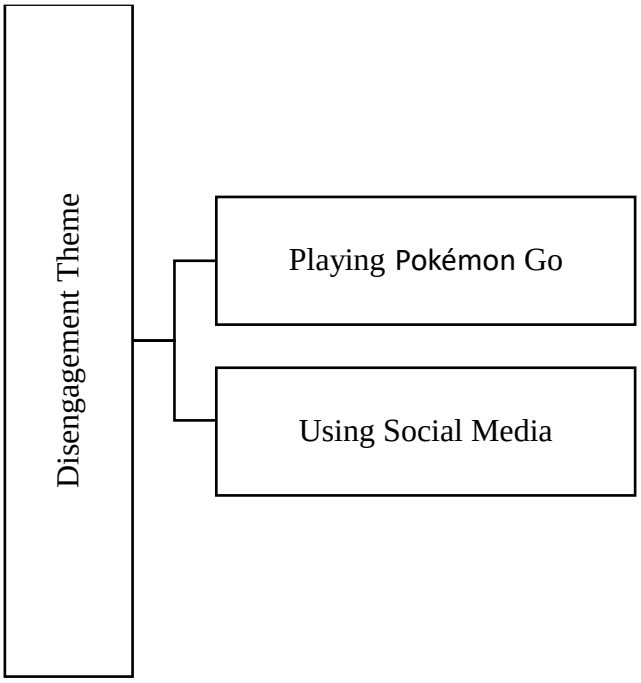

Figure 3. Disengagement Theme with Supporting Codes.

Connecting with the curriculum. Another emergent theme found recurring throughout the data was the theme *connecting with the curriculum*, which consisted of two subthemes: *participant perceptions* and *prior experiences.* Making connections to the curriculum took many forms: perceived learning about trees, curriculum informative and interesting, perceptions about trees and nature, previous knowledge, and childhood experiences. The theme, subthemes, and associated codes are illustrated in Figure 4. Following Figure 4, an examination of each subtheme and its supporting codes has been presented.

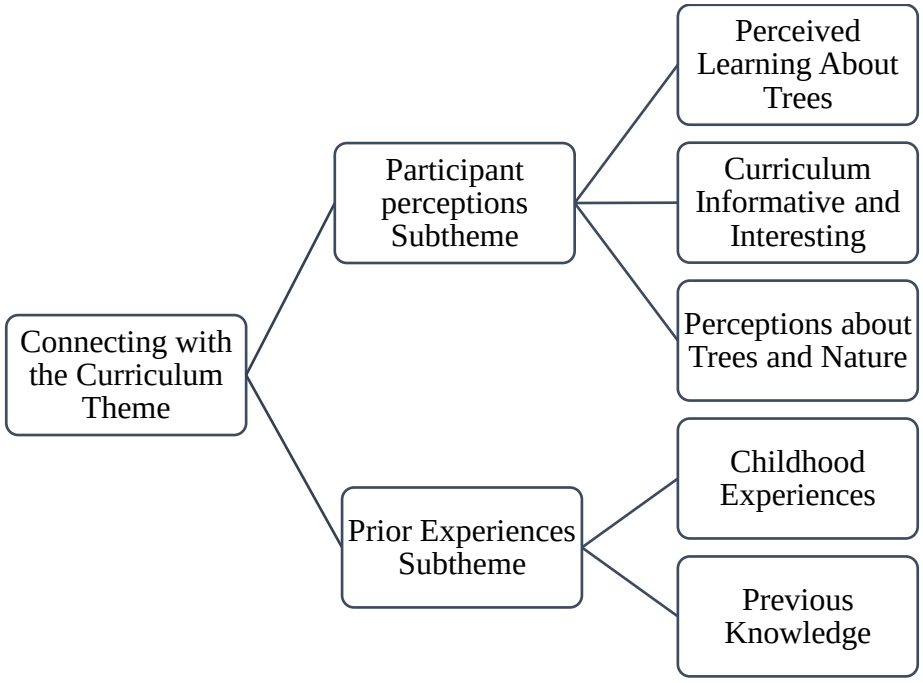

Figure 4. Connecting with the Curriculum Theme, Subthemes, and Supporting Codes.

Participant perceptions subtheme. The first subtheme elicited from the data for the emergent theme *connecting with the curriculum* was the subtheme *participant perceptions.* Three codes supported this subtheme: (1) *Perceived learning about trees,* (2) *Curriculum informative and interesting,* and (3) *Perceptions about trees and nature*. A discussion of each of these codes and their supporting citations is presented in the following paragraphs.

Perceived learning about trees. The participants repeatedly expressed the perception that the curriculum had increased their knowledge of trees. For instance, Angelica stated, "Now when I go back, 'cause [*sic*] I'm from East Tennessee, when I go home, on my way home, I was like looking at trees and I was like, 'I know these trees'" (Angelica, Post-interview, 7/27/16). She continued, "I just feel like this information that we learned on this tree tour will help me

years from now, something I can tell my kids" (Angelica, Post-interview, 7/27/16). Clearly, Angelica believed she had learned about trees from the curriculum and that this perceived learning had added meaningfully to her personal experiences outside of class.

Peggy also perceived she had learned more about trees. During her post-interview, she indicated that she had enjoyed the arboretum activities.

> I liked learning. I didn't really know a whole lot about trees. I might have known, like "Oh, that's an oak tree," but I didn't know specifics about it. So I thought it was really interesting learning details about each tree. (Peggy, Post-interview, 7/26/16)

For Peggy, her perceived learning about trees related to specific characteristics and details of the different types of trees examined during the arboretum curriculum activities.

In addition, Eliza also perceived that she had learned more about trees from participating in the arboretum curriculum activities. During her post-interview, she shared an account of a recent trip with her mother during her post-interview. Eliza said, "I was in Gatlinburg with my mom this weekend and we were going through the woods and I was like 'I bet if I saw that leaf, I could tell you what kind of tree it is'" (Eliza, Post-interview, 7/27/16). This indicated that Eliza believed she would be able to identify the trees on her walk in the woods with her mother based on the characteristics of their leaves.

Later during the post-interview, Eliza discussed how her perceived learning about the arboretum curriculum had affected her appreciation of the diversity and usefulness of trees in the environment. She stated, "I did learn things, and a lot of the stuff was really neat to see (such as) different types of barks, different types of leaves, what those trees are used for" (Eliza, Post-

interview, 7/27/16). She continued to elaborate on her perceived learning toward the end of her post-interview.

> We're doing our tree journals and I was laminating leaves last night and I was like "It's so sad that I can look at this and know what kind of leaf it is." But it's neat at the same time, it broadens your vocabulary and you're learning everything, so I thought it was pretty neat just to add that in like, "Hey, I know more stuff now." (Eliza, Post-interview, 7/27/16)

These statements indicated that both Eliza and Peggy believed they learned about trees from the curriculum. Peggy's perceived learning involved understanding the development and individual characteristics of trees, while Eliza's perceived learning related to the characteristics and uses of trees and being able to identify tree species based on the characteristics of their leaves.

In contrast to the other participants, Alexander's perception that the arboretum curriculum had increased his knowledge of trees related to their environmental function. For example, during his post-interview he talked about the role of trees in the environment. He said, "The tree tour was able to elaborate on just how important trees are to the environment" (Alexander, Post-interview, 7/26/16). Alexander continued by providing more detail related to his perceived learning.

> What I learned today was that trees can help with pollution, which is something I did not know. But [*sic*] even though we are the ones who are polluting the earth, the trees are still trying to absorb some of that pollution. (Alexander, Post-interview, 7/26/16)

Like the other participants, Alexander's statements indicated he believed that he had learned more about trees from his experiences with the arboretum curriculum. For him, the perceived learning about trees related to one of their important environmental functions.

In summary, all four participants expressed the perception that the arboretum curriculum had increased their knowledge of trees. For Angelica, the perceived learning about trees had added meaningfully to her personal experiences outside of class. In contrast, Peggy's perceived learning about trees related to the characteristics and details of the different types of trees she encountered. Similarly, Eliza's perceived learning about trees was associated with her perceived ability to identify tree species based on their leaf characteristics. Unlike Peggy and Eliza, Alexander's perceived learning about trees was not related to their physical characteristics. Instead, his perceived learning related to the environmental function of trees.

Curriculum informative and interesting. Statements from the participants also indicated that they found the arboretum curriculum and its associated activities informative and interesting. For example, Alexander was asked during his post-interview whether or not he enjoyed the arboretum activities. He said, "Yeah, it was very informative . . . very, very informative. We learned a lot of information. And I know, probably all of us, didn't know so, yeah" (Alexander, Post-interview, 7/26/16). During her post-interview, Peggy also made statements that suggested she found the curriculum informative and interesting.

> I didn't really know a whole lot about trees. I might have known, like "Oh, that's an oak tree," but I didn't know specifics about it. So I thought it was really interesting learning details about each tree. That's quite interesting. (Peggy, Post-interview, 7/26/16)

So both Alexander and Peggy indicated they found the arboretum curriculum informative, while Peggy also stated that she found it interesting.

Like Alexander and Peggy, Angelica also indicated she found the arboretum curriculum informative. During her post-interview, Angelica was asked if she had anything else she would like to share about her experiences with the arboretum curriculum. She stated, "The whole tree tour thing helped me and the class in general. Like I said, I learned a lot about trees and just little facts that I didn't know" (Angelica, Post-interview, 7/25/16). She continued, "And it's on your phone. Like, that's neat, I don't know if other campuses have that, but I think that's a neat thing" (Angelica, Post-interview, 7/25/16). Like Alexander and Peggy, Angelica found the arboretum curriculum informative. She also indicated her fondness for a technological aspect of the arboretum.

Thus, these statements from the participants indicated they found the arboretum curriculum and its associated activities informative and interesting. Alexander, Peggy, and Angelica made statements that indicated they found the curriculum informative. In addition, Peggy indicated she found the arboretum curriculum and its associated activities interesting. Finally, Angelica also made statements indicating her fondness for the mobile technology aspect of the online arboretum.

Perceptions about trees and nature. Importantly, the participants also made statements that appeared to indicate their experiences with the curriculum affected the way they thought about trees and nature. Angelica stated, "I look at [trees] in a different way, and that's really the truth, because before it was just a tree to me. But then now, I'm like 'Oh, I know information, I

can claim these, identify them'" (Angelica, Post-interview, 7/27/16). For this participant, knowing about the trees, identifying them, seemed to give them value.

Looking at the trees on her drive home to East Tennessee, Angelica's perceived new knowledge appeared to give them meaning. She said, "Now when I go back, 'cause [*sic*] I'm from East Tennessee, when I go home, on my way home, I was like looking at trees and I was like, 'I know these trees'" (Angelica, Post-interview, 7/27/16). At home Angelica shared her perceived new knowledge with her family. She said, "I was like telling my family, I was like, 'Yeah I know this, this, this and this'" (Angelica, Post-interview, 7/27/16). For Angelica, what was once just a tree had now become more personal. Her perceived new knowledge seemed to make the trees meaningful and she appeared to relish her ability to share this information with her family.

Relatedly, Alexander revealed a change in his perceived attitude toward nature. He said, "I've noticed like, 'Hey, this stuff is pretty cool.' 'Cause [*sic*] I was one of the ones who would just blow it all off, 'It's nature. Chop the tree down. It won't hurt nothing [*sic*]'" (Alexander, Post-interview, 7/26/16). He continued, "But now, I've gained more information, so it's actually pretty cool to me" (Alexander, Post-interview, 7/26/16). Citing his experiences during the study, Alexander also expressed a newly realized admiration for the natural world. He said, "I kind of realized that [*sic*] how much I like nature. I never really just verbally stated how much I think about nature, or how much I like nature, but from this I can tell I really like it" (Alexander, Post-interview, 7/26/16). His experiences during the study seemed to have affected his perception of nature and encouraged him to think about how he valued nature.

For Peggy, it was a transition from beliefs articulated during her pre-interview such as "nothing has truly been done to preserve what we have" (Peggy, Pre-interview, 7/11/16) and that over time human error will make nature "fall apart on itself" (Peggy, Pre-interview, 7/11/16), to a somewhat different perspective. During her post-interview, she expressed sentiments regarding nature that stood in contrast to her earlier statements. Peggy stated, "I guess change is happening in little ways, more than I know. And through the tree tour I guess, [is] a good way to help preserve or transform what's been broken or damaged" (Peggy, Post-interview, 7/26/2016).

Toward the end of the post-interview she said, "I feel like by planting just these trees and knowing a little bit about what each one can do for a specific environment, can really help that area I suppose" (Peggy, Post-interview, 7/26/16). These statements by Peggy indicated that she had transitioned from a somewhat pessimistic to a more optimistic outlook about our ability to preserve nature.

Like the other participants in the study, Eliza also made statements which supported the interpretation that the curriculum had affected her perceptions about trees and nature. During her pre-interview, Eliza's perception of nature centered around the impact of littering and recycling. When asked why she agreed with the statement that human impacts on natural environments have had negative consequences she said, "Littering is a huge deal, it gets in the water and all that and it's bad for the animals" (Eliza, Pre-interview, 7/7/16). Later Eliza was asked about agreeing with a statement regarding humans severely abusing natural environments she said, "It's just, yeah, mainly people being lazy and even taking the time to recycle at home" (Eliza, Pre-interview, 7/7/16).

During her post-interview, Eliza's perception of nature focused on her awareness and acknowledgment of trees. When asked about an earlier conversation from her pre-interview about increasing regulations to preserve nature, she focused on being aware of trees instead of concentrating on littering and recycling as she did before. She said, "Hey, this [tree] is a precious thing. We saw trees that have been here for years and we saw new ones, so it kinda tells you it's important, it's like us, it grows, it changes, it needs things to survive" (Eliza, Post-interview, 7/27/16).

Eliza further discussed a recent trip that suggested the curriculum had impacted her perceptions about trees and nature. She stated, "It's funny, like I said, when I was in Gatlinburg, when you're aware of [nature] and know what's going on, when you're out on a day-to-day basis, you acknowledge it more" (Eliza, Post-interview, 7/27/16). Together these statements denoted a shift from focusing on littering and recycling as primary concerns, to perceptions highlighting the importance of awareness and acknowledgement of nature. This evidence supports the assertion that the arboretum curriculum affected Eliza's perceptions about trees and nature.

As demonstrated by their statements, the participants indicated their experiences with the arboretum curriculum affected their perceptions of trees and nature. Angelica conveyed a difference in the way she looked at trees, while Alexander declared a newly realized admiration for nature. Peggy expressed a more optimistic perception about our ability to preserve nature, whereas Eliza indicated a new awareness and acknowledgement of trees.

Prior Experiences Subtheme. The second subtheme elicited from the data for the emergent theme *connecting with the curriculum* was the subtheme *prior experiences.* Two codes supported this subtheme: (1) *Childhood experiences* and (2) *Previous knowledge.* A discussion of each of these codes along with their supporting citations is presented in the following paragraphs.

Childhood experiences. Perhaps some of the most poignant evidence of connecting to the curriculum related to how it brought back memories of the participants' childhood experiences. Their encounters with the curriculum brought up memories of similar experiences, by rekindling childhood memories and reminding them of earlier experiences in their lives. For Eliza, learning about how trees serve as resources brought back memories of "picking pecans at Grandma's house" (Eliza, Observation protocol, 7/25/16) and "using trees for swings" (Eliza, Observation protocol, 7/11/16).

Similarly, Angelica shared memories about her father and his love for the outdoors. "I can remember growing up, we would go on hikes and he would point to these trees and he would try to [teach me] . . . and of course, now I've forgotten them all" (Angelica, Post-interview, 7/25/16). She added, "It was kinda [*sic*] sentimental 'cause [*sic*] it refreshed all those memories of my dad on the trees. Now that I know all the tree names again, I feel myself doing the same thing to my sisters and stuff" (Angelica, Post-interview, 7/25/16). So, for Eliza and Angelica the curriculum brought up pleasant memories from their childhoods about being outside and learning about trees. Notably, the connections they made between the curriculum and their childhood experiences were positive.

Previous knowledge. Connecting with the curriculum also involved previous knowledge of the participants. Eliza recalled learning earlier about the oxygen produced during photosynthesis, but the knowledge was detached from her everyday life. "You learn throughout school that we get oxygen from plants or we get this and that, but on a daily basis when you breathe, you're not like, 'Oh, thank you tree for letting me have this oxygen'" (Eliza, Post-interview, 7/27/16). She then explained how her previous knowledge gained more meaning because of her experiences with the curriculum. "So, when you put it into a perspective, when you know more about it . . . you have a visual of, 'Okay, this is what's helping me as a person and this is what we should have in our environment'" (Eliza, Post-interview, 7/27/16). These statements supported the assertion that Eliza made connections between the curriculum and her previous learning, enhancing her understanding of its significance.

Nature is important. The final theme elicited from the data related to the importance of nature. From analyzing the data collected from each participant, it was clear that the underlying theme of *nature is important* was a common thread. However, it became apparent there were two diverging perspectives underlying this theme. This resulted in two subthemes*: human-centered* and *intrinsic value* (see Figure 5). Some evidence collected revealed that nature was considered important for anthropocentric reasons. From this perspective, the importance of nature related to its role as a resource for humans. This resulted in the *human-centered* subtheme. Contrarily, other data relating to the importance of nature referenced its inherent value. Nature and the organisms in it were noted as having value not related to their use by humans. Instead, nature and

its inhabitants were perceived as entities with intrinsic value apart from humans. This resulted in the *intrinsic value* subtheme.

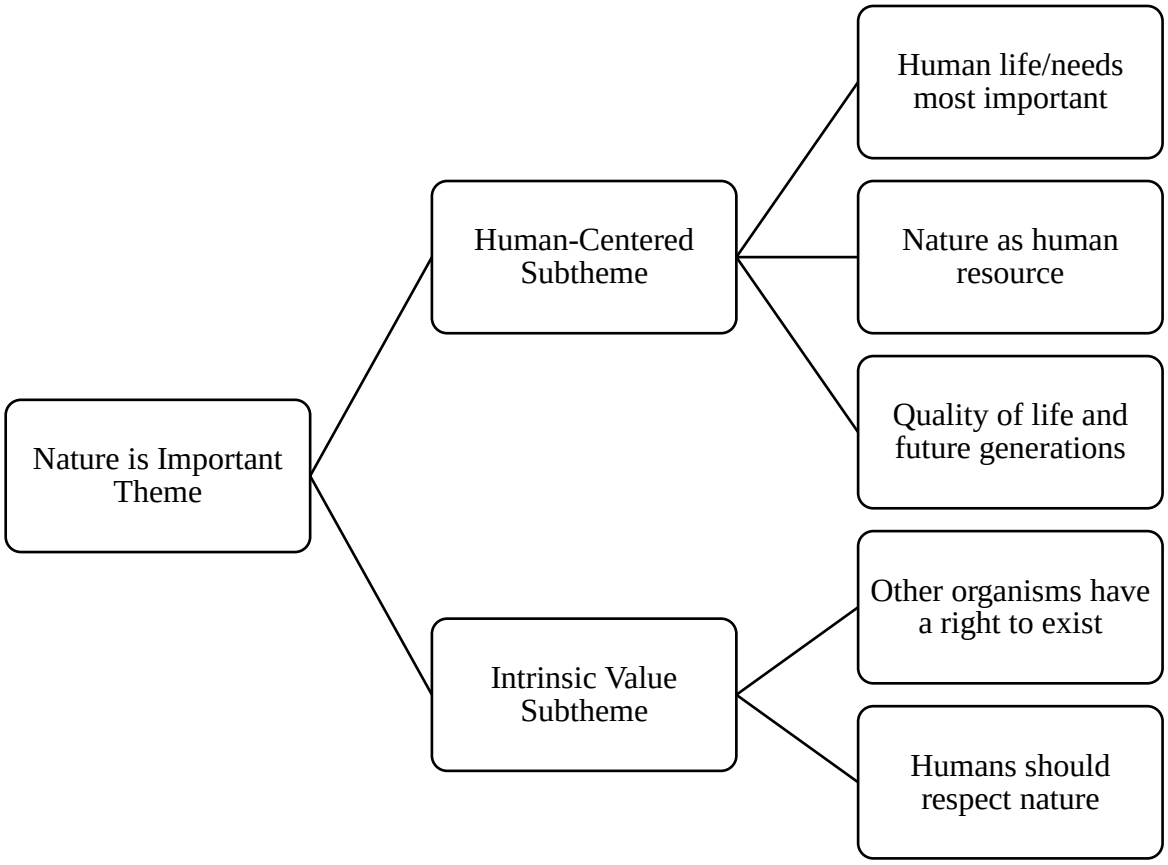

Figure 5. Nature is Important Theme, Subthemes, and Supporting Codes.

Human-centered subtheme. This subtheme emerged as an underlying thread throughout the pre- and post-interviews, as well as in the open-ended written reflections. Repeatedly, some participants stated that humans and their needs were more important than other organisms. Also, the perception that the primary role of the environment was as a resource for humans arose frequently in the data. Preserving nature for future generations was also deemed important by participants, as well as preserving it to maintain a higher quality of life for humans. Evidence for this subtheme is provided in the following paragraphs.

Human life and needs more important. On several occasions, Angelica revealed the belief that human life and needs superseded those of other organisms. On the pre-survey, she disagreed with a statement that maintained plants and animals have as much right to exist as humans (Angelica, pre-survey, 7/5/16). During her pre-interview, Angelica was asked to elaborate on her response to that question. She stated, "You can't base a human life compared to an animal life" (Angelica, Pre-interview, 7/6/16). Angelica continued, "Like [if] you had to take one life, that's why I would . . . You would save the human" (Angelica, Pre-interview, 7/6/16). For Angelica, human life and needs took precedence over those of other organisms.

During her post-interview, she was asked if her thoughts regarding this belief had changed or remained the same as a result of her experiences with the arboretum curriculum. Angelica maintained that her beliefs had not changed. She stated, "I do feel the same in regards [*sic*] to that, a human life being more important over an animal or plant" (Angelica, Post-interview, 7/27/16). These statements supported the interpretation that Angelica believed human life and needs were more important than those of other organisms. This was important, because

it illustrated that her perceived environmental beliefs regarding the preeminence of humans did not change because of her experiences with the arboretum curriculum.

Nature as a human resource. Nature was also deemed important by the participants due to its role as a human resource. During her pre-interview, Angelica explained why she believed nature was important. She said, "What we're needed [*sic*] as humans to keep evolving needs is nature and animals" (Angelica, Pre-interview, 7/6/16). When asked during the same interview why she agreed with a statement from the pre-survey stating that humans were meant to rule over the rest of nature, Angelica gave a reason for her belief. She said, "Because what we feed off was [*sic*] animals and plants, so therefore, we're kinda [*sic*] the top of the food chain" (Angelica, Pre-interview, 7/6/16). Angelica held onto this perception throughout the course of the study. During her post-interview she stated, "Animals and plants are resources for humans" (Angelica, Post-interview, 7/27/16). Her perception that the importance of nature related to its role as a human resource did not appear to change as a result of her experiences with the arboretum curriculum.

Similarly, Eliza appeared to view nature primarily in terms of its role in satisfying human needs. When asked why she thought it was important to preserve natural environments, her reasoning involved natural resources. She said, "You can't have an endless supply like oil and plastic and all that stuff . . . it's gonna go away" (Eliza, Pre-interview, 7/7/16). During her post-interview, she reiterated why she felt nature was important. She said, "We have to have it. The waters in nature, you gotta [*sic*] have that to survive, you've got the plants and everything that give you oxygen to breathe" (Eliza, Post-interview, 7/27/16).

Like her interviews, this perspective was also expressed in Eliza's reflective writing prompts. When responding to a prompt concerning the appropriateness of changing the environment to meet human needs, Eliza indicated changes to the environment would be alright if they benefited humans. She wrote, "I do think that if we could [change the environment] it would be important to help out the people" (Eliza, K-W-L Writing Prompt 2, 7/18/16). These statements and the response to the writing prompt illustrated her perceived belief that nature was important because of its role as a human resource. Importantly, her perceptions regarding the importance of nature did not appear to change as a result of her experiences with the arboretum curriculum.

Quality of life and future generations. In addition to serving as a resource, statements made by the participants indicated they believed nature was important in terms of quality of life and for future generations. For Eliza, the connection between nature and quality of life was clear. She explained, "If you have a bad environment you're not gonna have a good life" (Eliza, Pre-interview, 7/7/16). During her post-interview, it appeared her perceived beliefs regarding this topic had not changed. Eliza said, "If you don't take care of it [nature], that's gonna limit how long do [*sic*] you live and your lifestyles as well" (Eliza, 7/27/16).

Peggy also expressed the perception that nature was important for future generations. She explained, "It'll be more important down the road for generations to come to have a place that they can exist in" (Peggy, Pre-interview, 7/11/16). She continued, "Not just while we're here, but later on down the line, they'll want a place to exist in that's safe and healthy, I guess" (Peggy, Pre-interview, 7/11/16). When asked near the conclusion of the study whether her

experiences with the arboretum curriculum might have affected these beliefs, Peggy explained that they had generally remained the same. She said, "My thought process on that hasn't really changed a whole lot" (Peggy, Postl-interview, 7/26/16). Like Angelica and Eliza, Peggy's perceptions about the value of nature did not appear to change as a result of her experiences with the arboretum curriculum.

Intrinsic value subtheme. In contrast to assessing nature in terms of human existence, evidence was also found that indicated one participant's perceived environmental beliefs indicated that nature possessed intrinsic value. Alexander expressed the perception that other organisms have a right to exist, as well as the perception that humans should respect nature. This resulted in the *intrinsic value* subtheme. The *intrinsic value* subtheme and its supporting codes are discussed in the following paragraphs.

Other organisms have a right to exist. Alexander was asked to elaborate on a survey response in which he indicated that plants and animals have as much right as humans to exist. He responded, "I'm not saying that they should be treated as equal as us, but they are a life form" (Alexander, Pre-interview, 7/11/16). He continued, "It's yeah, taking away a life pretty much, if you just kill a plant or kill an animal. And I know we eat animals and plants, but there's a difference" (Alexander, Pre-interview, 7/11/16). These statements indicated that Preston believed other organisms have an intrinsic value.

Humans should respect nature. During his post-interview, Alexander was asked again about his beliefs about valuing and respecting nature. He stated, "Well, from doing the tree tour, it remains the same, if not, I'm even more for it" (Alexander, Post-interview, 7/26/16).

Alexander continued, “It’s [nature] very important and I still believe that we should treat everything with the utmost respect” (Alexander, Post-interview, 7/26/16). These statements from Alexander’s pre- and post-interviews support the interpretation that he deemed nature important for its intrinsic value. Notably, Alexander’s perceived beliefs regarding the importance of nature did not appear to have been affected by his experiences with the arboretum curriculum.

Qualitative Results Summary

Unlike the quantitative component for this study, the qualitative analysis focused solely on the variable environmental attitudes and beliefs. The qualitative research question was: How does participation in the arboretum curriculum influence the perceived environmental attitudes and beliefs of undergraduate students, if at all? Qualitative data were collected from two individuals in each experimental section, for a total of four participants. The data consisted of open-ended written reflections, observations, and transcribed pre- and post-interviews with participants.

Using an open coding process, four themes emerged from the qualitative data: (1) *Engagement*; (2*) Disengagement*; (3) *Connecting with the curriculum*; and (4) *Nature is important*. The theme *connecting with the curriculum* was found to consist of two subthemes: (1) *Prior experiences* and (2) *Participant perceptions.* The theme *nature is important* was also found to consist of two subthemes: (1) *Human-centered reasons* and (2) *Intrinsic value*. Two of the four emergent themes were most closely associated with the qualitative research question: *connecting with the curriculum* and *nature is important*.

Notably, the qualitative data indicated participation in the arboretum curriculum activities did not affect the perceived environmental attitudes and beliefs of participants. However, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum helped participants develop an appreciation for trees and nature and led them to believe they increased their knowledge about trees. The four emergent themes from the qualitative data are briefly revisited in the following paragraphs.

Engagement. First, a broad theme of *engagement* emerged from analysis of participant observations collected during this study. This theme was defined as participants being actively engaged with the curriculum by engaging in activities such as accessing the online arboretum, taking notes, collecting artifacts, making observations, and discussing relevant topics. Despite providing evidence that the participants engaged in the arboretum curriculum, its importance was limited because it did not address the research question.

Disengagement. In addition to evidence of participant engagement, disengagement was also another emergent theme. Disengagement was defined as off topic conversation, phone use not related to activities (i.e., phone call, texting, social media, and email), or participating in other activities not related to the curriculum. Evidence for the *disengagement* theme was limited, consisting primarily of participants using their phones for unrelated activities.

Connecting with the curriculum. The first of the two emergent themes most closely associated with the qualitative research question**,** *connecting with the curriculum* consisted of two subthemes: *participant perceptions* and *prior experiences*. This theme was supported by the following codes: perceived learning about trees, curriculum informative and interesting, previous

learning and childhood experiences, and perceptions about trees and nature. Both subthemes and their supporting codes are briefly discussed in the following paragraphs, beginning with the subtheme *participant perceptions.*

Participant perceptions. Three codes supported this subtheme: *perceived learning about trees, curriculum informative and interesting,* and *perceptions about trees and nature*. Each participant expressed the perception that the arboretum curriculum had increased their knowledge of trees. Additionally, statements from the participants indicated they found the arboretum curriculum and its associated activities informative and interesting. Finally, the participants also made statements that appeared to indicate their experiences with the curriculum affected the way they thought about trees and nature.

Prior experiences. Two codes supported this subtheme: *childhood experiences* and *previous learning.* Participating in the arboretum curriculum activities brought up memories of similar experiences the participants had from their childhood, such as being outside and learning about trees. Connecting with the curriculum also involved previous learning of the participants, including connecting a prior understanding of photosynthesis with an acknowledgement and appreciation of trees in the landscape.

Nature is important. The final emergent theme of *nature is important* also consisted of two subthemes: *human-centered* and *intrinsic value.* This theme was supported by the following codes: *human life/needs most important, nature as human resource, quality of life and future generations, other organisms have a right to exist, and humans should respect nature.*

Both subthemes and their supporting codes are briefly discussed in the following paragraphs, beginning with the subtheme *human-centered.*

Human-centered. Three of the participants indicated that nature was important for extrinsic reasons. Three codes supported this subtheme: *human life/needs most important*, *nature as human resource,* and *quality of life and future generations*. These participants indicated humans and their needs were more important than other organisms and that the primary role of nature was as a human resource. Members of this group also stated nature should be preserved as a resource for use by future generations and to maintain a higher quality of life for humans. Importantly, the perceptions of these participants about the importance of nature did not appear to change as a result of their experiences with the arboretum curriculum.

Intrinsic value. In contrast to assessing nature in terms of human existence, evidence was also found that indicated one participant believed nature possessed intrinsic value. Two codes supported this subtheme: *other organisms have a right to exist* and *humans should respect nature*. Evidence from this participant suggested he held the perception that nature was important for intrinsic reasons. Like the participants who deemed nature important for extrinsic reasons, this participant's perception of the importance of nature did not change as a result of his experiences with the arboretum curriculum.

Merged Results

As part of the convergent parallel design chosen for the study (Creswell & Plano Clark, 2011), results that emerged from the exploratory qualitative data concerning participants' environmental attitudes and beliefs were used to support an enhanced understanding of results

from the quantitative data collected measuring these same concepts. To better understand the relation between the two sets of data, the quantitative and qualitative data and their results have been merged in a comparison matrix (see Table 4) as done by Li, Marquart, and Zercher (2000) and Wittink, Barg, and Gallo (2006). The quantitative data consists of the combined mean pre- and post-survey scores for environmental attitudes and beliefs. The qualitative data is comprised of the emergent themes *connecting with the curriculum*, *nature is important*, and supporting statements from participants.

Table 4

Comparing Quantitative and Qualitative Results: Data from Surveys and Participant Interviews

Dimension	Qualitative Results (n = 4)		Quantitative Results (n = 32)
Environmental Attitudes and Beliefs of Participants	Theme, Subthemes, and Supporting Quotations *Nature is Important: Intrinsic value*	Theme and Supporting Quotations *Connecting with the Curriculum*	Environmental Attitudes and Beliefs Pre- and Post-Survey Scores
	"I'm not saying that they should be treated as equal as us, but they are a life form" (Alexander, Pre-interview, 7/11/16).	"I look at it in a different way, and that's really the truth, because before it was just a tree to me" (Angelica, Post-interview, 7/27/16).	Pre-survey: M = 3.38 SD = 0.50 Post survey: M = 3.49 SD = 0.46 p = .0559
	Nature is Important: Human-centered "It'll be more important down the road for generations to come to have a place that they can exist in" (Peggy, Pre-interview, 7/11/16).	"'Cause I was one of the ones who would just blow it all off, 'It's nature. Chop the tree down. It won't hurt nothing.' But now . . . it's actually pretty cool to me" (Alexander, Post-interview, 7/26/16).	
	"If you have a bad environment you're not gonna have a good life" (Eliza, Pre-interview, 7/11/16).	"I kinda realized that [*sic*] how much I like nature" (Alexander, Post-interview, 7/26/16).	
		"I guess change is happening in little ways, more than I know" (Peggy, Post-interview, 7/26/16).	
	"Animals and plants are resources for humans" (Angelica, Post-interview, 7/27/16).	"When you're aware of it and know what's going on, when you're out on a day-to-day basis, you acknowledge it more" (Eliza, Post-interview, 7/27/16).	

A comparison of the quantitative and qualitative results showed both convergence and divergence between the two sets of data. Convergence between the qualitative and quantitative data was found for environmental attitudes and beliefs. While results from the mixed design ANOVA showed that the difference between pre- and post-survey scores for environmental attitudes and beliefs was approaching significance, the difference between the two was not statistically significant ($p = .0559$). This implied that the arboretum curriculum had no effect on the environmental attitudes and beliefs of the students in the sample. Although qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum helped participants develop an appreciation for trees and nature and led them to believe they increased their knowledge about trees, there was no evidence these experiences impacted their perceived environmental attitudes and beliefs regarding the importance of nature.

For example, qualitative data from pre- and post-interviews (see Table 4) indicated that the perceived environmental attitudes and beliefs of participants regarding the importance of nature were unaffected by the arboretum curriculum. Whether the participant perceived nature as important for human-centered reasons or its intrinsic value, their perceived environmental attitudes and beliefs regarding the importance of nature remained consistent throughout the study. These results aligned with quantitative results indicating no significant difference between the pre- and post-survey results measuring environmental attitudes and beliefs.

Conversely, a comparison of the quantitative and qualitative results also showed divergence between the two data sets. Although results from both the quantitative and qualitative components of the study indicated the arboretum curriculum had no impact on the

environmental attitudes and beliefs of the participants, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum did lead participants to believe they increased their knowledge about trees and helped them develop an appreciation for trees and nature.

For example, statements from all four participants supporting the theme *connecting with the curriculum* (see Table 4) indicated their experiences with the arboretum curriculum helped foster an awareness of both trees and nature. Additionally, statements from post-interviews revealed a perceived increase in participants' knowledge about trees. For instance, Angelica commented on her trip back home. She said, "I was like looking at trees and I was like, 'I know these trees'" (Angelica, Post-interview, 7/27/16). Another example of perceived learning about trees came from Peggy. She said, "I liked learning. I didn't really know a whole lot about trees . . . I thought it was really interesting learning details about each tree" (Peggy, Post-interview, 7/26/16). These statements from the post-interviews supported the assertion that experiences with the arboretum curriculum led participants to believe they increased their knowledge about trees and helped them develop an appreciation for trees and nature.

Chapter Summary

The intent of this chapter was to report the results from the analysis of the quantitative data, the qualitative data, and the merged results from both sets of data concerning the environmental attitudes and beliefs of the participants. The quantitative analysis indicated a significant difference between the pre- and post-survey scores for ecological knowledge, with no significant difference between the pre- and post-survey scores for the remaining variables

environmental attitudes and beliefs and environmental behaviors. However, no significant difference was found among the groups for all three variables. Additionally, there were no significant interaction effects between the group and survey factors for any of the three variables.

Following thematic analysis of the qualitative data, four themes emerged: (1) *Engagement*; (2) *Disengagement*; (3) *Connecting with the curriculum*; and (4) *Nature is important*. The theme *connecting with the curriculum* consisted of two subthemes: (1) *Prior experiences* and (2) *Participant perceptions*. Additionally, the theme *nature is important* also consisted of two subthemes: (1) *Human-centered reasons* and (2) *Intrinsic value*. Using a comparison matrix, the analysis of the merged results compared the differences and similarities between the two data sets within the overarching dimension of environmental attitudes and beliefs.

When the two data sets were compared, the results from the quantitative and qualitative components were found to converge and diverge. Quantitative data indicated the environmental attitudes and beliefs of participants were unaffected by the arboretum curriculum. Similarly, qualitative data regarding participants' perceived environmental attitudes and beliefs regarding the importance of nature remained unchanged throughout the course of the study. However, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum helped participants develop an appreciation for trees and nature and led them to believe they increased their knowledge about trees.

CHAPTER 5: DISCUSSION

Human activities such as urbanization pose an increasing threat to biological diversity (McKinney, 2002). Preserving biological diversity is a necessity, and increasing individual ecological literacy levels may help citizens make informed choices about the environmental challenges confronting society (Hsu, 2004; UNESCO, 1980). Unfortunately, basic knowledge of our natural surroundings is declining among individuals (Atran et al., 2004).

The purpose of the study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers. As future teachers, the pre-service K-8 group have the potential to impact the ecological literacy of a large number of subsequent students. Using a convergent parallel mixed-methods design (Creswell & Plano Clark, 2011), both quantitative and qualitative data were collected at the same time, analyzed separately, and later merged to create an enhanced understanding of the impact of the curriculum on the perceived environmental attitudes and beliefs of the participants.

Importantly, there are potential limitations and delimitations associated with the design of the study. The lack of individual randomization is an important limitation inherent in many quasi-experimental designs used in educational research. Also, having multiple instructors may have impacted the results of the study. In addition, choosing to conduct the study during the summer semester resulted in a limited quantitative sample size that may affect the generalizability of the quantitative results. The structure of summer courses and the sample of

students enrolled in summer courses may differ from those of courses offered during the fall and spring semesters, both of which may potentially affect the generalizability of the results from the study. However, the summer semester offered classes with a more manageable size and access to the arboretum trees while they were fully-leafed out and flowering.

The intent of this chapter is to provide a discussion of the results from the study. The chapter has been organized into several sections, beginning with an overview of the research problem. Next, a review of the methodology is offered. Then, a discussion of the results is provided. The quantitative and qualitative results are first discussed separately, followed by a discussion of the merged results that attempts to provide an enhanced understanding of the impact of the curriculum on the perceived environmental attitudes and beliefs of the participants. Afterward, an examination of the implications of the results of the study for biology education has been included. Next, a discussion of future areas of research suggested by the results of the study has been offered. Finally, the discussion of the results of the study are reviewed in a chapter summary.

Research Problem

For the first time in history, most people live in urban areas (UNDESA, 2014). In addition to degrading and diminishing habitat (Marzluff, 2001), urbanization may increase the separation people feel from natural environments, isolate them from natural systems, and decrease the quantity and quality of human interactions with nature (Lin et al., 2014; Turner et al., 2004). Despite the widely recognized need for ecological literacy among citizens to make

informed decisions regarding the environmental problems facing society, basic knowledge of our natural surroundings is decreasing (Atran, Medin, & Ross, 2004).

However, urban green infrastructure and urban green space help conserve biological diversity and may help people develop and maintain connections with natural spaces (Brown & Grant, 2005; Shwartz et al., 2014). Additionally, direct experience with nature has been widely noted as a critical factor affecting individual ecological literacy levels (Cooper, 2008; Eaton, 1998; Parker, 2009; Preston & Griffiths, 1995; Wagner, 2008). Furthermore, mobile technology has the potential to facilitate collaboration and cooperation among peers that is not limited by time and space (Looi et al., 2011) and make learning more student-centered (Gikas & Grant, 2013).

Yet, studies investigating the effects of urban green space on ecological literacy (e.g., Shwartz et al., 2012; Shwartz et al., 2014) are not widespread in the literature (Lin et al., 2014; Standish et al., 2013). Similarly, studies exploring the combined use of mobile technology and place-based environmental education (e.g., Liu et al., 2009; Ruchter et al., 2010; Zimmerman & Land, 2014) are also not widespread in the literature. Because studies investigating the effects of urban green space on ecological literacy are not widespread in the literature, this study sought to contribute to that understanding. Similarly, because studies exploring the combined use of mobile technology and place-based environmental education are also limited this study also sought to advance this area of inquiry.

Review of Methodology

The purpose of this section is to provide a review of the methodology of the study. A new interactive online guide for the campus arboretum was created and employed, in conjunction with a series of ecological activities designed to promote student exploration of the trees in the campus arboretum. After receiving IRB approval, students enrolled in two undergraduate biology classes participated in ecological and environmental activities designed to enhance ecological literacy. Students enrolled in a third undergraduate biology class served as a comparison group and did not participate in the ecological and environmental activities.

Using a convergent parallel mixed methods design, both qualitative and quantitative data were collected concurrently and analyzed separately (Creswell & Plano Clark, 2011). Using three survey instruments, quantitative data was collected using pre- and post-surveys on individual student ecological literacy levels, environmental attitudes and beliefs, and environmental behaviors. Additionally, demographic information was collected on age, gender, ethnicity, parents' level of education, hometown (i.e., urban or rural), and college major. Qualitative data consisted of open-ended written reflections, interviews with participants, and observations.

Quantitative data were analyzed using three separate 3(between-subjects) x 2(within-subjects) mixed design ANOVAs conducted through the MANOVA approach to test for statistical significance. Qualitative data analysis involved becoming familiar with the data, recording reflective notes and memos, generating and defining the initial codes using an open

coding process, establishing the veracity of the codes through inter-coder agreement, and combining the codes to elicit themes from the data.

As part of the convergent parallel design (Creswell & Plano Clark, 2011), results that emerged from the exploratory qualitative data concerning students' perceived environmental attitudes and beliefs were compared with the quantitative results from the environmental attitudes and beliefs pre- and post-surveys. The merged results were then used to support an enhanced understanding of the impact of the curriculum on the perceived environmental attitudes and beliefs of the participants.

Discussion of Results

The objective of this section is to interpret the results of the study. The quantitative results are discussed first, with the separate hypotheses addressed according to their related quantitative variable. Next, the qualitative results are examined to determine whether participation in the arboretum curriculum influenced the perceived environmental attitudes and beliefs of undergraduate students. Finally, the quantitative and qualitative results are compared to support an enhanced understanding of the impact of the arboretum curriculum on the perceived environmental attitudes and beliefs of the participants.

Interpreting the Quantitative Results

The quantitative component of the study sought to answer several questions. First, were there significant differences between the pre- and post-survey scores for ecological knowledge, environmental attitudes and beliefs, and environmental behaviors? Next, were there significant differences among the three groups on ecological knowledge, environmental attitudes and

beliefs, and environmental behaviors? Finally, were there significant interaction effects between the group and survey factors on ecological knowledge, environmental attitudes and beliefs, and environmental behaviors? In the remainder of this section, each of the quantitative hypotheses is addressed according to their related quantitative variable. Possible explanations for the results are discussed, as the researcher attempts to situate the findings in the related literature and address the limitations of the study.

Ecological knowledge. For the variable ecological knowledge three hypotheses were tested: (1) There is a significant difference between pre- and post-survey scores on ecological knowledge; (2) There is a significant difference among the three groups on ecological knowledge; and (3) There is a significant interaction effect between the group and survey factors on ecological knowledge. To test the three hypotheses related to the variable ecological knowledge, a 3 (between-subjects) x 2 (within-subjects) mixed design ANOVA using the MANOVA approach was conducted.

As noted earlier, all three groups had significant differences between their pre- and post-survey scores for ecological knowledge. The combined mean score from the pre- to post-survey increased from 21.53 to 22.84. However, there was no significant difference among the three groups on ecological knowledge. Any differences between pre- and post-survey scores for the treatment groups could not be attributed to the arboretum curriculum, because they were not significantly different from differences in the pre- and post-survey scores for the comparison group. There was also no significant interaction effect between the group and survey factors for

ecological knowledge, indicating that the group factor and the time factor had no differential effect on the survey scores for this variable.

Prior research provided strong evidence that direct experience with nature and local environments is a critical factor affecting individual ecological literacy levels across many demographic and socioeconomic factors (Cooper, 2008; Eaton, 1998; Goldman et al., 2013; Luksa et al., 2009; Mancl et al., 1999; Parker, 2009; Pilgrim et al., 2007; Pilgrim et al., 2008; Preston & Griffiths, 1995; Prokop et al., 2007; Wagner, 2008). Additionally, the literature also revealed that environmental and ecological learning activities incorporating mobile technology had positive effects on learning, attitudes, and awareness (Hougham, 2015; Hung et al., 2010; Hwang et al., 2011; Land et al., 2015; T. C. Liu et al., 2009; T. Y. Liu et al., 2009; Looi et al., 2011; Ruchter et al., 2010; Song et al., 2012; Uzunboylu et al., 2009; Zimmerman & Land, 2014; Zimmerman et al., 2015).

However, the results of the present study did not indicate a significant difference between the mean differences of the pre- and post-survey responses for the treatment and comparison groups. These results stand in contrast to results reported widely in the literature that this type of intervention impacts ecological knowledge. It is possible that sampling limitations affected the results of the study. The sample size was lower than initially planned ($N = 32$), due to decisions made to conduct the study during the summer and difficulties in obtaining permission to conduct the study in other classes. Additionally, although validated for content and tested for reliability for eight broad ecological concepts, the instrument developed by Morrone et al. (2001) may not

have measured gains in ecological knowledge produced by the more tree specific arboretum curriculum.

Environmental attitudes and beliefs. For the variable environmental attitudes and beliefs three hypotheses were also tested: (1) There is a significant difference between pre- and post-survey scores on environmental attitudes and beliefs; (2) There is a significant difference among the three groups on environmental attitudes and beliefs; and (3) There is a significant interaction effect between the group and survey factors on environmental attitudes and beliefs. To test the three hypotheses related to the variable environmental beliefs and attitudes, a 3 (between-subjects) x 2 (within-subjects) mixed design ANOVA using the MANOVA approach was conducted.

Like ecological knowledge, there was an increase in the means from the pre- to the post-survey scores for the variable environmental attitudes and beliefs. The combined mean for this variable showed an increase from 3.38 to 3.49. However, the difference between pre- and post-survey scores for environmental attitudes and beliefs was only approaching significance (p = 0.559). Additionally, there was no significant difference among the three groups on environmental attitudes and beliefs.

Furthermore, there was also no significant interaction effect between the group and survey factors for environmental attitudes and beliefs. Like ecological knowledge, the group and time factors had no differential effect on the survey scores for environmental attitudes and beliefs. Importantly, without a significant difference between the changes in pre- and post-survey scores for the treatment and comparison groups, the improvements in the environmental

attitudes and beliefs scores for the experimental groups could not be attributed to the arboretum curriculum.

Overall, the arboretum curriculum had no differential effect on the treatment group for environmental attitudes and beliefs. This contrasts with assertions made by Noss (2004) and Standish et al. (2013) that interacting with urban greenspaces may result in positive effects on environmental attitudes and beliefs. It also differs from findings by Shwartz et al. (2012) indicating a strong positive correlation between participation in urban natural activities and increased interest in local urban biodiversity. Additionally, these results contrast with findings by Uzunboylu et al. (2009) that reported enhanced environmental awareness among undergraduates that participated in a similar study employing the use of mobile technology.

Again, possible limitations with sampling and the instrument used to measure environmental beliefs and awareness may have affected the results. Additionally, the amount of time subjects were exposed to the arboretum curriculum was limited. Over the course of the semester, the arboretum curriculum was employed during three separate occasions over a period of three weeks. This differs from Uzunboylu et al.'s (2009) study, in which subjects were exposed to the treatment for a total of six weeks and were required to participate in online discussion forums. Thus, it is possible that the restricted scope of the intervention limited its impact. That would be consistent with Shwartz et al.'s (2012) finding of limited development of larger-scale environmental understanding with brief participative environmental education.

Environmental behaviors. As was done for the previous quantitative variables, three hypotheses were tested: (1) There is a significant difference between pre- and post-survey scores

on environmental behaviors; (2) There is a significant difference among the three groups on environmental behaviors; and (3) There is a significant interaction effect between the group and survey factors on environmental behaviors. To test the three hypotheses related to the variable environmental behaviors, a 3 (between-subjects) x 2 (within-subjects) mixed design ANOVA using the MANOVA approach was conducted.

In contrast to the results for the previous quantitative variables, the difference between pre- and post-survey scores on environmental behaviors was neither significant nor approaching significance. This indicated the arboretum curriculum had no impact on the environmental behaviors of the subjects. There was also no significant difference among the three groups on environmental behaviors. Like the other variables, this indicated that the differences in the environmental behaviors pre- and post-survey scores for the experimental groups were not significantly different than the pre- and post-survey scores differences for the comparison group. Similarly, there was no significant interaction effect between the group and survey factors on environmental behaviors. This indicated that the group and time factors also had no differential effect on the survey scores for environmental behaviors.

To increase the impact of interventions designed to impact environmental behaviors, Staats, Wit, and Midden (1996) suggested including elements designed to enhance ecological knowledge and change environmental attitudes and beliefs. Though these elements were included in the study design, the arboretum curriculum appeared to have no impact on the environmental behaviors of the subjects. Findings from a meta-analysis of intervention studies

designed to promote environmental behaviors associated with energy conservation (Abrahamse, Steg, Vlek, & Rothengatter, 2005) may offer insight into the current findings.

In their review of the literature, Abrahamse et al. (2005) found that providing subjects with information about environmental behaviors increased knowledge but did not necessarily result in changes in environmental behaviors. The authors found that the most effective strategies for influencing environmental behaviors were offering rewards and frequent feedback (Abrahamse et al., 2005). In another meta-analysis of studies designed to impact environmental behaviors, demonstration, goal setting, and consequences were found to be the most effective strategies for promoting environmentally responsible behaviors (Dwyer, Leeming, Cobern, Porter, & Jackson, 1993). However, including the elements highlighted in these meta-analyses in the design study was deemed beyond the scope of the arboretum curriculum.

Interpreting the Qualitative Results

In contrast to the quantitative component, the qualitative analysis focused on one research question: How does participation in the arboretum curriculum influence the perceived environmental attitudes and beliefs of undergraduate students, if at all? Following thematic analysis of the qualitative data, four themes emerged: (1) *Engagement*; (2) *Disengagement*; (3) *Connecting with the curriculum*; and (4) *Nature is important*. The theme *connecting with the curriculum* consisted of two subthemes: (1) *Prior experiences* and (2) *Participant perceptions.* In addition, the theme nature is important consisted of two subthemes: (1) *Human-centered* and (2) *Intrinsic value*.

Of the four emergent themes, the themes *connecting with the curriculum* and *nature is important* most directly addressed the research question. Supporting evidence for these emergent themes and the associated subthemes was examined to assess how they addressed the qualitative research question. Importantly, the qualitative data indicated participation in the arboretum curriculum activities did not affect the perceived environmental attitudes and beliefs of participants. However, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum did lead participants to believe they increased their knowledge about trees and helped them develop an appreciation for trees and nature. The discussion of these findings has been presented in the following paragraphs. Included in the discussion are possible explanations for the results, as the researcher attempts to situate the findings in the related literature and address the limitations of the study.

Importance of nature. Anthropocentrism may be broadly defined as a human centered world view, in which humans are the most important element (Anthropocentrism, n.d.). An individual with an anthropocentric worldview tends to assign importance to nature for its extrinsic value to humans (Dunlap et al., 2000). Anthropocentrism is a key attribute specifically measured by the survey instrument developed by Dunlap et al. (2000) employed in this study to measure environmental attitudes and beliefs.

Notably, *Nature is important* was one of the emergent themes from the data. It consisted of two subthemes: (1) *Human centered* and (2) *Intrinsic value*. Evidence for this emergent theme, its related subthemes, and supporting codes consisted of statements made by the participants regarding nature presented in the results section. These were examined to determine

the impact of the arboretum curriculum on the perceived environmental attitudes and beliefs of the participants regarding the importance of nature.

Throughout the course of the study, three participants repeatedly cited human-centered reasons for the importance of nature: Angelica, Eliza, and Peggy. These reasons included humans and their needs superseding those of other organisms, the primary role of the environment as a resource for humans, preserving nature for future generations, and preserving nature to maintain a higher quality of life for humans. The fourth participant, Alexander, noted the intrinsic value of nature as the reason for its importance throughout the study. The participants' perceptions regarding the importance of nature did not appear to change, indicating that the arboretum curriculum did not impact their perceived environmental attitudes and beliefs regarding the importance of nature.

The reason for the lack of change in the perceptions of the participants may be related to their values. The values held by individuals have been linked to their environmental beliefs (Spash, 2006). For instance, an individual who values the welfare of others might believe preserving the environment is important because it affects human health (Spash, 2006). Due to study constraints, the personal values of the participants were not examined. Subsequently, any relationship between the values of the participants and their perceptions of nature was not explored and this may represent a limitation of the study.

Perceptions about trees. Unlike their perceptions regarding the importance of nature, the participants expressed apparent changes in the way they perceived trees and how they valued them. For example, Angelica appeared to indicate her perception of trees had changed. She said,

"I look at (trees) in a different way, and that's really the truth, because before it was just a tree to me. But then now, I'm like 'Oh, I know information, I can claim these, identify them'" (Angelica, Post-interview, 7/27/16). After participating in the curriculum, Angelica did not just see a tree. She saw certain types of trees that she could identify and claim. She continued, 'I think a lot of people, especially me going into this, I didn't ever look at [trees]" (Angelica, Post-interview, 7/27/16). For this participant, knowing about the trees and being able to identify them seemed to increase their value and importance.

These statements from Angelica relating to trees suggested that her experiences with the arboretum curriculum led to an increase in her awareness and acknowledgement of trees. In a similar study involving participants investigating various ecological aspects of trees growing on school grounds, Hougham (2015) also reported significant gains in student interest in learning about plants. Additionally, Shwartz et al. (2012) reported participants developing interest in local biodiversity as a result of taking part in urban natural activities.

Eliza also cited becoming familiar with the age structure of the campus tree community and their ontogeny as perceived knowledge that increased their importance. She said, "Hey, this [tree] is a precious thing" (Eliza, Post-interview, 7/27/16). Eliza continued, "We saw trees that have been here for years and we saw new ones, so it kinda [*sic*] tells you (a tree) is important, it's like us, it grows, it changes, it needs things to survive" (Eliza, Post-interview, 7/27/16). Like Angelica, the data for Eliza suggested that a perceived increase in knowledge of trees may be related to a perceived increase in environmental awareness and acknowledgement of nature.

This may explain the strong positive correlation between the participation of individuals in urban natural activities and their interest in local urban biodiversity found by Shwartz et al. (2012).

Perceptions about nature. Citing his experiences during the study, Alexander expressed a newly realized admiration for the natural world. He said, "I kinda realized that [*sic*] how much I like nature. I never really just verbally stated how much I think about nature, or how much I like nature, but from this I can tell I really like it" (Alexander, Post-interview, 7/26/16). During that same interview, Alexander continued to elaborate on the change in his perceptions toward nature. He stated, "I've noticed like, 'Hey, this stuff is pretty cool.' 'Cause I was one of the ones who would just blow it all off, 'It's nature. Chop the tree down. It won't hurt nothing'" (Alexander, Post-interview, 7/26/16). Alexander then explained why he believed this change occurred. He said, "But now, I've gained more information, so it's actually pretty cool to me" (Alexander, Post-interview, 7/26/16). Apparently, Alexander attributed the change in his awareness of nature to a perceived increase in knowledge about trees.

However, Noss (2004) would argue that the urban greenspace incorporated into the arboretum curriculum provided him with the opportunity to maintain his intrinsic appreciation of nature. Both environmental appreciation and ecological knowledge are considered components of environment literacy (McBride et al., 2013), a concept often compared with ecological literacy. This study adopted the definition of ecological literacy advanced by Nair et al. (2002) and Orr (1991), which does not specifically address environmental appreciation. Although this may be a potential limitation of the study, the characterizations of ecological literacy developed

to guide researchers and practitioners have varied widely in the literature (Jordan et al., 2008; McBride et al., 2013).

Like the others in the study, Eliza also made statements which support the interpretation that the curriculum had affected her perception of nature. When asked if there was anything else that she would like to share about her experiences involving the arboretum curriculum, Eliza mentioned a recent trip to Gatlinburg. She said, "It's funny, like I said, when I was in Gatlinburg, when you're aware of (nature) and know what's going on, when you're out on a day-to-day basis, you acknowledge it more" (Eliza, Post-interview, 7/27/16). This statement was interpreted as an indication that the curriculum facilitated perceived connections between its content and Eliza's daily life, which aligned with findings by Zimmerman et al. (2015).

Merged Results

As part of the convergent parallel design of the study, the quantitative and qualitative results were compared to support an enhanced understanding of the impact of the arboretum curriculum on the perceived environmental attitudes and beliefs of the participants. Using a technique suggested by Creswell and Plano Clark (2011), the analysis of the merged results assessed the differences and similarities between the two data sets within the overarching dimension of environmental attitudes and beliefs. A discussion of the implications of how the databases converged and diverged has been included, as well as potential limitations and connections to the literature.

Convergence. Having been widely recognized as a reliable tool to measure environmental attitudes and beliefs (Lundmark, 2007), the survey instrument by Dunlap et al.

(2000) was seen as an ideal instrument to measure environmental attitudes and beliefs for the current study. As noted earlier, the *importance of nature* and its associated subthemes *human centered* and *intrinsic value* were constructs associated with the intrinsic and extrinsic value of nature. Fittingly, this instrument was designed to directly measure the beliefs of subjects regarding their perception of the importance of nature (anthropocentrism) (Dunlap et al., 2000).

Subsequent analysis of the qualitative data indicated three of the participants perceived nature as important for human-centered reasons, while one participant expressed the perception that nature was important for intrinsic reasons. The qualitative data indicated that the perceived environmental attitudes and beliefs of participants regarding the importance of nature were unaffected by the arboretum curriculum, remaining consistent throughout the study. These results are aligned with the quantitative results that indicate no significant difference between the pre- and post-survey results measuring environmental attitudes and beliefs.

Divergence. Although both the quantitative and qualitative results indicated the arboretum curriculum had no impact on the environmental attitudes and beliefs of the participants, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum did lead participants to believe they increased their knowledge about trees and helped them develop an appreciation for trees and nature. Due to the exploratory nature of qualitative research, themes emerge from the data during analysis (Creswell, 2013). As a result, the perceptions of the participants about trees and nature that surfaced in the data were unknown at the time the quantitative instrument was selected.

After re-examining the instrument by Dunlap et al. (2000) used to collect the quantitative data on the environmental attitudes and beliefs of the subjects, it was determined that it was not constructed to measure appreciation and awareness of nature. Because the instrument selected did not fully measure the perceptions of participants that emerged during qualitative data analysis, this may represent a potential limitation of the study.

Merged results summary. Results from the qualitative component indicated the participants' perceived environmental attitudes and beliefs related to the importance of nature remained consistent throughout the study, aligning with the quantitative results that indicated no statistically significant difference between the environmental attitudes and beliefs measured by the instrument.

For the quantitative data, the difference between pre- and post-survey scores was approaching significance ($p = 0.559$). However, there was no significant difference between the treatment and comparison groups. Therefore, any change in the pre- and post-survey scores for environmental attitudes and beliefs could not be attributed to the arboretum curriculum.

Similarly, the qualitative data indicated that the perceived environmental attitudes and beliefs of participants regarding the importance of nature were unaffected by the arboretum curriculum. For example, the three participants that deemed nature important for extrinsic reasons during their pre-interviews maintained the same perception during their post-interviews. Likewise, the sole participant that indicated nature was important for intrinsic reasons during his pre-interview affirmed that perception during his post-interview. Thus, the participants'

perceived environmental attitudes and beliefs regarding the importance of nature remained consistent throughout the study.

Notably, qualitative data supporting the theme *connecting with the curriculum* suggested experiences with the arboretum curriculum led participants to perceive an increase in their knowledge about trees and helped them develop an appreciation for trees and nature. Because the instrument selected to measure environmental attitudes and beliefs did not assess participants' appreciation for trees and nature, this may represent a potential limitation of the study.

Implications for Biology Education

Preserving biological and ecological diversity is an essential goal for continued human survival. However, individual ecological literacy levels are declining (Atran et al., 2004), probably in part due to the diminishing amount of time people spend in natural environments (Pilgrim et al., 2007). Although the ecological literacy of the average American is unknown, it is widely believed that it is not advanced enough to facilitate the development of effective solutions to our current environmental problems (Jordan et al., 2008).

There is national support for improving individual ecological literacy levels among K-12 students (NGSS Lead States, 2013) and at the undergraduate level (AAAS, 2011). Accordingly, it is important for biology educators to implement strategies designed to enhance the ecological literacy of their students. Although results from this study did not indicate combining direct experience with urban greenspaces and mobile technology led to an increase in ecological knowledge, qualitative results indicated a perceived increase in knowledge of trees and an

increased appreciation of trees and nature. Notably, the participants cited their perceived increase in ecological knowledge as the primary reason for the perceived change in their perceptions about trees and nature.

Because most people live in urban areas (UNDESA, 2014), it appears sensible to teach them about nature using green spaces in the urban areas where they live. The ecosystems in these urban areas provide instructors with opportunities to educate students about biodiversity, conservation, and ecological processes (Dearborn & Kark, 2010). For biology educators, the qualitative results suggest providing opportunities for students to engage in ecological learning activities in these urban environments may impact their perceptions about trees and nature. Additionally, the arboretum curriculum provided students with an opportunity to engage in purposefully directed use of the mobile technology that has become an integral part of their lives.

Future Areas of Research

Although studies evaluating the ability of urban green space to increase ecological literacy have been conducted (e.g., Shwartz et al., 2012; Shwartz et al., 2014), they were not widespread in the literature (Lin et al., 2014; Standish, Hobbs, & Miller, 2013). Similarly, studies exploring the combined use of outdoor environmental education and mobile technologies (e.g., Liu et al., 2009; Ruchter et al., 2010; Zimmerman & Land, 2014) were also not prevalent in the literature. This mixed-methods study has added to these areas of inquiry, with convergence found between both quantitative and qualitative components of the study. Notably, changes in participant perceptions regarding trees and nature that emerged from qualitative analysis were not measured by the quantitative component of the study.

Potential limitations involving quantitative sampling and instrumentation may be partly responsible for this dichotomy, indicating the need for more research. Based on experience gained during this study, important changes to the study design to address these potential limitations include an increased quantitative sample size and the use different instruments to measure ecological knowledge and environmental attitudes and beliefs. An increased quantitative sample may be obtained by conducting a further study during the fall or spring semesters when class sections are considerably larger than during the summer. While it may be possible to locate more appropriate instruments to measure the ecological knowledge and environmental attitudes and beliefs of subjects, it would be preferable to develop and validate instruments designed to measure the tree-specific ecological content found in the arboretum curriculum.

Importantly, only one of the studies examined focused specifically on undergraduate education students (Uzunboylu et al., 2009). Most of the related studies examined K-12 subjects (e.g., Chen et al., 2014; Hougham, 2015; Liu et al., 2009; Ruchter et al., 2010; Wagner, 2008) or subjects in informal learnings settings (e.g., Land et al., 2015; Zimmerman & Land, 2014; Zimmerman et al., 2015). The relative scarcity of related studies emphasizes the importance of using undergraduate students as subjects for a future study combining the use of urban ecosystems and mobile technology.

Finally, more research examining the impacts of urban ecosystems on ecological literacy in informal educational settings may be warranted. Urban green spaces provide opportunities for people in urban environments to interact with intact local natural and semi-natural areas, which

has been shown to increase individual levels of ecological literacy (Cooper, 2008; Lindemann-Matthies, 2005; Parker, 2009; Pilgrim et al., 2008).

In a nationwide study by Schipperijn et al. (2010), Danish researchers revealed that 43% of residents surveyed visited an urban green space every day and an astonishing 91.5% visited green space at least once a week. Additionally, urban green spaces were found to be more inclusive than non-urban green areas and have more ethnically diverse visitors (Peters, Elands, & Buijs, 2010). Thus, using urban green spaces in informal educational settings may present educators an opportunity to enhance the ecological knowledge of a large and diverse segment of the population outside of traditional educational environments.

Chapter Summary

Basic knowledge of our natural surroundings is diminishing (Atran et al., 2004). However, increasing individual ecological literacy levels may help citizens make informed choices about the environmental challenges confronting society (Hsu, 2004; UNESCO, 1980). The purpose of the study was to explore the impacts of an arboretum curriculum incorporating mobile technology and an urban greenspace on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate biology students and pre-service K-8 teachers.

Using a convergent parallel mixed-methods design (Creswell & Plano Clark, 2011), both quantitative and qualitative data were collected at the same time, analyzed separately, and later merged to create an enhanced understanding of the impact of the curriculum on the environmental attitudes and beliefs of the participants. Quantitative results revealed a significant

difference between pre- and post-survey scores for ecological knowledge, with no significant differences between the groups, and no significant interaction effects. This indicated that any difference between the pre- and post-survey scores could not be attributed to the arboretum curriculum.

Additionally, no significant differences were found between the pre- and post-survey scores for environmental attitudes and beliefs and environmental behaviors. Also, no significant group differences or interaction effects were found for these variables. This indicated that the arboretum curriculum had no discernable effect on either variable. These results stand in contrast to results reported widely in the literature regarding the impact of similar interventions on the variables examined. It is possible that the limited scope of the interventions implemented in this study may explain this discrepancy. Additionally, potential limitations in the study involving sampling, multiple instructors, and instrumentation may have affected the results of the study.

In contrast to the quantitative component, the qualitative analysis focused on the perceived environmental attitudes and beliefs of the undergraduate biology students and pre-service K-8 teachers. Following thematic analysis of the qualitative data, four themes emerged: (1) *Engagement*; (2) *Disengagement*; (3) *Connecting with the curriculum*; and (4) *Nature is important*. The theme *connecting with the curriculum* was found to consist of two subthemes: (1) *Prior experiences* and (2) *Participant perceptions.* In addition, the theme *nature is important* consisted of two subthemes: (1) *Human-centered* and (2) *Intrinsic value*. Of the four emergent

themes, the themes *connecting with the curriculum* and *nature is important* most directly addressed the research question.

Analysis of the qualitative data indicated that experiences with the arboretum curriculum did not influence the environmental attitudes and beliefs of the undergraduate students. The perceived environmental attitudes and beliefs of the participants relating to the importance of nature remained consistent throughout the study. For example, participants that initially maintained nature was important for human centered reasons held that perception at the end of the study. Similarly, the participant that maintained nature was important for intrinsic reasons continued to express that perception in his post-interview. Notably, qualitative data from the emergent theme *connecting with the curriculum* suggested experiences with the arboretum curriculum led participants to perceive an increase in their knowledge about trees and helped them develop an appreciation for trees and nature.

As part of the convergent parallel design of the study, the quantitative and qualitative results were compared to support an enhanced understanding of the impact of the arboretum curriculum on the perceived environmental attitudes and beliefs of the participants. The analysis of the merged results assessed the differences and similarities between the two data sets within the overarching dimension of environmental attitudes and beliefs. Results from the qualitative component indicated the participants' perceived environmental attitudes and beliefs related to the importance of nature remained consistent throughout the study, aligning with quantitative results indicating no statistically significant difference between the pre- and post-survey scores for environmental attitudes and beliefs. However, qualitative data supporting the theme *connecting*

with the curriculum suggested experiences with the arboretum curriculum led participants to believe they increased their knowledge about trees and helped them develop an appreciation for trees and nature.

Although individual ecological literacy levels are declining (Atran et al., 2004), there is national support for improving individual ecological literacy levels among K-12 and undergraduate students (AAAS, 2011; NGSS Lead States, 2013). Qualitative results from this study suggested experiences with the arboretum curriculum led participants to perceive an increase in their knowledge about trees and helped them develop an appreciation for trees and nature. This supported the assertion by Dearborn and Kark (2010) that urban ecosystems may provide educators with opportunities to enhance the ecological knowledge of students. Coupled with the fact that most of the human population is now urban (UNDESA, 2014), it may be useful to teach them about nature using green spaces in the urban areas where they live.

Importantly, this mixed-methods study has added to what is known about the effects of combining the use of urban green spaces and mobile technology to enhance ecological literacy, with convergence found between both quantitative and qualitative components of the study. Notably, changes in participant perceptions regarding trees and nature that emerged from qualitative analysis were not measured by the quantitative component of the study.

Potential limitations involving sampling, instrumentation, multiple instructors, and the limited skill level of the researcher may explain this difference. Future studies that address these potential limitations may include a larger quantitative sample size, more specialized survey instruments, and a single instructor for treatment and comparison groups.

In addition, research involving undergraduate students in this area of inquiry was restricted to one study (Uzunboylu et al., 2009). Combined with the minimal amount of related studies, this highlights the need for further exploration of the impacts of using urban ecosystems and mobile technology to enhance the ecological literacy of undergraduate students.

As a final point, urban green spaces have been found to be used extensively by an ethnically diverse group of city residents (Peters et al., 2010; Schipperijn et al., 2010). Consequently, they represent an opportunity for biology educators to develop the ecological knowledge of a substantial portion of urban residents removed from traditional learning environments.

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APPENDICES

APPENDIX A

IRB Protocol Approval Notice

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Monday, June 06, 2016

Investigator(s): Patrick E. Phoebus (Student PI), Michael Rutledge (FA) and Kim Saddler (FA)
Investigator(s') Email(s): *pep2j@mtmail.mtsu.edu; michael.rutledge@mtsu.edu; kim.saddler@mtsu.edu*
Department: Biology/CBAS

Study Title: ***Ecological literacy, urban green space, and mobile technology: Exploring the impacts of an arboretum curriculum designed for undergraduate biology courses***
Protocol ID: **16-2292**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior* A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year from the date of this notification
Date of expiration	**6/6/2017**
Sample Size	75 (SEVENTY FIVE)
Participant Pool	**MTSU students enrolled in biology courses**

Exceptions	Collection of full name, voice recordings and handwriting samples permitted till a unique identifier has been assigned	
Restrictions	**Identifiable information must be destroyed once the data were transcribed**	
Comments	NONE	
Amendments	**Date**	**Post-approval Amendments** NONE

This protocol can be continued for up to THREE years (**6/6/2019**) by obtaining a continuation approval prior to **6/6/2017**. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	5/6/2017	INCOMPLETE
Second year report	5/6/2018	INCOMPLETE

Final report	5/6/2019	INCOMPLETE

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage

must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University
Email: irb_information@mtsu.edu (for questions)
irb_submissions@mtsu.edu (for documents)

APPENDIX B

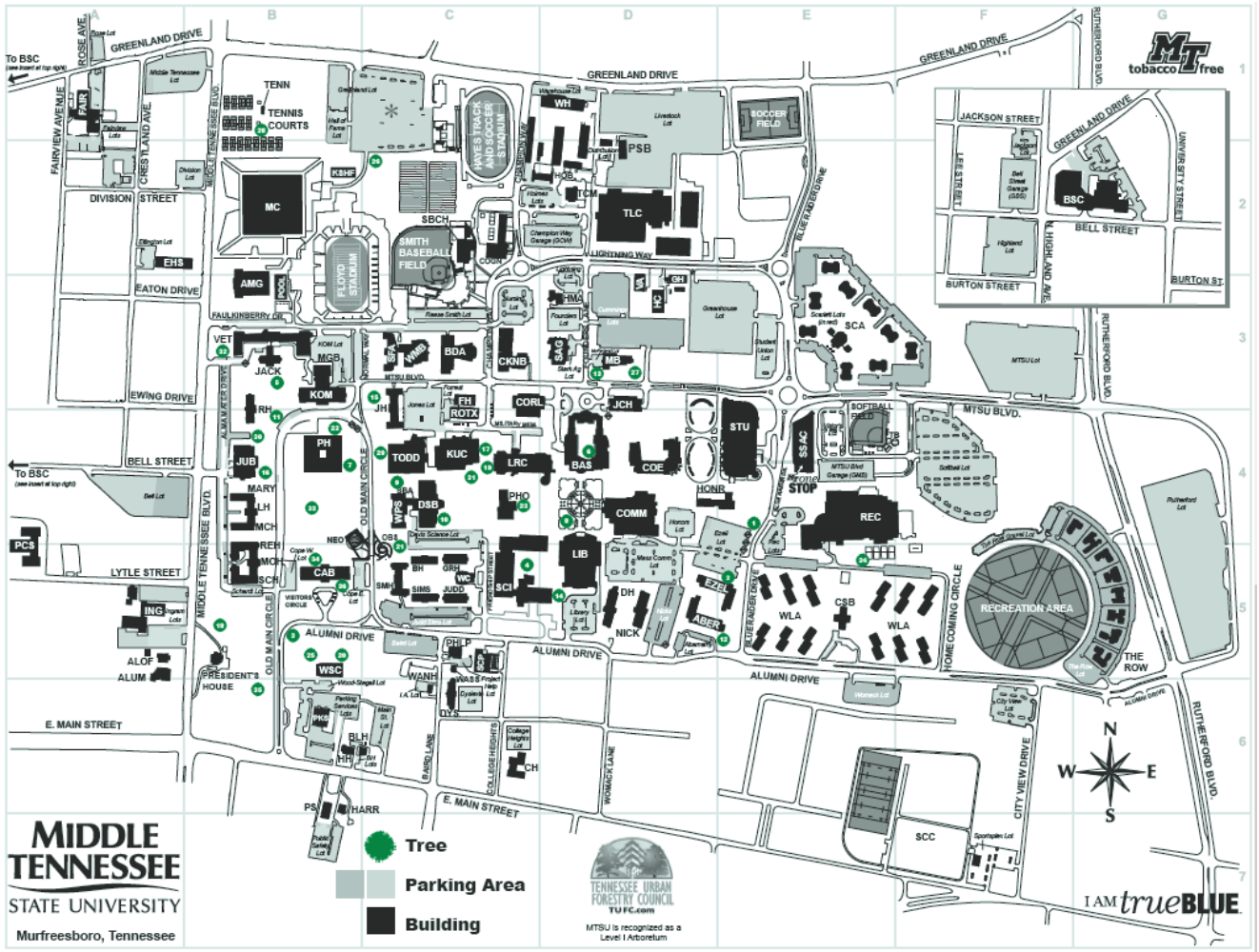
MTSU Arboretum Tree Tour Links and Map

http://bioimages.vanderbilt.edu/mtsu.htm

Start the MTSU Arboretum Tour 1 

Start the MTSU Arboretum Tour 2 

Start the MTSU Arboretum Tour 3 



Number	Common Name	Grid Location
1	Sugar Maple	E4
2	Flowering Dogwood	E5
3	White Ash	B5
4	Pin Oak	C5
5	Southern Magnolia	B3
7	Ginkgo	B4
8	Willow Oak	D4
9	American Holly	C4

Number	Common Name	Grid Location
10	Sweet Bay Magnolia	C4
11	Basswood	B4
12	American Elm	E5
13	Red Maple	D3
14	American Sycamore	D5
15	Northern Catalpa	C3
16	Shagbark Hickory	B4
17	Downy Serviceberry	C4
18	Eastern White Pine	B5

Number	Common Name	Grid Location
19	Bur Oak	C4
20	Sugarberry	B5
21	American Beech	C5
22	White Oak	B4
23	Kentucky Coffeetree	C4
24	American Sweetgum	E5
25	Common Sassafras	B5
26	September Elm	C2
27	Black Gum	D3

Number	Common Name	Grid Location
28	Swamp Chestnut Oak	B1
30	Common Persimmon	B4
31	Eastern Redbud	C4
32	Black Cherry	B3
33	Black Walnut	B4
34	Eastern Red Cedar	B5
35	Tulip Poplar	B6
36	Green Ash	B5

APPENDIX C

Demographic Survey

The purpose of this survey is to gather background information of the students participating in the study. This information will be used to describe the group of students participating in the study. Individual student data will not be shared. Please indicate your responses to the following questions.

1. What year were you born?

_____

__ I do not wish to respond.

2.What is your race?

___White/Caucasian

___African American

___Hispanic

___Asian

___Native American

___Pacific Islander

___Other

___I do not wish to respond.

3. What is your gender?

___Female

___Male

___I do not wish to respond

4. What is the highest level of education your parents or guardians have completed?

___Less than high school

___High school / GED

___Some college

___2-year college degree

___4-year college degree

___Master's degree

___Doctoral degree

___Professional degree (JD, MD)

___I do not wish to respond.

5. Did you grow up in a rural area or an urban area?

___Rural

___Urban

___Not Sure

___I do not wish to respond.

6. In what College is your major or program of study?

___Basic and Applied Sciences

___Business

___Education

___Liberal Arts

___Mass Communication

___Behavioral and Health Sciences

___Other

___I do not wish to respond.

APPENDIX D

Ecological Knowledge Questions (adapted from Morrone et al., 2001)

The purpose of this survey is to determine the ecological knowledge of students participating in the study. Individual student data will not be shared.

Directions: Please read each question and indicate your response by circling the letter of your answer.

1. Flooding on a river renews and replenishes the river environment.
   a) True
   b) False

2. People around Tennessee cities are moving into wooded areas to build homes, clearing away all the trees to plant a lawn. What type of care will be needed to maintain these lawns?
   a) no special care
   b) regular mowing to keep trees from growing in the lawn
   c) a lawn will not do well no matter what care you give it

3. Landowners sometimes build dams on streams to create ponds. What is the impact of a dam on a stream?

a) no major impact

b) changes the stream in the pond area

c) changes the entire stream

4. Wetland areas have been drained in Tennessee for decades. New efforts are in place to restore wetlands to their natural state. Filling those drained areas again with water:

   a) restores a wetland to its natural state right away

   b) begins a restoration process that will take years

   c) will not be effective, because once destroyed a wetland cannot be restored.

5. At the present rate of use the world's supply of coal, oil and natural gas will:

   a) last forever

   b) be used up eventually

   c) renew itself

6. The primary source of energy on earth is the sun.

   a) True

   b) False

7. For a person to get the most food energy out of 100 pounds of vegetables and grain the person should:

a) eat the vegetables and grain

b) feed the vegetables and grain to an animal and eat the meat

c) feed the vegetables and grain to a cow to produce milk, feed the milk to an animal and eat the meat

8. To protect an area from flooding, walls are constructed along the river banks. As a result, downstream flooding will:

   a) increase

   b) decrease

   c) stay the same

9. The total space being used to produce food to feed Tennesseans is adequate even if the population of Tennessee increases.

   a) True

   b) False

10. There is a limit to how many people the world can support.

    a) True

    b) False

11. As the population in an area increases, the potential for pollution:

a) increases

b) decreases

c) stays the same

12. Rangers observe deer eating all the small plants in a park. To maintain a healthy deer population in the park, the rangers should:

a) decrease the number of deer in the park

b) bring in extra food for the deer

c) no action is necessary

13. A farmer plants corn one year, soybeans the next year and follows with wheat. This is called crop rotation. The need for pesticides on a farm using crop rotation will:

a) increase

b) decrease

c) stay the same

14. Mary plants tomato plants in the same garden spot every year. Bob also plants tomatoes, but plants them in a different part of the yard each year. With everything else being the same, who will harvest the most tomatoes?

a) Mary, who plants in the same spot

b) Bob, who plants in different spots

c) they harvest the same amount of tomatoes

15. Today chickens in the US are raised in large buildings containing thousands of birds. Under those conditions, in the mid-1980s poultry flu killed millions of chickens in the US, eliminating entire flocks. Today's farming practices will prevent this from happening again.
    a) True
    b) False

16. People living in a rural area grow only potatoes year after year with great success. To join in their success, each year more people in the area start growing only potatoes. As more potatoes are planted in the area, the risk of a disease or an insect damaging the potato crop will:
    a) increase
    b) decrease
    c) stay the same

17. Each summer your neighborhood is sprayed with the same insecticide to control mosquitoes. After a few years of spraying the same product what do you think will happen? The mosquitoes will likely:
    a) disappear

b) become resistant to the spray

c) remain the same year after year

18. When colonizing a new area, plants, animals and even people compete for resources to live, grow and reproduce. What usually happens when an area gets crowded?

    a) they compete against each other

    b) they cooperate with each other

    c) they usually die out

19. Tremendous numbers of flies are bothering people who live near some of Tennessee's large chicken farms. Special fly-eating beetles were imported to Tennessee and placed in the chicken houses to solve the problem. While the beetles do a good job controlling the flies in the chicken house, once the beetles get out they become so numerous that they get into nearby homes and become a pest. Why are the beetles a pest?

    a) they are a pest everywhere in the world

    b) they are only a pest in a new area with no natural controls on their growth

    c) they are not as big a pest as people think

20. As Tennessee and other states were settled, people encountered wolves that hunted deer and other wild animals, but the wolves threatened their families and livestock. As the wolves were eliminated to protect people, did the number of deer:

a) increase

b) decrease

c) stay the same

21. Saving an endangered plant species is just as important as saving an endangered animal species.

a) True

b) False

22. The most effective way to save an endangered animal is to:

a) stop hunting or eating the animal

b) provide it with an adequate food supply

c) establish a large enough reserve area for it to live and reproduce

23. The land area needed to protect an endangered animal should be:

a) large enough to support one family of animals

b) large enough to support several animal families

c) the same size reserve for all endangered animals

24. Some tropical birds that live in Central and South America migrate to and live in Tennessee for part of the year. Which of the following is the greatest threat to these birds? Loss of habitat in:

    a) Central & South America

    b) Tennessee

    c) both places

25. PCBs, a toxic chemical, can be found in very low levels in lakes and streams. The PCBs are taken up by small shellfish that live in the water. Which will have the highest level of PCBs?

    a) the shellfish

    b) fish that eat the shellfish

    c) birds that eat the fish

26. Phosphorus fertilizer is applied to lawns, gardens and crop fields to encourage plant growth. What happens when phosphorus washes into a lake?

    a) the phosphorus kills the fish

    b) phosphorus will increase the growth of algae

    c) not much will happen

27. Nitrogen fertilizer is applied to gardens and crop fields to increase food production. The nitrogen is taken up into the food. When a person eats food for energy and growth they produce sewage wastes. The human sewage contains some of the nitrogen that was first applied as fertilizer.
    a) True
    b) False

28. The amount of water on earth is:
    a) increasing
    b) decreasing
    c) staying the same

29. The warming of the Pacific Ocean influences the weather
    a) just in California
    b) just in the US
    c) throughout North and South America

30. Burning fuel in Tennessee to heat homes, operate cars, and produce electricity contributes to air pollution:
    a) only in the city where it's burned
    b) throughout Tennessee and neighboring states

c) burning fuel does not contribute to air pollution

31. A major volcanic eruption in the Philippines creates dust and reduces sunlight only near the volcano during the eruption.

a) True

b) False

32. Fruit, vegetables, milk and meat produced in rural Tennessee are sold and trucked to grocery stores to feed people in many large cities. The people who live in these cities produce sewage sludge. Spreading sewage sludge from big cities on Tennessee farm land:

a) pollutes the soil

b) is a form of recycling

c) gets rid of the sludge

APPENDIX E

New Ecological Paradigm Scale

Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you strongly agree (SA), mildly agree (MA), are unsure (U), mildly disagree (MD), or strongly disagree (SD) by circling the corresponding number.	Strongly Agree	Mildly Agree	Unsure	Mildly Disagree	Strongly Disagree
We are approaching the limit of the number of people the earth can support.	1	2	3	4	5
Humans have the right to modify the natural environment to suit their needs.	1	2	3	4	5
When humans interfere with nature it often produces disastrous consequences.	1	2	3	4	5
Human ingenuity will ensure that we do not make the earth unlivable.	1	2	3	4	5
Humans are severely abusing the environment.	1	2	3	4	5
The earth has plenty of natural resources if we just learn how to develop them.	1	2	3	4	5
Plants and animals have as much right as humans to exist.	1	2	3	4	5
The balance of nature is strong enough to cope with the impacts of modern industrial nations.	1	2	3	4	5
Despite our special abilities humans are still subject to the laws of nature.	1	2	3	4	5
The so-called “ecological crisis” facing humankind has been greatly exaggerated.	1	2	3	4	5

The earth is like a spaceship with very limited room and resources.	1	2	3	4	5
Humans were meant to rule over the rest of nature.	1	2	3	4	5
	Strongly Agree	Mildly Agree	Unsure	Mildly Disagree	Strongly Disagree
The balance of nature is very delicate and easily upset.	1	2	3	4	5
Humans will eventually learn enough about how nature works to be able to control it.	1	2	3	4	5
If things continue on their present course, we will soon experience a major ecological catastrophe.	1	2	3	4	5

APPENDIX F

Environmental Behavior Survey

In this survey you are asked to assess your own behavior regarding the environment. Please indicate the frequency that you participate in the behaviors listed below.	Never	Rarely	Sometimes	Often	Nearly Always	Always
I use both sides of the paper for notes, lists, and messages.	1	2	3	4	5	6
I recycle materials such as paper, glass, plastic, and metal.	1	2	3	4	5	6
I take steps to conserve energy like turning off lights and appliances when I am not using them.	1	2	3	4	5	6
I take steps to reduce water use such as taking shorter showers.	1	2	3	4	5	6
I pick up litter in public places.	1	2	3	4	5	6
I use my own cup instead of paper or plastic disposable cups.	1	2	3	4	5	6
I avoid purchasing products that are over-packaged.	1	2	3	4	5	6
I use reusable food storage containers instead of purchasing aluminum foil or plastic wrap.	1	2	3	4	5	6
I avoid purchasing products directly associated with damage to wildlife or their habitats.	1	2	3	4	5	6
I switch from one brand to another due to concern for the environment.	1	2	3	4	5	6

I purchase products from manufacturers who are concerned about the environment.	1	2	3	4	5	6
I pay membership fees or donate money to conservation/environmental groups.	1	2	3	4	5	6
Please indicate the frequency that you participate in the behaviors listed below.	Never	Rarely	Sometimes	Often	Nearly Always	Always
I encourage others to recycle or reuse materials, conserve water, and energy.	1	2	3	4	5	6
I encourage others to support pro-environmental candidates.	1	2	3	4	5	6
I actively tell others about the importance of protecting the environment.	1	2	3	4	5	6
I encourage others to engage in improving the quality of the environment surrounding them (e.g., planting trees or flowers, participating in community cleanup projects).	1	2	3	4	5	6
I encourage others to report someone who violates environmental laws (e.g. illegal hunting/ fishing, illegal cultivating, polluting water and air, dumping) to the proper authorities.	1	2	3	4	5	6
I publicly display "pro" environmental messages.	1	2	3	4	5	6
I vote for pro-environment candidates.	1	2	3	4	5	6
I write or call elected officials to persuade them to support environmental protection.	1	2	3	4	5	6
I publicly endorse a candidate and/or give time to support a candidate due to his/her positions on environmental issues.	1	2	3	4	5	6

I participate in political rallies over concern for an environmental problem.	1	2	3	4	5	6
I vote against a candidate based on his/her stand on an environmental issue.	1	2	3	4	5	6
I participate in political meetings or hearings concerning environmental policies or plans (e.g., city council meeting, political party meeting).	1	2	3	4	5	6
Please indicate the frequency that you participate in the behaviors listed below.	Never	Rarely	Sometimes	Often	Nearly Always	Always
I report pollution violations to authorities (e.g., polluting water/air, noise, dumping).	1	2	3	4	5	6
I report violations of fishing, hunting laws to authorities.	1	2	3	4	5	6
I report illegal collection in national parks or preserves to authorities (e.g., plants, butterflies).	1	2	3	4	5	6
I report illegal logging and cultivating to authorities.	1	2	3	4	5	6
I persuade others not to break environmental laws or inform others they are breaking such laws.	1	2	3	4	5	6
I help authorities patrol areas (e.g., rivers, national parks) for the purpose of enforcing environmental laws.	1	2	3	4	5	6

APPENDIX G

Ecological Literacy Questions for Tree Tours

Ecological Literacy Questions for Tree Tour 1

1. The American elm was once a popular and widely planted shade and ornamental tree, because of its beauty and tolerance for difficult urban growing conditions. Since the introduction of the non-native fungus Dutch elm disease spread by a bark beetle, many American Elms have died and are they are now no longer widely planted. Introducing exotic species like the bark beetle can have unintended consequences. Why might exotic species pose a threat to native species, when in their own environments they are not problematic?

2. American sycamore is a major pioneer species in the floodplains of rivers and streams. The water disperses their seeds and deposits them on muddy flat areas after spring floods, which are very conducive to seed germination. Humans have modified many rivers and streams by placing dams across them to control flooding and store water. As a result, many riparian areas have been permanently changed, natural flood cycles have been altered, less water flows downstream, and aquatic seed distribution is often compromised. How might these changes affect the population of American Sycamores?

3. Although the Kentucky coffeetree is not endangered, its numbers are declining rapidly due to over harvesting. It is found in the wild in small clusters that form from root sprouting that produces new trees. Their seeds and pulp are toxic and are not dispersed by wildlife such as deer or raccoons. Would the best way to prevent the species from extinction be to set aside areas for the trees to reproduce or to prohibit harvesting of the trees? Explain your answer. Is saving the Kentucky coffeetree as important as saving an animal like the Eastern box turtle (also declining)? Why or why not?

Ecological Literacy Questions for Tree Tour 2

1. Planting shade trees like the southern magnolia can help substantially reduce energy consumption and lower electricity bills. Why might this be important in terms of safeguarding non-renewable energy resources such as coal and other fossil fuels?

2. Besides offering shade, how can planting more urban trees affect the environment? How might they help reduce pollution from distant coal plants?

3. Southern forests are highly complex associations of plant species and plant communities that have developed due to varying topography and environments. Most of these forests have been highly modified and fragmented due to human actions. In response to a growing demand for timber, much of this forest has been replanted with pine tree plantations consisting of even-aged monocultures (one species, all trees the same age). Besides the obvious differences in the number of tree species, how might the diversity of other organisms differ between a tree plantation and a regular forest? What environmental risks might be associated with large scale tree plantations? What might happen to the tree plantation if the species of tree planted became susceptible to a quickly spreading pathogen like an introduced insect or disease?

Ecological Literacy Questions for Tree Tour 3

1. The MTSU campus is part of the Stones River watershed. Rain that falls on campus travels overland in small stormwater channels and drainages carrying soil, leaves, litter, motor oil, and fertilizer. Some of these substances are toxic. How might these substances affect organisms living downstream in the Stones River? How can campus trees help reduce pollutants in stormwater?

2. As the city of Murfreesboro continues to grow, many forested areas will be lost to urban and suburban development. Will the potential for stormwater pollution increase, decrease, or stay the same? Explain your answer.

APPENDIX H

MTSU Arboretum Tree Tour K-W-L Activities

MTSU Arboretum Tree Tour 1 K-W-L

Directions: Reflect on your knowledge of the tree species below and record what you already know and what you would like to learn during today's activity. After the tree tour, reflect on and record what you have learned about the tree species we observed. Then, respond to the writing prompt below.

Trees we will see today:

Pin Oak	Flowering Dogwood	Kentucky Coffeetree
American Sycamore	Sugar Maple	
American Elm	Willow Oak	

What I <u>K</u>now:
What I <u>W</u>onder (or <u>w</u>ant to know):
What I have <u>L</u>earned:

Writing Prompt: Explain why you agree or disagree with this statement: the balance of nature is very delicate and easily upset.

MTSU Arboretum Tree Tour 2 K-W-L

Directions: Reflect on your knowledge of the tree species below and record what you already know and what you would like to learn during today's activity. After the tree tour, reflect on and record what you have learned about the tree species we observed. Then, respond to the writing prompt below.

Trees we will see today:

Eastern Redbud	White Oak	Common Persimmon
Bur Oak	Southern Magnolia	Ginkgo
Downy Serviceberry	Basswood	
Northern Catalpa	Shagbark Hickory	

What I <u>K</u>now:
What I <u>W</u>onder (or <u>w</u>ant to know):
What I have <u>L</u>earned:

Writing prompt: Suppose you overheard a classmate saying that changing our environment to meet the needs of people really isn't that big a deal. Do you agree with this classmate? Why or why not?

MTSU Arboretum Tree Tour 3 K-W-L

Directions: Reflect on your knowledge of the tree species below and record what you already know and what you would like to learn during today's activity. After the tree tour, reflect on and record what you have learned about the tree species we observed. Then, respond to the writing prompt below.

Trees we will see today:

Black Walnut
Eastern Red Cedar
Green Ash
White Ash
Eastern White Pine
Tulip Poplar
Common Sassafras
Sugarberry

What I Know:
What I Wonder (or want to know):
What I have Learned:

Writing prompt: While watching a news story about a recent storm that destroyed homes and caused significant damage, the reporter states that despite our special abilities humans are still subject to the laws of nature. Do you agree with this statement? Why or why not?

APPENDIX I

Pre- Activities Interview Protocol

Introductory Statement

I am going to ask you some questions related to one of the surveys you completed the other day. Please answer truthfully. Everything you say is strictly confidential. Audio of our conversation will be recorded, so that I may transcribe it later.

Semi-Structured Interview Questions

1. Explain why you agree or disagree with this statement: Human impacts on the environment have had negative consequences.
2. I noticed on the survey that you strongly agreed/disagreed with statement #___. Share a little bit about your reasoning behind this.
3. Please explain why you think it is important to preserve natural environments, if at all.
4. I noticed on the survey that you strongly agreed/disagreed with statement #___. Share a little bit about your reasoning behind this.
5. Is there anything else you would like to share with me related to our discussion today?

APPENDIX J

Post- Activities Interview Protocol

Introductory Statement

I am going to ask you some questions about your experiences during the class that relate to the tree activities you participated in. Please answer truthfully. Everything you say is strictly confidential. Audio of our conversation will be recorded, so that I may transcribe it later.

Semi-Structured Interview Questions

1. Did you enjoy the tree activities, if at all?
2. When I talked with a few weeks ago, you said “XXX”. Talk a little bit about how your thoughts related to this have changed or remained the same. What aspects of the tree tours, if any, might have influenced your ideas?
3. Why do you think it is important for people to learn about nature, if at all?
4. When I talked with a few weeks ago, you also said “XXX”. Talk a little bit about how your thoughts related to this have changed or remained the same. What aspects of the tree tours, if any, might have influenced your ideas?
5. Is there anything else you would like to share with me about your experiences involving the tree activities?

APPENDIX K

Observation Protocol

Tree Tour ___

Instructor:	Date:	Person observed:	Class:

Positive Statements/Actions	Negative Statements/Actions	Personal Connections
□ taking tree pictures □ taking notes □ asking questions □ discussing trees □ collecting tree artifacts □ using QR codes/websites □ other _____ _____	□ expressing disinterest □ complaining about activity □ other _____ _____	□ childhood experience □ student activity on campus □ historical connection □ ethnobotanical □ other _____ _____

Off Task:	□ off topic conversation □ phone use not related to activities (voice call, texting, email, social media, etc.) □ other _____ _____

APPENDIX L

Consent Form

Principal Investigator: Patrick E. Phoebus

Study Title: Ecological Literacy, Urban Green Space, and Mobile Technology: Exploring the Impacts of an Arboretum Curriculum Designed for Undergraduate Biology Courses

Institution: Middle Tennessee State University

Name of participant: _____

Age:_____

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**

   You are being asked to participate in a research study because you are enrolled in one of several undergraduate biology courses chosen to explore the impact of formal instruction using urban green spaces and mobile technology on the ecological knowledge, environmental attitudes and beliefs, and environmental behaviors of undergraduate students.

2. **Description of procedures to be followed and approximate duration of the study:**

   A new interactive online guide for the campus arboretum designed to enhance ecological literacy will be employed, in conjunction with a series of ecological activities designed to promote student exploration of the trees in the campus arboretum. Students enrolled in one of three undergraduate biology classes will participate in ecological and environmental activities designed to enhance ecological literacy. Data will be collected using surveys, writing prompts, interviews with participants, and observations. Student demographics data will be collected. Data collection for the study will take place during the semester and will be completed during the last week of class.

3. **Expected costs:**

   There will be no additional costs to the participants related to the study.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**

   The discomforts, inconveniences, and/or risks associated with this study are minimal. The ecological and environmental activities that comprise the arboretum curriculum employed in the study involve minimal physical activity and do not require students to participate in any activities that would be considered dangerous or risky. The activities consist of responding to surveys, reflecting on and responding to writing prompts, accompanying the instructor and classmates on short campus tree tours, and participating in semi-structured interviews.

5. **Compensation in case of study-related injury:**

   MTSU will not provide compensation in the case of study related injury.

6. **Anticipated benefits from this study:**

a) The potential benefits to science and humankind that may result from this study include enhancing the ecological literacy of citizens to help them make informed choices about the environmental issues facing society and the distribution of species data to the broader scientific community through the use of biodiversity aggregators such as the Encyclopedia of Life and the Global Biodiversity Information Facility.

b) Students will not get increased grades by agreeing to participate (even in the control group).

7. **Alternative treatments available:**

There are no alternative treatments available. However, participation in the study is voluntary. Although the arboretum curriculum activities are part of the class curriculum, no data will be collected from students who do not consent to participate.

8. **Compensation for participation:**

   Students will not get extra credit for participating in the study. There is no compensation for participation in this study.

9. **Circumstances under which the Principal Investigator may withdraw you from study participation:**

   Students who consent to participate in the study and later withdraw from the class will be withdrawn from the study.

10. **What happens if you choose to withdraw from study participation:**

    Participating in the study is voluntary, and withdrawing from the study at any time during the project will involve no penalty or loss of benefits to which you might otherwise be entitled.

11. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact Patrick E. Phoebus at 615-788-9062 or my Faculty Advisors**,** Dr. Michael Rutledge at 615-898-5951 or Dr. Kim Sadler at 615-904-8283.

12. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

13. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**

I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

_____ _____

Date Signature of patient/volunteer

Consent obtained by:

Date	Signature
	Printed Name and Title