CONNECTEDNESS WITH NATURE AND IMPLICATIONS FOR SCIENCE LEARNING

by

Scott Andrew Carter

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2022

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

ABSTRACT

Connectedness with nature is described as the subjective sense of relatedness one has with the natural environment. Individuals with high self-perceived connectedness with nature see themselves as part of, not separate from the natural world. Classroom observations and anecdotal evidence contributed to the hypothesis that connectedness with nature may impact science learning. The purpose of this study was to investigate connectedness with nature and its implications for science education. Identifying factors that influence connectedness with nature and investigating teaching strategies to enhance this characteristic in students were secondary goals of the study. The Nature Relatedness Scale (NRS) was employed in measuring the human-nature relationship through the course of the investigation. Other data sources included student interview, student achievement records, and student work samples. Satellite imagery was utilized in conducting greenspace assessments at sites surrounding each subject's home. A negative correlation between nature relatedness scores and science achievement was discovered, indicating a lack of association between the two variables in the sample (N=61). A relationship between tree canopy in the at-home environment and nature relatedness scores emerged, suggesting exposure to high-quality greenspace during childhood and adolescence may influence one's perception of nature. Finally, place-based learning strategies were shown to be successful in enhancing connectedness with nature in the study group of 12th grade environmental science students. Evidence compiled from the sample suggests students with high nature relatedness scores may differ from peers with lower values, particularly in what they bring to and take from science instruction.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

In Aldo Leopold's seminal work, *A Sand County Almanac*, the naturalist states, "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect" (Leopold, 1949, p. viii). A wide range of interdisciplinary research on the human-nature relationship has transpired since Leopold first expressed his philosophy of the *Land Ethic*. This new body of research suggests humans continue to diverge from their origins in the natural world. The growing disconnect between man and nature since Leopold's era is evident in changing cultural values and lifestyles. The shift toward a more human-centered reality can even be tracked though steadily decreasing references to nature in books, films, and songs since the 1950's (Kesebir & Kesebir, 2017).

Exposure to nature provides many benefits while a lack thereof has opposite effects. A negative association exists between urbanization and mortality, heart rate, and violence while positive associations with attention, mood, and physical activity have been documented (Kondo et al., 2021). In 2019, Swedish researchers established an association between green space during childhood and a lower risk of psychiatric disorders from adolescence into adulthood (Engemann et al., 2019). There are also cognitive benefits to spending time outdoors. Regular walks in nature have been shown to improve directed-attention abilities in test subjects (Berman, 2014). In a 2020 study, strong relationships between feelings of connectedness to nature and self-

reported happiness were observed in school children (Barrera-Hernandez et al., 2020). Perhaps this is justification for the recent popularity of forest kindergartens. Forest kindergartens are learning programs that include several hours of daily free play in the woods, regardless of weather conditions. Research suggests forest kindergartens build confidence and reduce symptoms of ADHD in school children, among other benefits (Walker, 2016).

This action research explores the unique and complex connections between nature and learning. The investigation was conducted at Martin Luther King High School, which is situated in downtown Nashville, Tennessee. MLK is one of twenty-five high schools in the Metropolitan Nashville Public Schools (MNPS) system. MNPS is a large, urban, and exceptionally diverse school district serving 88,000 students. Most students served by the district (75%) qualify as economically disadvantaged. The schools are not demographically representative of the county they serve. Nashville consists of 61.7% white residents, but only 28% of the district's student body is represented by that group (Public School Review, 2022).

I have taught honors and Advanced Placement (AP) Environmental Science to 12th graders at Martin Luther King for the past five years. The historic campus (built 1936) was the sole secondary school option for African-American students prior to desegregation in 1957 and was the site of several of the first interracial athletic competitions in Tennessee during the 1960's. The current student body consists of 1,189 students. MLK's student population is ethnically diverse, with students representing over 70 different countries of origin. At least 44 languages are spoken at home. The following ethnicities are represented in the population: Black or African American (39%), Caucasian (42%), Asian/Pacific Islander (9.92%), Hispanic (8.67%). Female students make up 49.84% of the population and males make up 50.16%. MLK

requires a science core of Biology (9th grade), Chemistry (10th grade), and Physics (11th grade) and offers several honors-level and advanced placement options to seniors, including Honors Environmental Science and AP Environmental Science. Metro Nashville Public Schools has no comprehensive environmental education curriculum and provides no local environmental resources to its teachers (Public School Review, 2022).

Focus Statement/Question

In this scientific study I will investigate connectedness with nature and its implications for learning in the science classroom. The purpose of the study is to examine the issue of detachment from the natural world. Many years of classroom observation have contributed to my hypothesis that a lack of connectedness to a larger ecological whole is prevalent among high school students and that this phenomenon influences science learning. Observations over several decades and in a variety of teaching environments led to my concern this disconnect is more pronounced in urban teens, negatively impacting their success in and enjoyment of science. A preliminary survey investigating connectedness with nature in high school students was conducted in my classroom in February 2021. Results from the survey supported both hypotheses mentioned above. Interviews conducted in the same year with science educators, including public high school teachers and naturalists from the Metropolitan Nashville park system produced similar findings.

Does a lack of self-perceived connectedness with nature affect learning in science? Prior to this investigation I had collected only anecdotal evidence that it does. A statement from a student in my AP Environmental Science class during the 2017-2018 school year sums up the problem I address in this Action Research. Upon informing his class that we were going on a

field trip to study a stream, the student responded, “I don’t do nature.” I’ve observed that when students come to this or similar conclusions, performance and engagement in science is negatively impacted.

Connectedness may even correlate with the value and meaning students draw from their science classes. This outcome has been consistent through my teaching of middle school science, Physical Science, Biology, Chemistry, Ecology, AP Biology and AP Environmental Science. Teaching environmental concepts to students who don’t see themselves connected to the wider context of the natural world can be challenging. Relatable examples are few, misconceptions abound, and cases of biophobia are common. I would like to determine what contributes to this mindset and investigate treatments that might reverse it.

One primary question will be addressed in this action research, How does self-perceived connectedness with nature influence science learning in high school students?

My sub-questions include the following:

1. What variables influence connectedness with nature in high school students?
2. Can connectedness with nature be enhanced through participation in a series of place-based learning modules?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

This research project, like the environmental science courses I teach, is about connections. The research questions investigate human-nature relationships. But to truly understand man's perception of nature, an appropriate context must be established. In the discussion below, I will explore an interdisciplinary network of connections between psychology, sociology, environmental science, ecology, physiology, wellness, education, and geography. I will attempt to build an appropriate background around my research questions while establishing a path through this web of scientific disciplines. I shall highlight the value of new and relevant research in the field of environmental psychology while supporting the rationale for my research plan and course of action.

Describing and Measuring Connectedness to Nature

The origins of nature connectedness can be traced back to the concept of biophilia, first described by social psychologist Erich Fromm as "the passionate love of life and all that is alive". This conception was later employed by ecologist E.O. Wilson in his biophilia hypothesis. Wilson stated that the tendency of humans to focus on and affiliate with nature has a genetic basis and that humans have an innate need to connect with nature based on evolution (Kellert & Wilson, 2013). The innate connection with nature likely came out of necessity for our human ancestors. Many of modern man's efforts to preserve connections to nature are evident in esthetic

preferences, outdoor interests, and pro-environmental behaviors. Writings by key environmental thinkers like Aldo Leopold, Arne Naess, and Rachel Carson, each of whom described and celebrated our connection to the natural world, remain popular among readers worldwide. Taoist, Buddhist, and Native American philosophies, with their aim of achieving harmony and balance with nature, continue to thrive in the face of environmental degradation around the world.

Despite the importance of connectedness for early humans, a detachment from nature is evidenced by cultural shifts, lifestyle changes, and the built environment. Disconnect from nature is a feature inherent to Western civilization and may be difficult to reverse (Lankenau, 2016). Robert Pyle referred to the "extinction of experience" in his 1978 description of the loss of daily experiences in nature caused by urbanization (Soga & Gaston, 2016). With this detachment has come serious and unexpected consequences. Physiological issues like an increased susceptibility to allergic diseases, asthma, and dermatitis have been associated with modernization, a Westernized diet, and decreased microbial exposure (Renz & Skevaki, 2020). A wide range of physiological and psychological impacts are associated with noise pollution in urban areas including hearing loss, hypertension, anxiety, concentration loss, and low performance levels (Tabraiz et al., 2015).

Many researchers have attempted to describe and quantify the human-nature relationship in recent decades, especially in the realm of psychological research. Research products worth noting are the psychological constructs known as environmental identity, connectedness with nature, and nature relatedness. The three concepts are similar in meaning and implications for education. Conservation psychologist Susan Clayton defines environmental identity as "a sense of connection to some part of the nonhuman natural environment, based on history, or emotional

attachment" And additionally, environmental identity "affects the ways in which we perceive and act toward the world; a belief that the environment is important to us and an important part of who we are" (Clayton, 2003, p. 1). In Susan Clayton's Environmental Identity Scale (EIS), subjects are asked to indicate the extent to which they identify with eleven statements concerning their relationship with nature. Along with an operational definition of environmental identity and this unique measurement tool, Clayton discusses the implications of environmental identity in her 2003 paper. Among these implications are how environmental identity influences human behavior.

The interpretation and application of the concept of environmental identity in the classroom was examined in "Bringing Environmental Identity Research into the Classroom Context: Examining the Theoretical Foundations Influencing its Current Use in the Literature" (Simms, 2019). The article published in *Studies in Science Education* discovered an association between environmental identity and the modern-day conservation movement and its encouragement of environmentally responsible behaviors. The author also discusses the connection between environmental identity and science identity, which has been linked to inequalities in science education and an under-representation of minorities in science and technology. Simms emphasizes that environmental identity differs from other identity theories which emerge in a social context. Though social context also plays a role in the emergence of environmental identity, the physical context (the natural world) seems to be of more importance. The relevance of physical context provides support for my proposed hypothesis that lack of connectedness to nature is pronounced in teens with little exposure to nature. And the connection between environmental identity and future behaviors is relevant to my research and the teenagers

I teach. Though positive changes in future environmental attitudes and behaviors are not measured in this research, these are intentionally pursued and desired outcomes of the instruction I provide. Positive changes in future environmental attitudes and behaviors are ancillary goals of this study.

The Connectedness to Nature Scale (CNS) offers an instrument for measuring an individual's feelings of connectedness to the natural world (Mayor & Frantz, 2004). Through a series of five studies, the authors found this 14-item assessment to be valid and reliable in describing connectedness. The tool was also found to be effective in predicting responsible environmental behavior and subjective well-being. The strengths of the CNS seem to be in its ability to describe the subject's self-concept and in predicting future behaviors.

Nature relatedness is defined as one's connection with natural environment, incorporating a person's experiences, knowledge, beliefs, and attitudes(Nisbet & Zelenski, 2013). Strong nature-relatedness is associated with greater happiness and ecologically sustainable behavior. The 21-item Nature Relatedness Scale was developed and tested in a study involving 831 participants. Experience sampling was utilized in comparing nature relatedness scores with frequency of time spent in nature. A strong correlation existed between these two variables (Nisbet et al., 2008). This suggests the scale is useful in triangulating with reported past experiences in nature. As childhood experience in nature was a data point examined in student interviews, the Nature Relatedness Scale was deemed the most appropriate tool for measuring human-nature relationships in my investigation.

Interaction with nature has been a commonly utilized independent variable in psychological, educational, and environmental psychology research over the past several

decades. Nature exposure and connectedness are related concepts, but it is important to distinguish between them here. Whereas contact with nature is an objective and easily quantifiable variable, connectedness with nature is subjective and generally considered a qualitative feature. Mayer and Frantz (2004) define connectedness with nature as a trait of individuals that enables them to feel emotionally connected to the natural world. Interactions with nature are not necessarily a prerequisite for connectedness but the two are closely associated. Positive experiences in nature are often cited as sources of self-reported feelings of connectedness (Wells & Lekies, 2018). Though interactions with nature will play an important role in this Action Research, the following discussion will focus primarily on connectedness with nature. Connectedness with nature is often, but not always, dependent upon exposure to and experiences in the natural world.

Environmental Education and Connectedness

The author Richard Louv, best known for his book *Last Child in the Woods*, coined the term nature-deficit disorder to describe the human costs of alienation from nature (Louv, 2008). According to Louv (2008), an accelerated human disconnect from the natural world is in progress and is the result of urbanization, the introduction of agriculture, indoor living, social change, and technological change. Recent psychological research examining the role of environmental identity in science education substantiates Mr. Louv's claim.

The 2017 article "Children's Environmental Identity and the Elementary Science Classroom" from *The Journal of Environmental Education* describes how fifth grade children view their relationship with nature and how that view coincides with their experiences in elementary school science instruction. Student interviews and surveys revealed that young

children can recognize and describe their own environmental identity (Tugurian & Carrier, 2016). Qualitative data collected suggest teachers often fail to acknowledge student environmental identity during instruction, thereby missing an opportunity to fully engage their pupils in lessons. In this example, teachers play a role in promoting disconnect by making science content more abstract and less accessible.

The author of this study hypothesizes that teachers can enhance the classroom experience by becoming more familiar with the environmental identities of their students. The investigation discovered a variety of environmental identities among the study group. Interestingly, most students, regardless of environmental identity, expressed a disinterest in science class. The author recommends strategies for engaging all students, of all environmental identity types. These include teaching in outdoor settings, providing opportunities for students to discuss feelings about nature, and allowing student choice in learning tasks. Allowing students to choose research topics and/or assessment methods allows them to connect science content with their own environmental identity. These recommendations directly inspired the design of the treatment used in my investigation. The Muir Map is a qualitative instrument I created to assess connectedness with nature in this study (Appendix A). The activity tasks students with demonstrating interdisciplinary and personal connections with the content being taught. An Earth Day Reflection was also employed mid-way through my investigation to encourage students to write about their relationship with nature. Both qualitative assessments supplemented the Nature Relatedness Scale surveys in monitoring student progress through the study.

"Fostering Connectedness to Nature in Higher Education" was published in the journal *Environmental Education Research* in 2018. The author states "nature is the living community,

of which we are members, the complex web of life to which we are connected" (Lankenau, 2018, p. 2). Connectedness to nature is again established as a predictor of pro-environmental behaviors. Cited studies demonstrate how connections to the natural world are constructed during childhood. Findings suggest connectedness to nature is a trait initiated in early childhood (Ernst & Theimer, 2011). If true, the potential for enhancing connectedness in teens deprived of early childhood experiences in nature could be limited.

The study employs pre and post-test administrations of the Nature Relatedness Scale (Nisbet et al., 2008) in an introductory college-level ecology course with the objective of assessing and increasing connectedness through participation in the course. These quantitative measures were supported and triangulated with student interviews. Participants' connectedness values were increased through participation in the course. Identification with nature and nature-focused worldview were two parameters significantly impacted by exposure to the independent variable. The study's relevance to my Action Research is evident, as my subjects were just one year younger than those participating in this college-level study.

The study "Evaluating the Effects of Environmental Education Programming on Connectedness to Nature" (Ernst & Theimer, 2011) published in *Environmental Education Research*, involved a partnership between the University of Minnesota, Duluth and the US Fish and Wildlife Service. The objective was to determine the effects of seven different environmental education programs on connectedness with nature, as measured by two distinct instruments. Despite a low efficacy of the environmental education programs employed in the study, the methods used in assessing the 385 participants were novel. The 22-item Children's Connection to Nature Index was utilized alongside a second instrument, the Nature

Connectedness Inventory. Employing both metrics eliminated single measure bias. As for the low effectiveness of the treatments used, the author cites a previous study that states the following: "because attitudes change slowly, it is not reasonable to expect a significant difference in pre- and post-measures of connectedness to nature" and "the two most significant predictors of affinity toward nature are frequency of time in nature and frequency of childhood time in nature" (Kals et al., 1999).

The evidence presented above highlights the complex and interdependent relationship between environmental education and self-perceived connectedness with nature. The research also calls attention to the role of environmental identity in science education. And interestingly, the findings shed light on new opportunities for science educators to engage and serve their students.

Effects of Greenspace

Greenspace data, including high resolution satellite images have become valuable tools in studying physical health, psychological health, wellness, and even learning. In a six-year study published in 2014, researchers investigated the association between the greenness surrounding Massachusetts elementary schools and academic achievement. The percentage of third grade students scoring Above Proficient in standardized math and English assessments was measured in 905 public schools. Surrounding greenness was measured using satellite images converted to Normalized Difference Vegetation Index values. Researchers discovered a significant positive relationship between greenness and test scores, particularly in spring months (Wu et al., 2014). This study provides insight into thinking about greenspace in several ways; as a potential tool for predicting academic achievement, as a potential treatment for improving academic achievement,

and as a potential treatment for enhancing connectedness with nature. The findings relate directly to the primary question in my study and influenced my decision to include student achievement as a data source in my investigation.

Normalized Difference Vegetation Index values can be used to study psychology as well. A ten-year study involving 900,000 people in Sweden revealed an association between residential greenspace and reduced risk of psychiatric disorders in adulthood (Engemann et al., 2019). Satellite images were used to calculate the Normalized Difference Vegetation Index surrounding Swedish residences. These findings raised an important question for my investigation: Could exposure to greenspace indirectly enhance learning through supporting social and emotional health? According to the Collaborative for Academic, Social, and Emotional Learning, the Social and Emotional Learning (SEL) model is a holistic approach to classroom learning which emphasizes the development of a variety of social skills requisite to learning. Managing emotions, communicating feelings, and making responsible decisions are just a few of these SEL skills. This study suggests that a treatment including exposure to greenspace could potentially support SEL objectives and enhance connectedness with nature, thereby supporting learning.

Connectedness and Future Behaviors

In the article "Nature and the Life Course: Pathways from Childhood Nature Experiences to Adult Environmentalism," the authors investigate the impacts of childhood experiences in nature on environmental attitudes and behaviors in adulthood. In the study, two thousand participants, age 18-90 were randomly selected to participate in a survey which included questions about childhood interactions with nature, participation in environmental education

(e.g., camps, scouts, church), and experiences in nature with other people. The dependent variable (adult environmentalism) was divided into two characters: environmental attitudes and environmental behaviors. Results indicated that experiences in wild nature including activities such as hiking, camping, and hunting were positively associated with environmental attitudes and behaviors (Wells, 2018). Experiences in domesticated nature like harvesting flowers, planting seeds, or caring for indoor plants were positively associated with environmental attitudes but not environmental behaviors. A key finding of the study was that children who participated in wild nature activities before the age of eleven were most likely to develop environmental behaviors as adults. This investigation aligns with my second research question: What factors influence connectedness with nature in high school students?

This study had implications for the items utilized in the interview portion of my own research. In developing an intentional and purposeful interview, the structure, sequence, and wording of the questions was critical. It was necessary to structure an interview that differentiated between wild and domestic experiences, early childhood and later childhood experiences, individual versus group experiences, and environmental attitudes and environmental behaviors. The connection established between experiences and future behaviors is also relevant to my study as the outcomes of the action research are to not only serve the teacher and students, but society through students' behaviors later in life. One challenge is posed by the results of this 2018 study, however. It implies that changing environmental attitudes and behaviors in 17 and 18-year-old subjects could be a difficult task.

Place-Based Learning

Author and educator David Sobel (2004) from the Center for Place-Based Education at Antioch University defines place-based education as the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science, and other concepts across the curriculum. The process, according to Sobel, helps students develop stronger ties to their community and engages local citizens and community organizations in the educational process. Gregory Allen Smith from Lewis and Clark College suggests using local phenomena as a source for curriculum development offers a way to bridge the gap many students experience between school and the rest of their lives (Smith, 2002).

"Place-based STEM education is consistent with the Next Generation Science Standards (NGSS) that focus on the applications of science and engineering practices students learn to solve problems in real world contexts" (Glasson, 2017, p.1). Place-based STEM education also connects students to local community resources and fosters engagement opportunities for entrepreneurial and workforce ready skills development through experiential education (Glasson, 2017). The natural alignment between the tenets of place-based education, the Next Generation Science Standards, and the environmental science courses I teach made place-based strategies a logical choice of treatment in my Action Research.

It was mentioned earlier in this paper that teachers can contribute to a disconnect with nature by making science content more abstract. Could place-based learning opportunities promote connectedness with nature in teenagers? Sense of place is a construct well characterized in environmental psychology. Place attachment and place meaning can even be quantified psychometrically (Semken & Freeman, 2008). The term topophilia, coined by the geographer Yi-

Fu Tuan is defined as “the affective bond with one’s environment-a person’s mental, emotional, and cognitive ties to a place” (Heimer, 2005, p.117). Place-based science teaching focuses on local and regional environments and synthesizes different ways of knowing them, leveraging the senses of place of students and teachers (Semken & Freeman, 2008). In this way, sense of place can be utilized as a tool for engagement. All place-based lessons developed for this project were introduced using images with which my students were familiar (e.g., limestone road cuts on a Nashville interstate). Sense of place can also be quantified, making it a valid and measurable learning outcome.

Best practices in place-based learning focus on the use of a variety of teaching methods to increase awareness of the local environment and tapping the “funds of knowledge” (Glasson, 2017, p.1) available in every community. Teachers enhance sense of place by connecting students to local experts and community resources. Problem-based learning, inquiry-based learning, laboratories, and hands-on activities can be effectively incorporated into place-based units. Reciprocal teaching, where teacher and student roles are reversed, is also a valuable place-based strategy as students share experiences and become experts on current and local issues. In employing place-based instruction, teachers will find that existing lessons can often be modified to incorporate local themes.

Efficacy of Place-Based Learning Techniques

Scientific literature provides little research on the effectiveness of place-based learning techniques. But the research that is available portrays place-based learning as a viable strategy for enhancing connectedness with nature and improving achievement. Lieberman and Hoody (1998) found that using the local environment significantly improved achievement in all subject

areas when compared to decontextualized teaching methods. The study involved forty environment-based school programs across the United States. A 2004 study investigated the effectiveness of environment-based educational strategies in improving motivation, achievement, and critical thinking skills (Ernst & Monroe, 2004). Over 400 high school students from eleven Florida schools participated. The researchers found environment-based teaching significantly improved achievement, motivation, and critical thinking. And a 2008 study published in *Science Education* described an investigation where an Arizona-based freshman geology curriculum was compared to a decontextualized freshman geology curriculum. Researchers were interested in determining the impacts of the contextualized course on sense of place, place attachment, and place meaning. Results showed significant gains in sense of place, place attachment, and place meaning. Results also suggest students experienced an enhanced richness of meaning when Arizona was used as a setting for the course (Semken & Freeman, 2008). A similar treatment was utilized in my Action Research, with several foci including Tennessee Rocks, Tennessee Trees, Tennessee Water, and Tennessee Air.

Summary

My research plan was informed and inspired by the many and varied experiments mentioned in this literature review. The successful deployment of several types of validated assessments in previous experiments (Nature Relatedness Scale, Connectedness to Nature Scale, Environmental Identity Scale) provide evidence the human-nature relationship can be measured accurately and with confidence. Three closely related and well-developed psychological constructs (Nature Relatedness, Connectedness with Nature, Environmental Identity) provide different lenses through which one can examine connectedness with nature while providing

options for zeroing in on specific attitudes, behaviors, and experiences if necessary. And a dearth of research foci on teenagers, urban residents, and implications for science learning presented a unique opportunity to shape new and interesting questions while contributing to and expanding the current knowledge base.

An array of scientific methods has been employed in connectedness with nature experimentation. Survey and interview are utilized in my research as they are commonly in the related studies mentioned above. But a new trend has emerged in the field. The use of greenspace as independent variable, indicator, and even treatment has produced novel results in recent years. These findings inspired me to incorporate greenspace data into my action research. Greenspace data is applied in addressing the second research question: What factors influence connectedness with nature in high school students?

Finally, ideas for treatment in my study were borne out of two studies highlighted in the literature review, both of which compared environment-based or place-based learning with decontextualized learning. Place-based programming was associated with gains in achievement, motivation, critical thinking in the first of these studies (Ernst & Monroe, 2004) and an increased sense of place and richness of contextual meaning among subjects in the second (Semken & Freeman, 2008). Both investigations involved students of similar age to my own. The findings suggest I might observe comparable results by designing similar treatments.

CHAPTER THREE

METHODOLOGY

After a thorough application process, permission was granted from Metro Nashville Public Schools Department of Research, Assessment, and Evaluation to conduct this Action Research (Appendix B). The research plan also received an exemption from Montana State University's Institutional Review Board in November 2021 (Appendix C). A triangulation matrix for the primary research question and two sub questions is presented in Table 1.

Table 1. Data Triangulation Matrix.

Questions	Data Source 1	Data Source 2	Data Source 3
Research Question: How does self-perceived connectedness with nature affect science learning in high school students?	Nature Relatedness Scale (NRS)	Student Interview	Student Achievement Data
Sub-question 1: What variables influence connectedness with nature in high school students?	Nature Relatedness Scale (NRS)	Student Interview	Residence/Greenspace Data
Sub-question 2: Can connectedness with nature be enhanced through participation in a series of place-based learning modules?	Nature Relatedness Scale (NRS)	Place-based module performance	Muir Map

In January 2022, a study group of sixty-one 12th grade students was recruited from the Honors and Advanced Placement Environmental Science courses at Martin Luther King High

School. All 134 students enrolled in my classes were given the opportunity to participate in the study. Two $25 gift cards were offered as incentive for participation and winners were drawn at the conclusion of the investigation. All subjects provided a consent form signed by parent and student (Appendix D).

Baseline data from an initial administration of the Nature Relatedness Scale was collected first. Each subject then participated in a one-to-one interview. The student interview consisted of nine previously prepared questions and took place in the days following the first administration of the Nature Relatedness Scale (Appendix E).

Access to science achievement and residence data of the sixty-one test subjects was requested through the Metro Nashville Department of Research, Assessment, and Evaluation and was granted in November 2021. Semester averages from Biology (9th Grade), Chemistry (10th Grade), and Physics (11th Grade) were provided by the district to address the primary research question: How does self-perceived connectedness to nature affect science learning in high school students?

Student residence data was also provided by the school district for all subjects. Student addresses were necessary to examine how greenspace near students' homes may or may not influence connectedness with nature. Greenspace data for each residence was then calculated using i-Tree Canopy, a web-based tool that estimates tree and other land cover classes (e.g., grass, buildings, roads). Greenspace values were triangulated with the initial administration of the Nature Relatedness Scale and the student interview to address the sub-question, What variables influence connectedness to nature in high school students? Treatment began in early

February 2022 to address the sub-question, Can connectedness to nature be enhanced through a series of place-based learning modules?

Demographics

Sixty-one individuals (25 females, 36 males) were recruited for this investigation. The following ethnicities were represented: 19.4% Asian, 27.4% Black or African American, 8.1% Hispanic/Latino, 45.2% White. The demographics of the study group were not representative of the Martin Luther King (MLK) student body or Metro Nashville Public Schools. As MLK is an academic magnet school, it draws students to the downtown campus from many areas of Nashville. Most study participants occupied single family homes, residing at an average distance of 11.9 miles from the city center.

All participants were 12th graders at the time of the investigation. Each had completed biology, chemistry, and physics and were enrolled in either Honors (17 students) or AP Environmental Science (44 students). The science and engineering focus of the MLK curriculum provides students a wide range of science/STEM elective options between 10th and 12th grade. Twenty-two of the study participants had elected to enroll in more than the four required science courses during their high school career.

This senior class was significantly impacted by the COVID-19 pandemic. Remote learning began in March 2020 (sophomore year/chemistry) and continued until March 2021 (junior year/physics) when students were given the option to return to school. Roughly 50% of students chose to continue remote learning for the remainder of the 2020-2021 school year. The 2021-2022 school year brought COVID-related challenges as well, with frequent quarantines

affecting attendance, instructional planning, and this investigation. Four snow days during the second semester also interrupted instruction and this study.

Treatment

Place-based Education (PBE) can be defined as the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science, and other concepts across the curriculum. The process helps students develop stronger ties to their community and engages local citizens and community organizations in the educational process. Place-based environmental science focuses on local ecosystems and encourages teachers to customize national curricula while leveraging the sense of place students already feel for their community. Research suggests place-based learning strategies can improve achievement, motivation, and critical thinking while enhancing richness of meaning when compared to decontextualized instruction.

The independent variable designated in research question three is a series of place-based learning modules focusing on the state of Tennessee. The module format was designed specifically for this study. Each of the four modules focuses on a central theme: Tennessee Rocks, Tennessee Water, Tennessee Air, and Tennessee Trees. Each of the four place-based modules lasted 2-3 days in length and included six components (Figure 1).

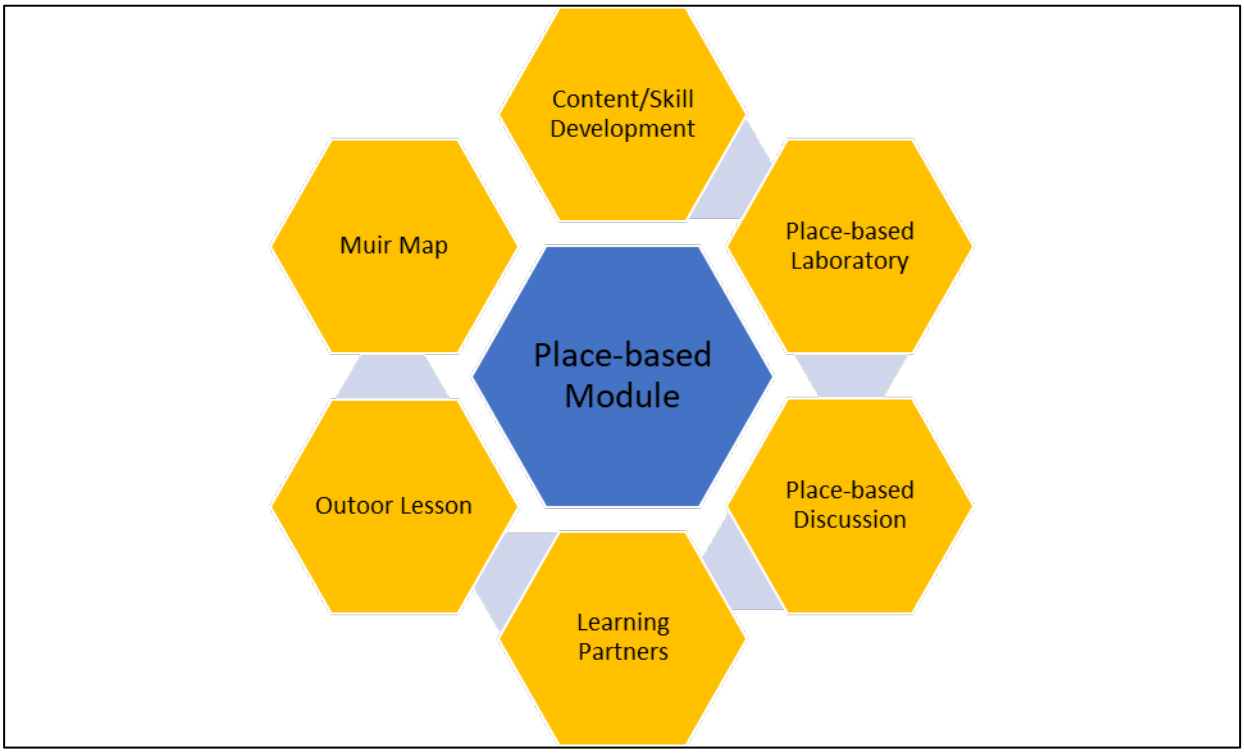


Figure 1. Components of a place-based learning module.

Content and skills for the four modules were sourced from state or AP Environmental Science standards. Each standard was then customized with a local spin. The local environment, local phenomena, and local expertise are implemented in teaching state or College Board standards. Place-based lessons can start with a simple, local point of interest and expand into a vast interdisciplinary web of instruction. One three-day module used in this study focused on freshwater mussels. Tennessee is well recognized for its exceptional mussel biodiversity with over 300 species in the state. The Tennessee Water module begins by engaging students with a mussel observation activity. This simple observation is followed by a series of activities, lectures, labs, and discussions that eventually address 22 learning standards from the AP Environmental Science curriculum. An overview of the four place-based modules is provided. It

is important to note that only three of the modules (Nashville Air, Nashville Rocks, Nashville Water) were assessed as treatments in this study (Table 2).

Table 2. Place-based treatment overview.

	Tennessee Trees	Tennessee Air	Tennessee Rocks	Tennessee Water
Units Addressed	Units 1, 3, 4, 5	Units 6, 7, 8, 9	Units 1, 4, 5, 6,	Units 1, 4, 5, 6, 8, 9
Chapter	Chapters 3, 10	Chapters 12, 15	Chapters 8, 10	Chapters 3, 9, 14
Outdoor Lesson	Tree planting with Nashville Tree Foundation, Hill State Natural Area Hike	Lichens as Indicator Species Biodiversity Comparison Lab	Tennessee Rocks and Soils Field Trip, Warner Park, Nashville	Water Quality Assessment Field Trip, Little Harpeth River, Nashville
Learning Partners	David Arnold, TN Forestry Division Dr. Sharon Jean-Phillipe, Forestry, University TN	Blake McClain, Metro Nashville Air Pollution Control	Vera Roberts, Warner Park, Nashville Rachel Anderson, Warner Park, Nashville	Dr. Hiba Baroud, Environmental Engineering, Vanderbilt University Julie Berbiglia, Metro Nashville Water Services
Place-based Lab	Virtual Succession Lab, Warner Park, Nashville Virtual Field Trip, Ellington Ag. Center	Student Auto Emissions Chemical Assessment	Local Rocks/Soils Chemical Properties Lab	Hay Infusion Culture/Invertebrate and Microorganism Observation Local surface waters microbe observation and assessment
Place-based Discussion	Environmental Equity/North Nashville tree planting project	Elimination of emissions testing in Nashville Nashville landfill expansion	Copper mining in Ducktown, Tennessee Acid Rain in Great Smoky Mountains National Park	August 2021 flood in Waverly, Tennessee Impacts of population growth on water quality in Nashville
Muir Map Focus	Nashville Trees	Air Pollution	Geology	Water

Each of the four place-based modules used in this study included a laboratory component, an online discussion, a visit from a local expert/learning partner, an outdoor lesson (on or off campus), and an interdisciplinary concept map known as a Muir Map. Labs were designed to utilize local student-collected or publicly available data (e.g., Nashville air quality, EPA database). Place-based issue discussions encouraged students to examine the viewpoints of multiple stakeholders and develop opinions of their own (e.g., Nashville landfill expansion).

A learning partner/local expert visited the classroom (in person or via Microsoft Teams meeting) during each module. Learning partners from local universities, government agencies, and nongovernment agencies were invited to answer student-prepared questions (e.g., Dr. Hiba Baroud, Vanderbilt University). Two outdoor lessons took place on the MLK campus and two were coordinated through Warner Park Nature Center in Nashville. The Muir Map served as a qualitative tool for assessing connectedness with nature at the end of each module.

Data Collection and Analysis

Copious amounts of quantitative and qualitative data were generated during this investigation. Quantitative data from the Nature Relatedness Scale, student achievement, and greenspace assessment were balanced by the qualitative student interview and work samples. The five instruments employed in the study are described in detail in this section, but a summary of the data collection and analysis techniques is provided below in Table 3.

Table 3. Summary of data collection and analysis strategies.

Data Source	Protocol
Nature Relatedness Scale (NRS)	• Administer baseline NRS • Administer post-treatment NRS #1-3 • Transfer data to digital files • Triangulate NRS with interview, achievement, greenspace data • Compare baseline NRS to post-treatment NRS
Student Interview	• Conduct interviews with 61 subjects • Thematically code interview data • Mine responses for inter-item correlates (within interview) • Mine responses for inter-item correlates (with NRS) • Mine responses for common vocabulary and themes • Triangulate with NRS, achievement, and greenspace
Student Achievement Data	• Request student achievement data • Visually represent achievement data of study group • Mine interview data for achievement correlates • Triangulate with NRS and greenspace data
Greenspace Data	• Create 5-acre study areas around each residence • Employ i-Tree Canopy to calculate percentages of ground cover classes • Graphically present greenspace data of residences • Mine interview data for greenspace correlates • Triangulate with NRS and achievement data

Nature relatedness is defined as the subjective sense of connection people have with the natural environment. It encompasses beliefs, attitudes, knowledge, and experiences. Strong nature-relatedness is associated with greater happiness and ecologically sustainable behavior. The 21-item Nature Relatedness Scale (NRS) was developed in 2008 by researchers Elizabeth Nisbet and John Zelenski. This validated instrument assesses an individual's level of connectedness with the natural world. NRS items are presented on a Likert scale from 1 (disagree strongly) to 5 (agree strongly). Higher scores indicate stronger connection to nature with eight items being reverse scored. The overall score is calculated as a mean of the 21

responses. Overall nature relatedness can therefore vary between 1 and 5. The NRS is designed to assess three subcategories as well: NR-Self, NR-Perspective, and NR-Experience. These subcategories emerged as valuable data segregation tools during analysis.

The Nature Relatedness Scale was administered four times during this investigation to address the primary research question. The first administration of the survey was used to establish a baseline and subsequent administrations assessed nature relatedness after each phase of treatment. Google forms were used to facilitate analysis of the survey results. Mean, median, mode, and quartiles were calculated and visually represented in box and whisker plots.

Short interviews were conducted with each participant following completion of the baseline NRS (Appendix F). The nine-item inquiry was designed as a qualitative support to the Nature Relatedness Scale and addressed the primary research question and sub-question one. Data provided by the NRS and student interview were mined to establish inter-item correlations between student responses during the analysis phase. The student interview examined the following characteristics in test subjects:

1. *Assessment of Connectedness* - The Nature Relatedness Scale is a valuable quantitative indicator in my study, but it's important to record specific vocabulary and examples subjects use to describe their own connection to nature. Student descriptions of connectedness (or lack thereof) provided a more accurate and meaningful assessment of each subject's relationship with nature.
2. *Connectedness and Life Experiences* – My literature review includes several studies that point to associations between connectedness and positive experiences in nature (Kals, et al. 1999; Nisbet et al. 2008; Wells, 2018). The student interview questions are designed to encourage subjects to share these experiences.
3. *Connectedness and Learning* - A secondary goal of the interview was to determine if connectedness to nature is impacting learning. Though achievement data shed light on academic performance, student-perceived success is also relevant. These responses provided qualitative support for my hypothesis that a lack of connectedness could influence science learning.

4. *If so, how* – In the interview, students relate self-perceived connectedness to their experiences in the science classroom. Questions are designed to establish associations between nature relatedness and performance in and enjoyment of science. Vocabulary and examples provided here contributed to a more nuanced view of the relationship between connectedness and success in the science classroom.

All sixty-one subjects were interviewed in January and February 2022. Questions were written and presented to encourage students to speak openly about the greenspace around their home, their experiences outdoors, their experiences as a science student, and their perceptions of nature. The outdoor experience sampling methodology used in the interview was inspired by a previously mentioned study in Conceptual Framework (Wells & Lekies, 2006). Meetings were set in a relaxed environment and took place at the end of classes and during lunch periods. Duration was not monitored, allowing for follow up questions and space for subjects to expound on ideas when appropriate. The average interview length was eight to nine minutes. Written notes from the interviews were used to conduct a thematic analysis of the data. Experiences mentioned in the interviews were classified as Level 1 (e.g., walking in neighborhood, going to the park, pet care), Level 2 (e.g., gardening, multiple pets, hiking), and Level 3 (e.g., whitewater rafting, camping, visiting a national park). Ages at which specific events occurred were coded along with the physical and social contexts associated with those experiences. Perceived success in science was assigned a numeric value and a student's ability to relate outdoor experiences to classroom learning was coded as a yes or no response. Two items involving a multiple choice/explain task were coded by response chosen. A single page, hand-drawn matrix was created to simplify and summarize responses from the sixty-one participants. Finally, the interview data was mined for common vocabulary usage and thematic trends.

An important quantitative support in addressing the primary research question was student achievement data. Semester averages from Biology (Grade 9), Chemistry (Grade 10), Physics (Grade 11), and Environmental Science (Grade 12) were collected. Inclusion of student achievement data was necessary as performance in prior science courses is directly related to the dependent variable in the primary research question. Numeric ratings from the Nature Relatedness Scale were compared to student achievement data from previous science courses to address the primary research question. Nature relatedness and science achievement were graphically represented on box and whisker plots to show relationships between these two variables.

The web-based tool i-Tree Canopy was used to estimate tree and other land cover classes (ex: grass, buildings, roads) in 5-acre study plots surrounding each subject's residence. Ground cover class estimates are expressed as percentages in web-based reports produced by i-Tree Canopy. An area of five acres was deemed appropriate for this investigation for several reasons. First, it was important to characterize the environment to which each subject was regularly exposed, particularly during early childhood and adolescence. A 5-acre boundary seemed appropriate in achieving this goal. Secondly, it was necessary to choose an area large enough to typify the environment in the surrounding neighborhood. And thirdly, for technical purposes, the 5-acre area provided a highly detailed characterization of each study area. The i-Tree Canopy program randomly lays 500 points onto Google Earth imagery, each of which the user must classify (Figure 2). Processing small areas with many random sampling points yielded strong results. Surveying 500 points on a 5-acre plot allowed me to characterize each plot with great accuracy.

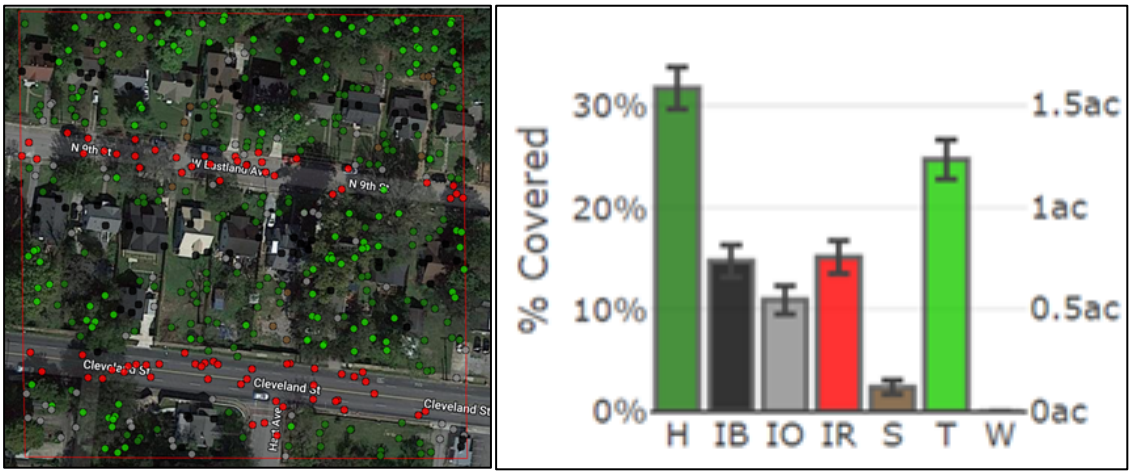


Figure 2. Satellite image of urban neighborhood and corresponding ground cover classes. (H=grass/herbaceous, IB=impermeable building, IO=impermeable other, IR=impermeable road, S=soil/bare ground, T=tree/shrub, W=water).

Five-acre plots were assessed for fifty-five study participants during this portion of the investigation. Subject residence during childhood and adolescence was verified during the interview process. Six individuals were excluded from this phase of the study as the participants moved several times or were not able to verify a previous address. Most subjects reported living at the same residence their entire life. A wide range of landscapes was observed despite all sites being situated within a 17-mile radius of the city center (Figure 3).

Figure 3. Examples of various landscapes observed in this investigation.

A qualitative assessment known as a Muir Map was specifically designed for this investigation. The task is a type of post-assessment cap, assigned immediately after the place-based module and/or a traditional unit test. An example of a completed Muir Map is presented in Figure 4. The assignment was inspired by a John Muir quote I have traditionally discussed with students on the first day of school each year: *"When we try to pick out anything by itself, we find it hitched to everything else in the universe."*

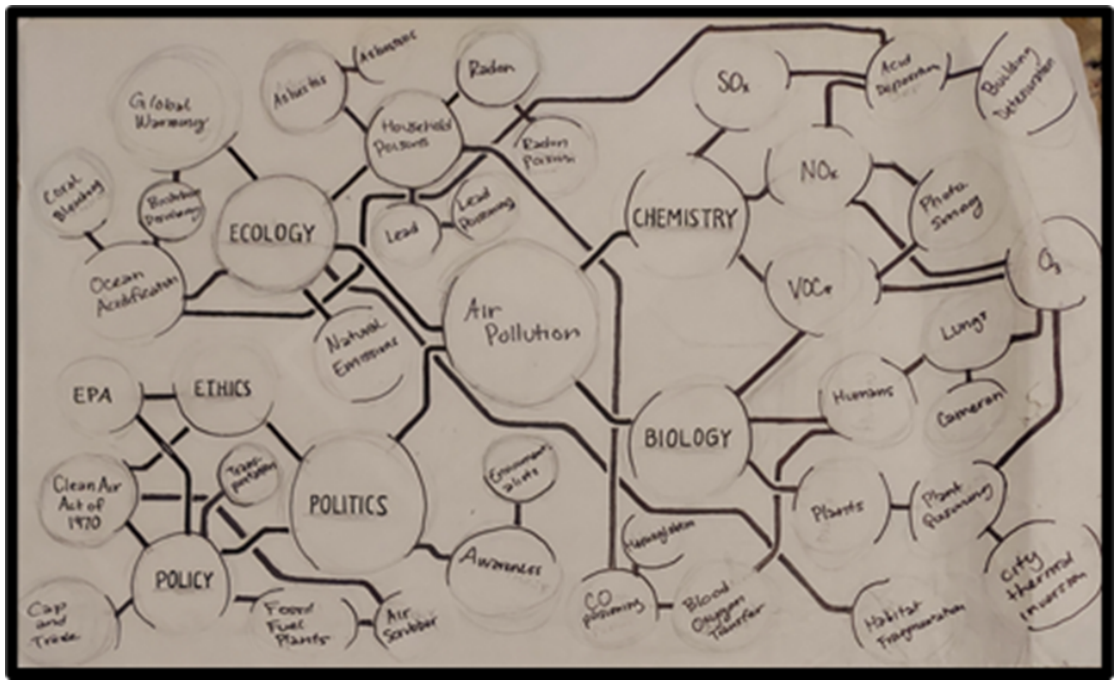


Figure 4. Student work sample, Muir Map.

The Muir Map is a modified concept map that tasks students with building an interdisciplinary web around the theme studied during the place-based module. Students then demonstrate how they are personally connected to this natural and anthropogenic web. There are no correct answers. The Muir Map is a sense-making exercise that encourages students to see

themselves as part of the natural world rather than outside observers. The maps were assessed using a simple rubric and used as qualitative supports during data analysis (Appendix G).

CHAPTER FOUR

DATA ANALYSIS

Results

A mixed methods approach was utilized in addressing three questions in this Action Research. The Nature Relatedness Scale (NRS), student interview, and science achievement data provided valuable information in describing how connectedness with nature may be impacting learning in science (research question one). Nature relatedness scores were compared to student interview responses and greenspace to examine two factors that may influence connectedness with nature (research question two). NRS scores would be used again to quantitatively assess gains in self-perceived connectedness with nature (research question three). In addition, Muir Maps, and informal observations of students during place-based modules provided qualitative supports in addressing the third research question.

The Nature Relatedness Scale was administered to sixty-one 12th grade environmental science students in early January 2022. The results of the survey would serve as a baseline for the remainder of the investigation. Relatedness values vary from 1 to 5 with higher scores indicating a stronger connection to nature. The NRS score range on this initial administration of the NRS was 1.29 to 4.90. The mean score for the sample was 3.49, the median 3.38, and the mode 3.38. Females (n=25) scored higher than males (n=36) with averages of 3.56 and 3.43, respectively. A frequency distribution of the baseline NRS is shown in Figure 5. Twenty-five nonparticipating students also agreed to take the survey and anonymously submit results for

comparison. The mean of the nonparticipants was 3.28 suggesting the recruitment process unintentionally selected for students with higher levels of connectedness with nature.

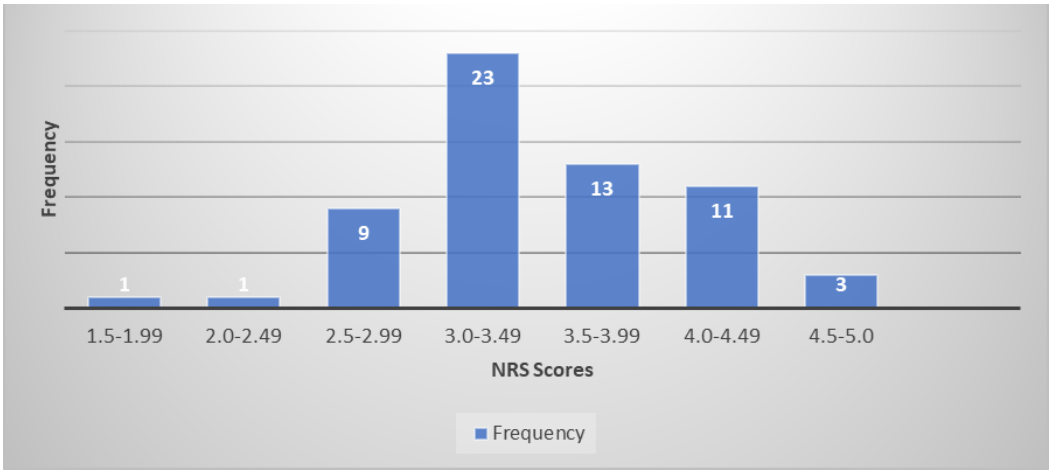


Figure 5. Score distribution of baseline Nature Relatedness Scale, (*N*=61).

Figure 5 shows 38% of students scoring between 3.0 and 3.49 on the baseline administration of the NRS. The distribution is skewed toward higher values with only two subjects scoring below 2.5 on the scale. The standard deviation of the sample was .58, evidence of the scores varying little from the mean. This distribution does align with national data collected in prior administrations of the Nature Relatedness Scale, however. Data collected from 1000 participants yielded average scores between 3.0 and 3.5, with 70% of participants scoring between 2.2 and 4.3 (Nisbet & Zelenski, 2013). The baseline NRS was next compared to academic achievement data. Semester averages from four high school science courses were compiled to produce a high school science composite score. Figure 6 demonstrates an association between these variables. There appears to be a weak negative correlation between nature relatedness and high school science achievement. The top two subsets on the graph exhibit mean scores well below the 3.49 sample average. In fact, the data demonstrates a decline in NRS

scores that intensifies with subsets of high achievers. For example, the average NRS score of the top ten science achievers was 3.23, and continuing to fall to 3.13 and 2.83 with the top five and top three achievers, respectively. Further confirmation of the downward trend in connectedness values in this subset is evidenced by responses to statement twelve on the Nature Relatedness Scale. Item 12 reads: I am not separate from nature, but a part of nature. Interestingly, the top three science achievers responded "disagree a little" to this statement. These findings suggest that connectedness to nature is not a prerequisite for, or associated with science achievement in this sample.

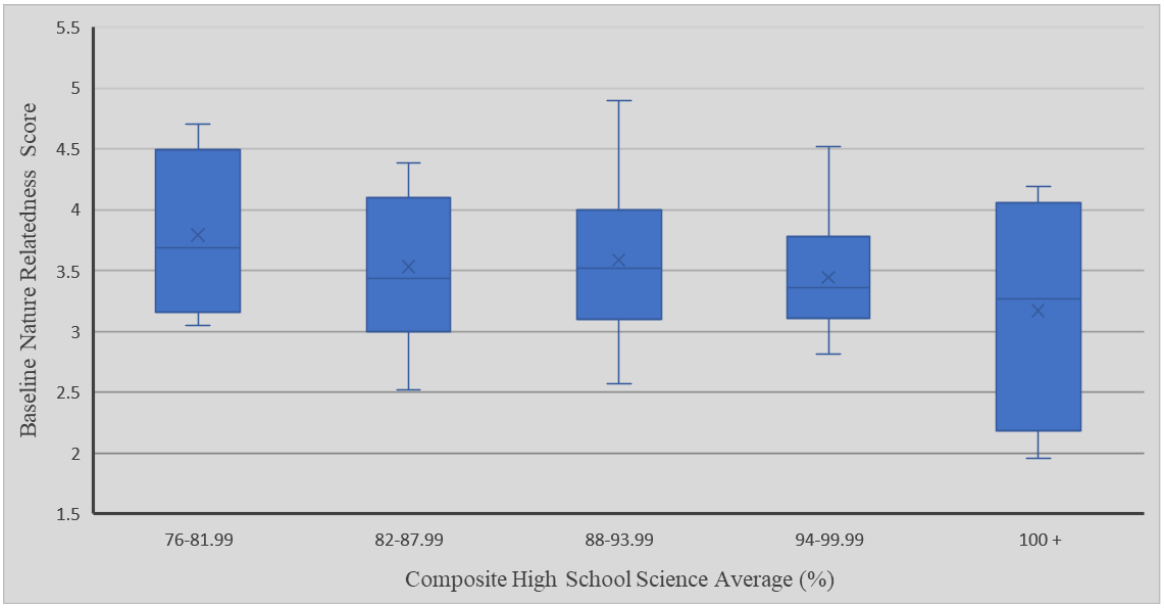


Figure 6. Baseline NRS and composite high school average, (*N*=61).

Qualitative data from student interviews also provided unique insights into student perceptions of, and interactions with nature. The coded interview produced several important data points. About 25% of the study group reported low exposure to nature in their lifetime (Level 1). About 32% reported intermediate exposure and 44% reported high exposure (Level 3).

Exposure to nature is compared with baseline NRS scores in Figure 7. The graphic confirms findings from similar studies where positive experiences in nature serve as a reliable predictor of one's self-perceived connectedness with nature.

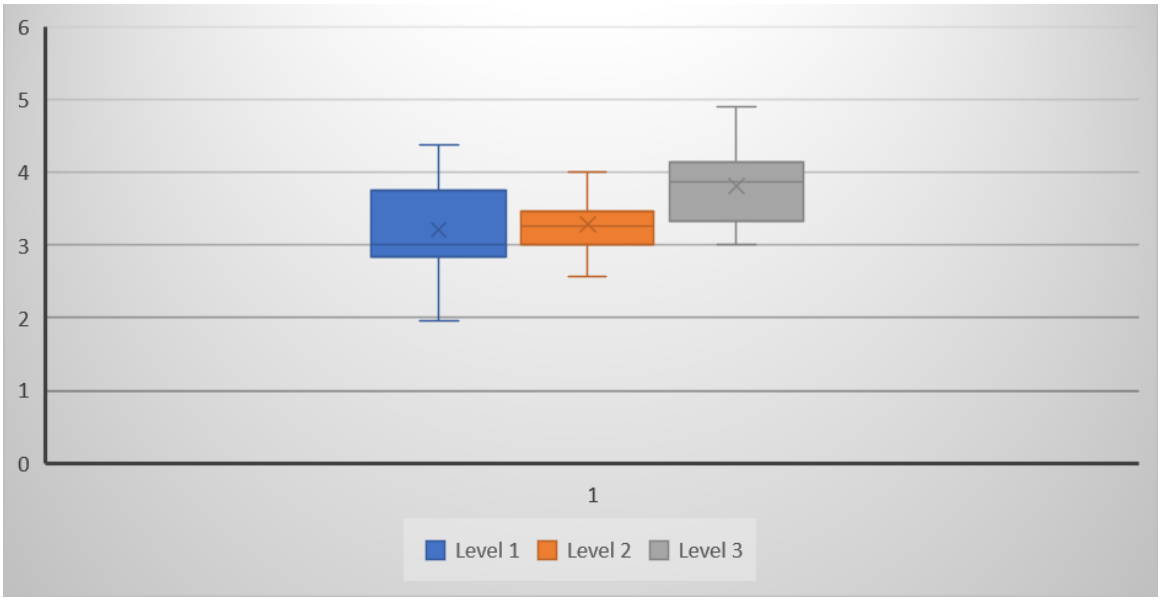


Figure 7. Baseline NRS scores and outdoor experience levels, (*N*=61).

Fifty-three of sixty-one participants were able to quickly provide an example of a positive experience in nature during interview (question 4). These positive experiences took place between the ages of four and sixteen with the average age of occurrence being twelve years. The social context of these experiences in nature is salient as mentioned in the conceptual framework. About 76% of participants mentioned a specific person in the description of their positive experience. Parents were most cited followed by grandparents, siblings, cousins, and friends. Responses recorded during the interviews highlight the importance of intergenerational interactions, school field trips, and faith-based activities in building and enhancing connectedness with nature. Several students mentioned how babysitting has provided an opportunity to revisit the nature they more deeply appreciated as a child. And many students

reported the development of a stronger appreciation for nature during the COVID-19 pandemic as families spent more time outdoors.

Two interview questions focused on how these outdoor experiences, or lack thereof, may be influencing one's experience in the science classroom. About 69% of participants believed their experiences with the natural world had helped them better understand concepts or skills taught in science class (question 6). Of the respondents that answered in the negative to question six, 88% reported low or intermediate exposure to nature (Levels 1, 2). This data reinforces my hypothesis that connectedness with nature may be influencing learning in science. Some reported occurrences of a reverse process; where concepts learned in science enhance their experiences in nature. Question 7 asks: Do you have an interest in understanding the deeper meaning behind scientific concepts? Or do you just study the vocabulary and concepts required to get a good grade? Does this vary depending on the class or content? About 54% reported an interest in understanding the deeper meaning behind scientific concepts. Roughly 38% of respondents said it depends on the content and 8% admitted they just want to learn the contents and skills required to pass. These responses were compared to baseline NRS scores in Figure 8. This comparison suggests students with higher NRS scores may differ from lower scoring peers in their approach to science instruction.

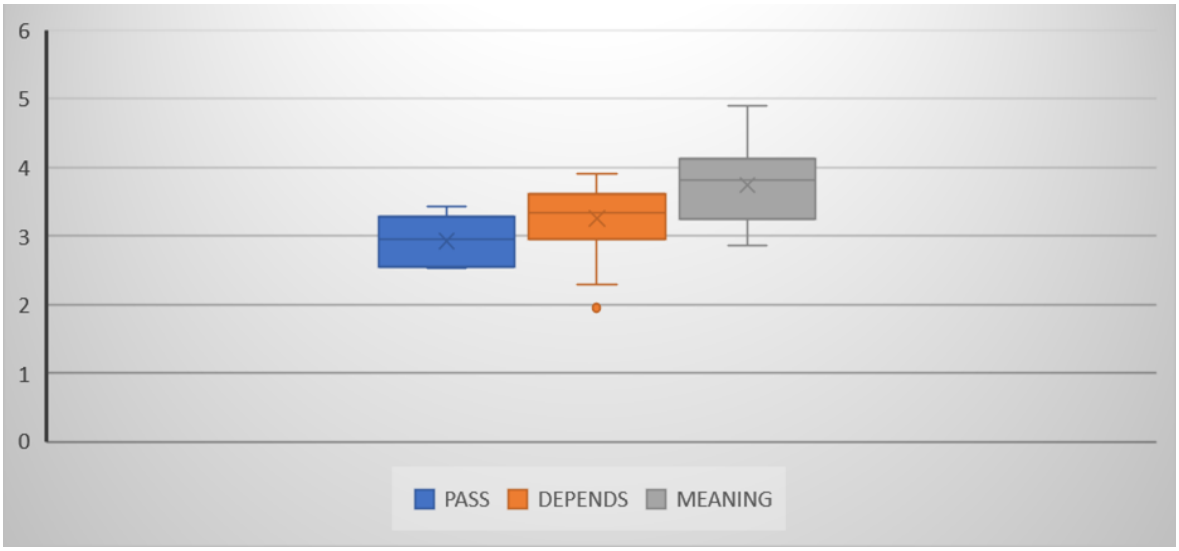


Figure 8. Baseline NRS scores and approach to science class. Student interview, Nature Relatedness Scale, (*N*=61). Question 7: When taking a science class, Blue=I'm interested in learning that which is required to pass, Orange=Depends on the class, Gray=I'm interested in understanding deeper meaning.

The final question of the interview asked students to examine a visual known as the Inclusion with Nature in Self, an instrument developed by the authors of the Nature Relatedness Scale (Nisbet et al., 2008). The visual presents subjects with five possible ways to describe their relationship with nature (Figure 9). This task was useful in that it provided an opportunity for subjects to summarize their relationship with nature at the end of the interview. And in almost all cases, this task initiated further productive discussion. My primary motive for using the item was to determine its efficacy for future use in quickly assessing a student's relationship with nature. To that end, a comparison between results on this item and baseline NRS scores was conducted (Figure 10). The graphic shows a moderate to strong correlation (r=.67) between the baseline NRS and Inclusion with Nature in Self, indicating that this simple instrument might prove valuable in assessing nature relatedness in the future.

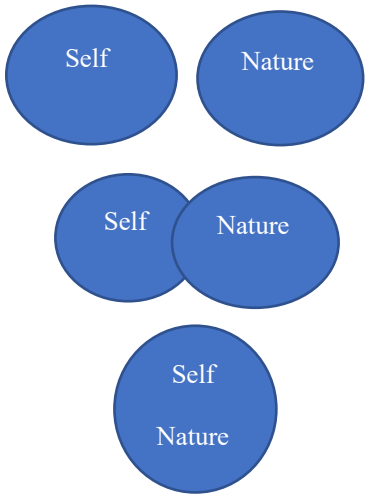


Figure 9. Inclusion with Nature in Self survey item. Single bubble=5 points, overlapping bubbles=3 points, separate bubbles=1 point. Two or four points are assigned for subjects choosing intermediate areas.

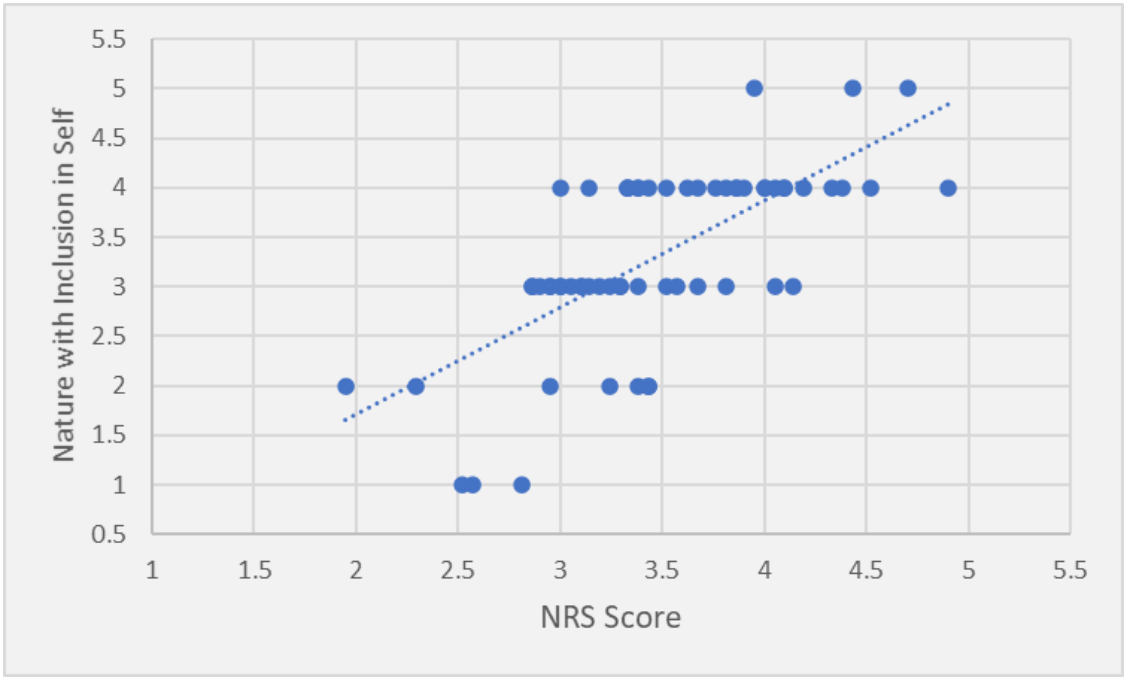


Figure 10. NRS baseline score and inclusion with nature in self survey item. Nature Relatedness Scale, Inclusion with Nature in Self, (*N*=61).

Greenspace assessments in at-home environments provided valuable insights in addressing research question two. Though many classes of ground cover were observed and recorded during these assessments (impermeable surfaces, buildings, water, grass, water), this discussion will focus on tree canopy percentages. Fifty-five sites were assessed, and the tree canopy was calculated as a proportion of each five-acre plot. Landscapes varied significantly depending on distance from city center, type of residence (single family, townhouse, apartment), and intensity of current development. The city of Nashville has experienced rapid population growth over the last decade and many sites used in this study have changed dramatically in subjects' lifetimes. It should be noted that measuring only current tree canopy percentages limits the validity of greenspace data for some study areas.

The minimum tree canopy percentage observed in the study was 0.2% while the maximum was 83.4%. The mean, median, and mode were 27.2%, 24.8%, and 21.2%, respectively. Considerable variation in the sites is evidenced by a standard deviation of 14.4. A frequency distribution of tree canopy percentages is shown in Figure 11. This visual shows that most subjects (35%) grew up in areas with 20-20.99% tree canopy coverage. Two outliers occupy the far-right side of the distribution with tree canopy values of 53.8% and 83.4%.

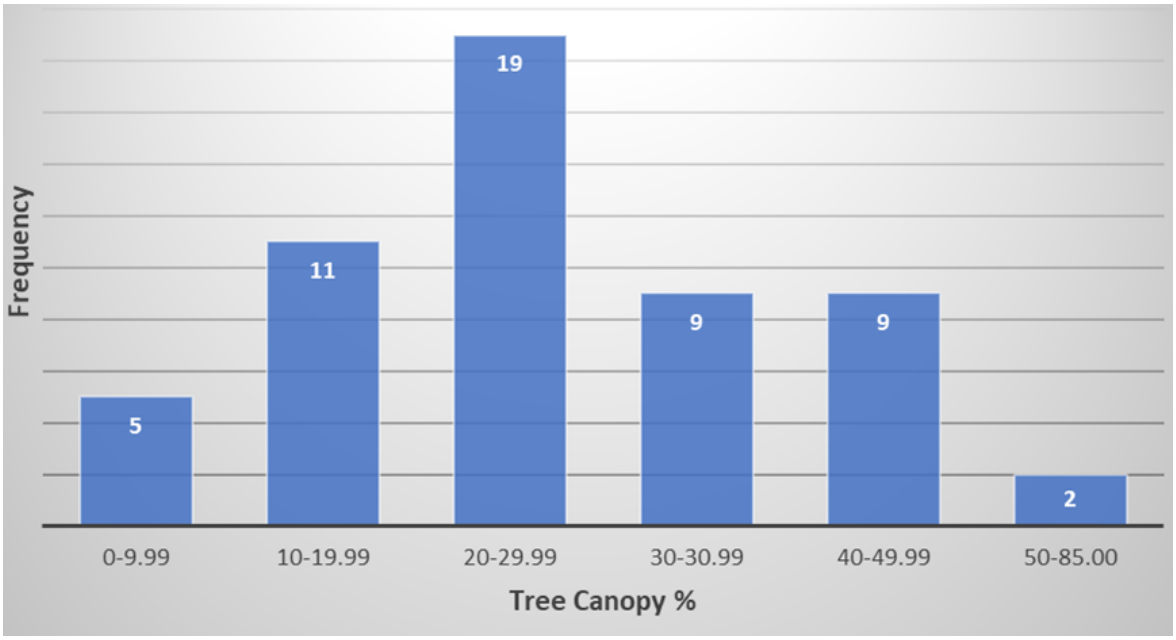


Figure 11. Tree canopy frequency distribution, greenspace assessment, i-Tree Canopy, (*N*=55).

Research question two considers what variables may be influencing a high school student's self-perceived connectedness with nature. It has been established through student interview that exposure to and experiences in nature are likely playing a role. But could greenspace in the at-home environment also be a contributor? When Nature Relatedness Scale scores and tree canopy percentages were compared, a weak to moderate positive correlation emerged (r=.44). This is demonstrated in the scatter plot shown in Figure 12. It is important to note that five outliers were excluded in the preparation of this plot. The positive correlation remains however (r=.35) with the inclusion of all fifty-five test subjects.

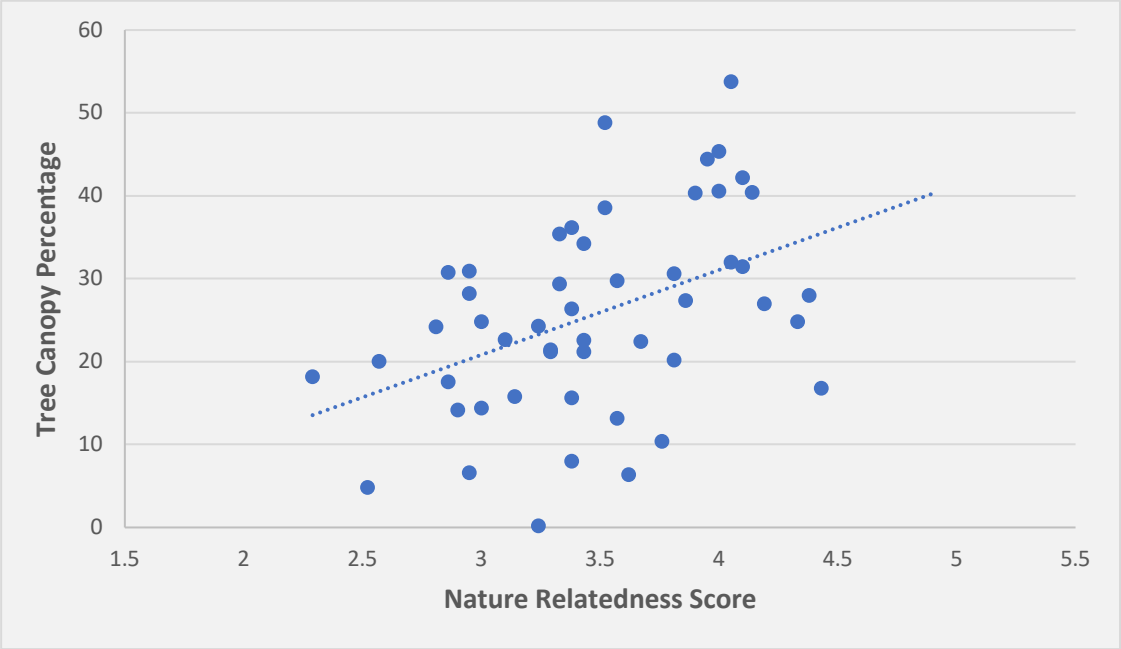


Figure 12. Scatter Plot (r=.44), NRS baseline score and tree canopy percentage. Nature Relatedness Scale, greenspace assessment, i-Tree Canopy, (*N*=50). Note: five outliers were removed in the creation of this scatter plot.

The general upward trend in NRS scores associated with increased tree canopy is also evident when subsets of the sample are established, as in the box and whisker plot shown in Figure 14. The means of the six subsets shown in this figure are as follows: 0-9.99%=3.19, 10-19.99%=3.48, 20-29.99%=3.45, 30-39.99%=3.49, 40-40.99%=3.76, 50-85%=4.38. Findings from Figures 12 and 13 provide strong supports for the argument that an association exists between NRS scores and tree canopy percentage in this sample.

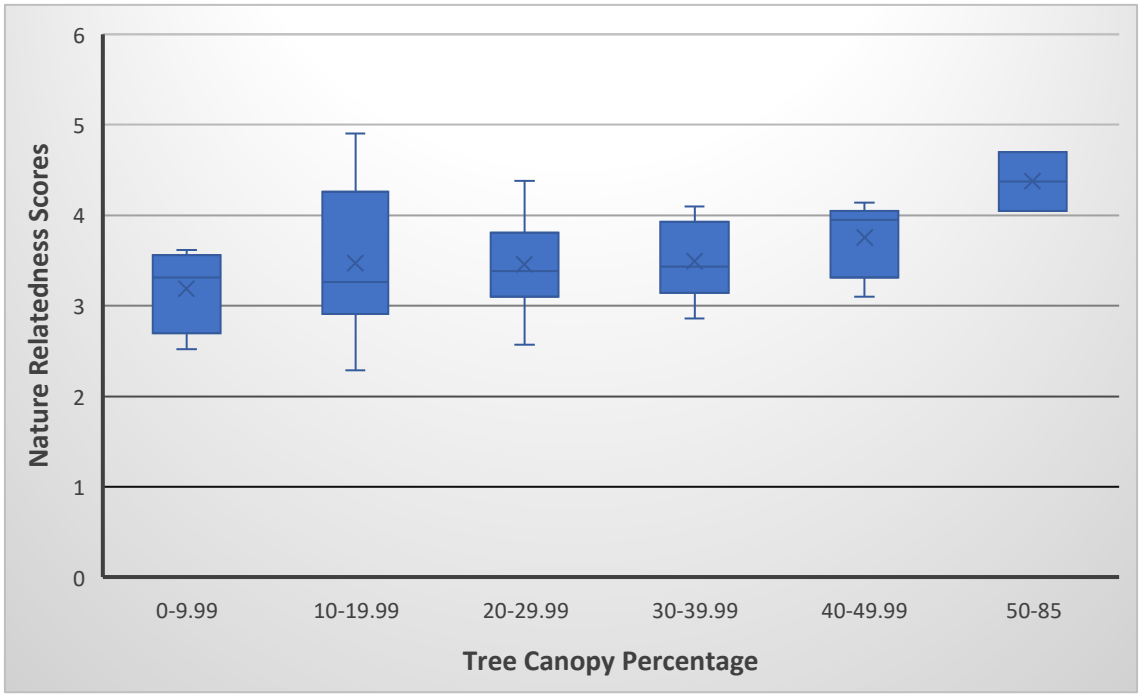


Figure 13. Box and whisker plot, NRS baseline score and tree canopy percentage. Nature Relatedness Scale, greenspace assessment, i-Tree Canopy, (*N*=55).

Not all subjects exposed to extensive tree canopy exhibited high NRS scores, however. This finding inspired a hypothesis that the orientation of trees in the at-home environment may be influencing NRS scores. Some of the sites exhibiting high tree canopy percentages contained a forested area adjacent to the community. Other sites characterized by extensive tree canopy were embedded with trees across the landscape. The example shown in Figure 14 demonstrates how both scenarios might yield a high tree canopy value. Both sites shown in Figure 14 have roughly 47% canopy but differ in the orientation of trees.

Figure 14. Adjacent orientation (left) versus embedded orientation (right).

An analysis of all plots with over 30% tree canopy was conducted to test the tree orientation hypothesis. A subset of nineteen subjects, all exposed to 30% or more tree canopy was established. Tree canopies from these twenty plots were classified as embedded, embedded/adjacent, or adjacent. These classifications were then paired with the NRS scores of the subjects inhabiting those sites. A box and whisker plot was created to demonstrate associations between tree orientation and nature relatedness scores. This comparison is shown in Figure 15. Mean scores from each subset provide some evidence of a relationship between the two variables. The mean NRS score of the embedded subset (n=4) was the highest at 3.99. The embedded/adjacent subset (n=10) had a mean of 3.84 and the adjacent subset (n=6) had a mean of 3.12. This visual suggests the embedded and embedded/adjacent landscapes may be strengthening the relationship between NRS values and green space in this sample.

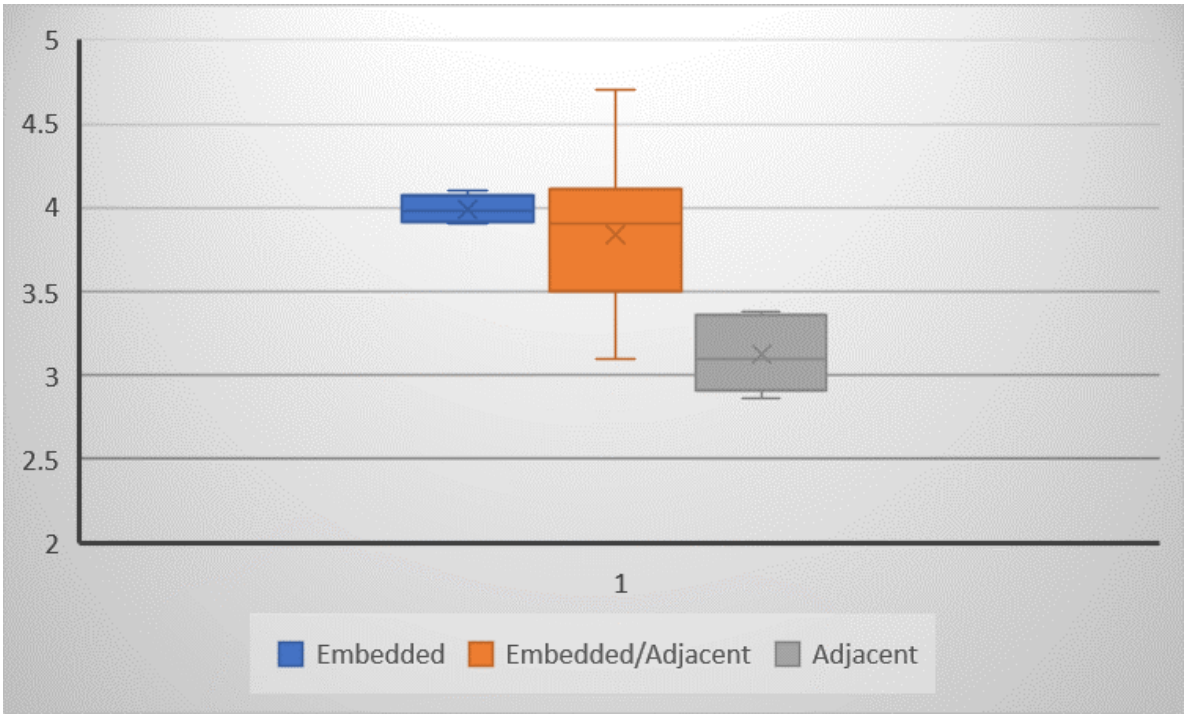


Figure 15. Box and whisker plot, NRS baseline score and tree orientation (embedded, embedded/adjacent, and adjacent) on sites with 30% or more tree canopy, greenspace assessment, i-Tree Canopy, Nature Relatedness Scale, (*n*=19).

The final greenspace analysis blends quantitative and qualitative data sources and compares two subsets from the overall sample. Nine students who shared exposure to over 40% tree canopy, characterized by embedded or embedded/adjacent tree orientation, make up the group termed high-quality greenspace. A second subset consists of ten students, all of which were exposed to less than 15% tree canopy during childhood and adolescence. This group was identified as the low-quality greenspace subset. Tree canopy, nature relatedness scores, science achievement, and interview responses were incorporated into this analysis. The compilation of data sources is shown in Tables 4 and 5.

Table 4. High-quality greenspace subset data compilation, (*n*=9).

Subject	Tree Canopy	Baseline NRS	Best NRS	Norm Growth	Composite Score	Q1	Q6	Q7	Q9
1	42.2%	4.10	4.29	.21	90.4%	L3	Yes	Meaning	4
2	40.36%	3.90	4.19	.26	92.4%	L3	Yes	Depends	4
3	48.8%	3.52	3.90	.26	98.3%	L3	Yes	Meaning	3
4	40.4%	4.14	4.67	.62	95.0%	L3	Yes	Meaning	3
5	45.4%	4.00	4.52	.52	76.8%	L3	Yes	Meaning	4
6	44.4%	3.95	4.52	.54	87.3%	L3	Yes	Meaning	5
7	48.8%	3.10	4.43	.70	92.8%	L3	Yes	Meaning	4
8	83.4%	4.70	5.00	1.0	80.8%	L3	Yes	Meaning	5
9	53.8%	4.05	4.71	.70	99.5%	L3	Yes	Meaning	4
AVG	49.7%	3.94	4.47	.59	90.3%	3	100%Y	89% M	3.89

The mean baseline NRS score for the high-quality greenspace subset was 3.94, well above the overall sample mean of 3.49. About 89% of these subjects lived in the same location for their entire life. Only 77% of the entire sample claimed lifetime residence during interview. All subset members showed significant growth in NRS scores over the course of the study with an average .59 normalized gain. A paired t-test was employed to compare this value with the normalized growth observed in the overall sample (.37). The t-test revealed a significant difference between the two data sets (calculated t-statistic 2.08, critical value 2.0), suggesting the variation did not occur by chance. The mean high school science composite score was 90.3%, below the average of 92.2% in the overall sample. Interview question one inquired about outdoor experiences. All members of this subset reported Level 3 outdoor experiences (camping, fishing, rock climbing, etc.). And all nine members replied yes when asked if experiences outdoors helped them better understand concepts and skills in science class (question six). In response to

question seven concerning the student's approach to science content, eight of nine members claimed they were interested in understanding the deeper meaning behind those concepts. Only 52% of the overall sample responded similarly to this question. Students in this group have an average score of 3.89 (out of 5) on the Inclusion with Nature in Self visual. An average of 3.29 was observed in the entire sample for this task.

And though anecdotal evidence is not included as a data source in my research plan, it may be useful in further describing this subset. Three of nine in this subset have been accepted into undergraduate science programs to study marine biology, agriculture, and environmental science. Five of the nine members participated in an optional after-school hike offered to all 134 of my students during the second semester. Another opportunity offered to all students during the study period involved volunteering at a local park for an annual spring festival. Three members from this subset volunteered their time on a Saturday to help the park.

Table 5. Low-quality greenspace subset data compilation, (*n*=10).

Subject	Tree Canopy	Baseline NRS	Best NRS	Norm Growth	Composite Score	Q1	Q6	Q7	Q9
1	0.2%	3.24	3.52	.16	98.0%	L2	Yes	Depends	3
2	8.0%	3.38	3.81	.27	96.8%	L3	Yes	Depends	2
3	6.4%	3.62	3.81	.14	96.4%	L3	Yes	Depends	2
4	9.6%	2.52	2.95	.17	83.0%	L2	Yes	Pass	1
5	6.6%	2.95	3.33	.19	94.4%	L2	Yes	Depends	3
6	14.4%	3.00	3.43	.22	84.1%	L1	No	Meaning	4
7	13.2%	3.86	3.57	-.25	95.8%	L2	Yes	Meaning	4
8	13.0%	4.52	4.90	.79	95.6%	L3	No	Depends	4
9	10.4%	3.76	4.14	.31	88.8%	L2	Yes	Meaning	4
10	14.2%	2.90	3.14	.11	91.1%	L2	Yes	Depends	3
AVG	9.6%	3.38	3.66	.21	92.4%	2.2	80%Y	30% M	3

The mean baseline NRS score for the low-quality greenspace subset was 3.38, below the overall sample mean of 3.49. About 67% of the group lived at the same location for their entire life, which is well below the overall sample average of 77%. Nine of ten members in the group experienced positive gains in NRS scores demonstrating .21 average normalized growth. When normalized gains of this subset were compared to those of the overall sample using a t-test, a nonsignificant difference between means was observed (t-statistic 1.80, critical value 2.0). However, when one outlier was excluded from the subset, a significant difference between data sets was apparent (t-statistic 2.08, critical value 2.0). Negative growth on the NRS was observed in one subject from this subset.

The mean high school science composite score for the low-quality greenspace subset was 92.4%, very close to the 92.2% average observed in the overall sample. Only three students from the subset reported Level 3 outdoor experiences in interview. There were six students reporting Level 2 experiences and one reporting Level 1 experiences. Eighty percent of the subset responded yes when asked if their experiences in nature helped them better understand science concepts, above the overall sample mean of 69%. In response to question 7 concerning the student's approach to science content, only 30% of members claimed they were interested in understanding the deeper meaning behind those concepts. For comparison, about 52% of the entire sample claimed an interest in understanding deeper meaning. Students in the low-quality greenspace subset showed an average score of 3.0 (out of 5) on the Inclusion with Nature in Self visual. An average of 3.29 was observed in the entire sample for this task.

Place-based learning techniques were employed as treatment in addressing research question three. The efficacy of these techniques was assessed through pre and post-test values on

the Nature Relatedness Scale. Participants in the study were asked to follow a protocol which involved completion of a Muir Map immediately after each place-based module. Administration of the NRS survey immediately followed completion of each Muir Map. This protocol proved difficult to manage with excessive COVID-related absences, snow days, and unforeseen schedule changes. Five subjects were excluded from this portion of the study due to missing or late NRS surveys and Muir Maps. The following data is therefore representative of fifty-six of the original sixty-one participants.

The mean normalized gain for the sample was .36 while median and mode were .36 and 0, respectively. The minimum normalized gain was -.25 and maximum gain was 1. Four students demonstrated no growth and one student exhibited negative growth after treatment. The standard deviation for the sample was .24, indicating a tightly grouped data set with little variation from the mean. A box and whisker plot showing the distribution of normalized gains is provided in Figure 16. Additionally, a chart depicting differences in pre and post-test raw scores is shown in Figure 17. A final analysis for this portion of the study involved comparing baseline NRS scores with normalized growth. A moderate correlation was discovered between the variables (r=.57). This suggests that a student's baseline score could influence their capacity for change in perspective, a point to be discussed in chapter five.

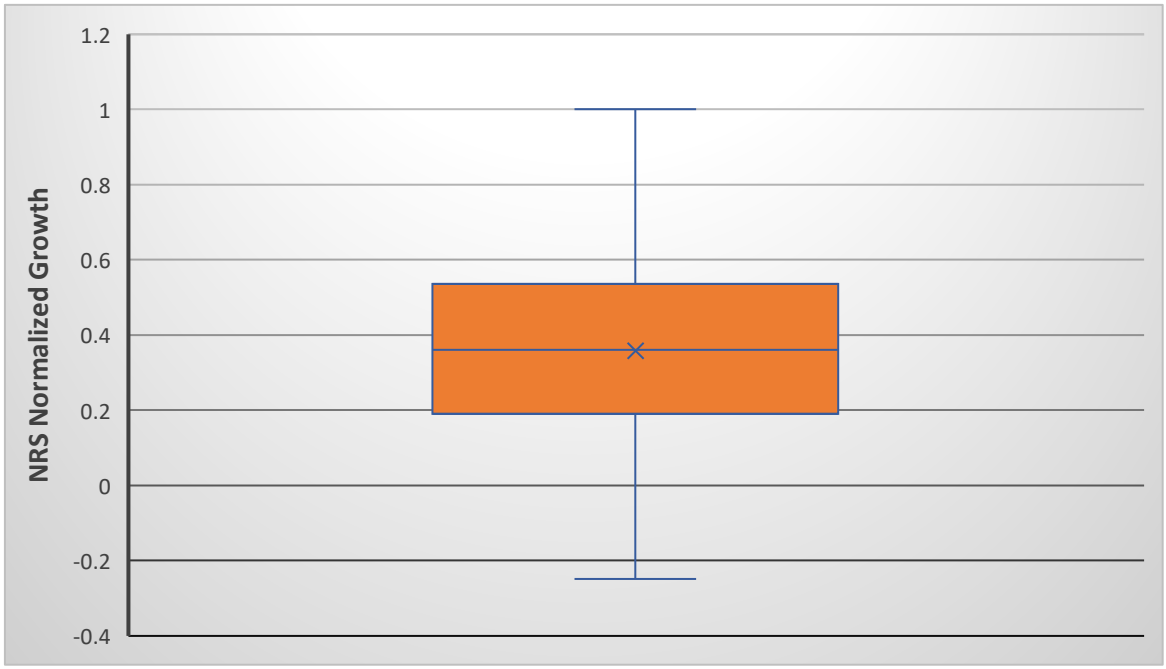


Figure 16. Box and whisker plot, normalized NRS growth from pre-test to post-test, Nature Relatedness Scale, (mean=.36), (*N*=56).

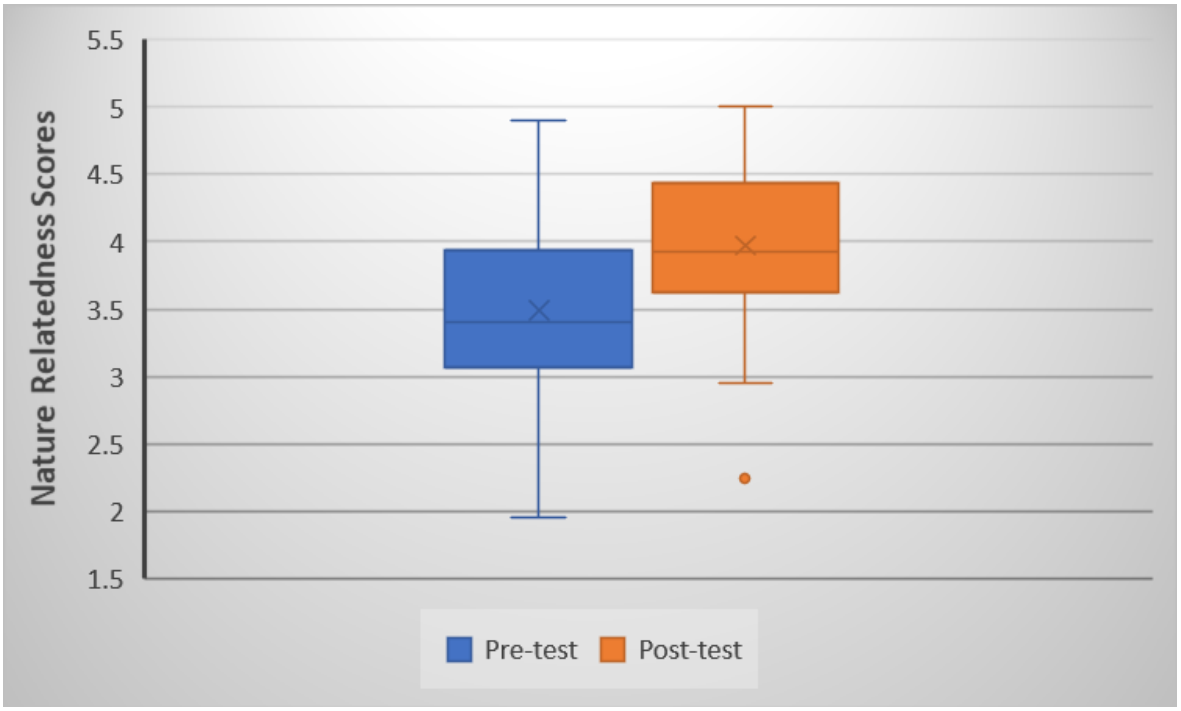


Figure 17. Box and whisker plot, NRS raw scores, pre-test and post-test, Nature Relatedness Scale, (*N*=56).

As mentioned previously, Muir Maps were used as a qualitative indicator of growth through the course of the study. In this assignment, students were asked to create an interdisciplinary web of concepts and provide a brief explanation of how they are personally connected to the theme of the place-based module. All students were successful in describing relevant connections to module themes in at least two of the three assignments. The mean score for all maps submitted during the study period was 84% (Table 6).

Table 6. Personal connection responses, Muir Map, (*N*=56).

Muir Map Theme	Student Response
Air Pollution	My personal connection comes mainly from how trains and semi-trucks affect the air quality around where I live. I live right next to I-65 and Radnor Train Yard which means a lot of pollutants are in the air near me. I've noticed after a while, things outside my house have a thin layer of black dust. I'm sure that's why I always have allergies.
Air Pollution	My Mom always tells me how her family would have to cook with coal at home. Over time, this affected my Grandma the most since she was always the one cooking. This led to her having respiratory issues which were the cause of her death. My Mom moved to the US so she wouldn't have to deal with something like this again.
Geology	Because of where I live in Nashville and the vast amounts of limestone, there is a lot of calcium in the soil. My pet chickens take in the calcium through the food they eat to make eggs, which my family eats.
Geology	I live in Tennessee where the rocks release a lot of radon gas. That's why it's important that my family get a radon test done to make sure we do not have a high concentration of radon in our home. High concentrations of radon can cause lung cancer and even death which can affect me and my family.
Water	I live about three blocks from one of Nashville's wastewater treatment plants. I can smell the wastewater whenever the wind blows a certain way.
Water	I'm connected to the theme through the Safe Drinking Water Act. This legislation passed laws that state the limits of pollutants in the water provided to the public.

Scores on Muir Maps did not correlate with other data sources used in this study. Effort on the maps varied from student to student as the assignment carried little weight in the overall

grading scheme and was viewed by students as a formative task. Even so, the maps proved useful in reminding students of connections between concepts and disciplines prior to taking each NRS survey. A double-sided hard copy of map and survey was supplied to facilitate a smooth progression from one task to the next. The maps also provided excellent qualitative data to track student progress as they assimilated what they learned into a larger and more complex scientific knowledge base.

CHAPTER FIVE

CLAIM EVIDENCE AND REASONING

Claims From the Study

The following discussion will highlight findings from this study, provide evidence for claims, and propose explanations for how and why the evidence supports each claim. Important takeaways from the research will also be presented with practical applications of the results provided where appropriate. Some findings can be compared to those of previous studies as the methods used here were gleaned from similar investigations. In situations where new combinations of variables were analyzed, comparisons will be more difficult. For example, no previous research exploring relationships between connectedness with nature and greenspace in the at-home environment were discovered in literature review.

Research Question One

Research question one asks: How does self-perceived connectedness with nature affect science learning in high school students? Though the answer to the question is still unclear, this investigation has produced some interesting findings. A most unexpected result came early in the analysis phase. A decline in NRS values near the top of the achievement spectrum was discovered, with the top 10 science achievers averaging 3.23, the top five averaging 3.13, and the top three averaging 2.83 on the Nature Relatedness Scale. This result along with the subset analysis shown in Figure 6 provide strong support that connectedness with nature and academic achievement in science are not associated in this sample. Whether science educators should be concerned about these findings is beyond the scope of this paper, but the trend is surprising.

Science after all, is about nature, and most definitions of science include the terms nature or natural world. Equally unexpected was the finding that the top three achievers in the study disagreed a little with the statement “I am not separate from nature, but a part of nature.” And when asked if they were interested in learning about the deeper meaning behind scientific concepts, four out of five of the highest achievers reported “it depends on the class.”

Another interesting finding emerged while addressing research question one. Interviews revealed that about 52% of students in the sample were interested in understanding the deeper meaning behind scientific concepts, despite the course. These students tended to have achievement scores closer to the average. More importantly, these students tended to have high NRS scores and most reported experience with Level 3 outdoor activities. Interview data also showed that 84% of the students interested in deeper meaning use what they learn from outdoor experiences to help them better understand concepts in science class. Some of these students are even willing to hike with their science teacher after school hours or volunteer at a local park.

There is a danger in stereotyping students, particularly when using evidence from a small study group. In addressing research question one, I learned the relationship between nature and learning is more complex than I thought it might be. That said, there were some observable trends that seemed to have a sorting effect on the sample. Factors beyond the scope of this paper are no doubt contributing to how students perceive nature, and one may be worth mentioning here. Students and families must make tough decisions when it comes to academic success. It may be difficult for students to both deeply engage with science content and be a high achiever. For many students, academic achievement can be all-consuming, leaving little space in the schedule for outdoor activities, appreciation of nature, or volunteering at a local park.

Though the mixed methods approach to addressing research question one provided valid quantitative and qualitative supports, the reliability of the findings should be viewed with a healthy sense of skepticism. No previous studies comparing nature relatedness and science achievement were discovered in literature review, and this study group (*N*=61) was not representative of its school or city. More research into this question is needed. The answer to how connectedness with nature influences science learning remains unanswered, but a key takeaway from this research is that richness of meaning likely plays a central role. And an interest in meaning affects what students bring to and take from science class.

Research Question Two

Research question two asks: What influences self-perceived connectedness with nature in high school students? The two variables examined closely in this study were exposure to nature and greenspace in the at-home environment. Evidence collected in this Action Research supports findings from previous and similar studies (Mayer & Frantz, 2004; Wells and Lekies, 2018). Positive experiences in nature, or lack thereof, appear to have a primary influence on connectedness with nature. Evidence for this claim is sourced from experience sampling conducted during student interviews. The amount of exposure to nature and type of outdoor activities were both important correlates to Nature Relatedness scores in the sample. Those subjects reporting Level 3 outdoor activities tended to exhibit the highest NRS scores.

Greenspace assessments were valuable in establishing a relationship between tree canopy percentage and NRS scores in the sample. Figures 12 and 13 provide evidence of the positive correlation between the two variables. However, it is likely that greenspace in the at-home environment is playing a supporting role in its influence on the Nature Relatedness score. Many

subjects with high NRS scores and low greenspace at home were observed, suggesting the variable may not be as important as exposure to nature in determining connectedness. Though tree canopy likely has a synergistic but weaker influence on NRS scores, its importance to science learning looks promising as shown in members of the high-quality greenspace subset shown in Table 3. Low-quality greenspace, on the other hand, was associated with interview responses that might negatively influence science learning (Table 4). The effects of tree orientation on NRS scores were also revealed in the sample. Evidence for the importance of trees embedded in the landscape is provided in Figure 15. This finding makes sense, as subjects living in neighborhoods adjacent to forested areas are not enjoying all the benefits trees have to offer.

Though anomalies were observed, quantitative and qualitative data collected from this sample suggest that experiences in nature and exposure to greenspace can influence one's nature relatedness scores. The size and composition of this study group must again be considered. And there are many variables that influence one's exposure to nature and greenspace at home that are not addressed in this research. Socioeconomic and psychological variables are worth mentioning, and both likely played a role in each student's initial decision to participate or not participate in this investigation. The findings presented here, though valid, do not tell the whole story. A more comprehensive research plan involving many subjects from various backgrounds would yield more reliable results.

Research Question Three

Research question three asks: Can connectedness with learning be enhanced by a series of place-based learning modules? According to the findings of this study, connectedness with nature can be enhanced in high school students. About 91% of students improved their score (.37

average normalized growth) on the Nature Relatedness Scale. Of the four students who showed no growth after treatment, one scored very high on the baseline (4.9) and one scored very low (2.29). This suggests changes in perspective were less likely to occur at the extreme ends of the nature relatedness spectrum. I can offer no explanation for why two subjects, both with baseline scores of 3.43, experienced no growth. Likewise, I can't explain the -.25-loss shown in one subject who started with a relatively high baseline score (3.86).

A reduced capacity for change in perspective was revealed in some subjects, which is concerning. This is highlighted in the analysis of the low-quality greenspace subset (Table 4). The ten subjects in this group demonstrated an average normalized growth of .21 which is significantly lower than the mean growth for entire sample (.37) and for the high-quality greenspace subset (.59). Significant variation from the mean of the overall sample and those of both subsets was demonstrated through t-statistic calculations. The low-quality greenspace subset also tended to have lower than average NRS baseline scores and were less likely to have participated in Level 3 outdoor activities. It is possible that a combination of low exposure to nature and low-quality greenspace in the at-home environment has a cumulative effect of lowering the baseline NRS, which in turn could contribute to a reduced capacity for change in perspective.

Another compelling finding was that growth on the NRS was not linear for all subjects. There is evidence that NRS scores varied with topic interest for some students. For example, one student who enjoys working on and modifying cars showed particular interest in our discussions about air pollution, auto emissions, and catalytic converters. I asked the student if we could collect exhaust samples from his vehicle for an auto emissions laboratory. The student was

delighted at the opportunity to showcase his vehicle. At the end of the air module, the student produced a highly detailed and extensive Muir Map and posted his highest NRS score of the study, almost 10% higher than other administrations of the survey. It was for this reason I chose to use each subject's highest NRS score as a post-test value when analyzing growth.

The findings presented here align with those from a similar study mentioned in the Conceptual Framework (Semken & Freeman, 2008). As in this 2008 study, students seem to have responded positively to a contextualized instructional approach. But there are limitations to the data worth that should be considered. For example, students were aware of the goal of the study; to enhance connectedness with nature. This fact may have influenced responses on the Nature Relatedness Scale and student interview. And though students were reminded on many occasions to respond honestly during survey and interview, some probably answered questions in ways they perceived to be more socially acceptable. Even so, student scores on the Nature Relatedness Scale did align with national values from previous studies and correlated with experience sampling from student interview. This suggests the NRS was effectively measuring what it was designed to measure, thereby validating the data collected from this sample.

Value of the Study and Consideration for Future Research

As explained in the conceptual framework, environmental psychology is an emerging field of study encompassing many disciplines and employing a wide variety of scientific methods. An interest in recently published studies about the human-nature relationship, particularly those involving remote sensing and satellite imagery inspired the topic for this project. As science is a study of nature, it seems logical that a student's perception of nature would influence their experience in science class. Evidence shown here supports this concept. I

believe it would be valuable for science educators to learn more about this topic and consider how their own environmental identity and those of their students may be affecting learning in their classrooms. And there is a need for more research on how environmental factors influence learning. This will require interdisciplinary collaborations between educational researchers and environmental scientists. The body of evidence from the conceptual framework and findings from this investigation warrant further study.

This Action Research demonstrated the value of discussing environmental identity with students. It was not easy finding time to conduct the sixty-one interviews used here, but there were unexpected benefits. The interviews changed my relationship with the participants and influenced the planning and execution of lessons. And as indicated in the conceptual framework, environmental identity may be linked to science identity. According to National Institutes of Health, science identity is described as "how an individual seeks to be a scientist, which is constructed through iterative interactions with scientific social and material contexts". Science identity influences career choices and is implicated in the underrepresentation of minorities in science and technical fields. More research into the connection between environmental identity and science identity is needed. And the relevance of such research for me as a high school science teacher in a highly diverse school system is evident. Student interviews are costly in terms of time, but I plan to continue the protocol and recommend other science educators implement their own strategy for assessing each student's relationship with nature.

In validating the Nature Relatedness Scale, authors Elizabeth Nisbet and John Zelenski discovered that high NRS scores corresponded with happiness and environmentally responsible behaviors. Aren't these characteristics every science teacher should hope for in their students?

I'm pleased with the findings that connectedness with nature can not only be measured but also enhanced. I'm hopeful my efforts will result in more happiness and more environmentally responsible behaviors in the future. Now more than ever, teachers are being asked to address the social and emotional needs of their students. Nature provides an antidote to social and emotional ills and science educators are uniquely positioned to leverage the power of nature without straying from the standards they are required to teach.

The efficacy of place-based learning techniques in enhancing connectedness with nature have been demonstrated through literature review and through the findings of this study. I've found that almost every national environmental standard can be taught with a local spin. Using place-based techniques to teach marine biology in Nashville, Tennessee might at first seem illogical. But when the geological history of the Nashville landscape is considered, students begin to see evidence they are completely immersed in an ancient marine environment. Relatable examples are everywhere. Sense of place and appreciation for home are enhanced. Learning partners from local universities, parks, and government organizations were invaluable contributors to the place-based instruction used in this study. In every case, I found these experts willing and happy to help. Students were completely engaged in preparing questions for these experts and enjoyed conducting the interviews themselves. I would recommend that every science teacher, regardless of grade level, build a network of local learning partners.

The findings of this Action Research highlight the importance environmental education in schools. Many school systems have outdoor school facilities and curricula, but they are rare in urban settings. As mentioned earlier, Metropolitan Nashville Public Schools has no such facility or curriculum and offers no environmental resources to science teachers. More research into the

benefits of environmental education in the urban setting is needed to encourage city school systems to implement such programs.

An area of educational research relevant to the topics discussed here is that of sensitive periods. Sensitive periods are stages in human development where individuals are highly responsive to a specific type of stimulus. One research question worth investigating: Are sensitive periods observed in nature exposure as they are in language and mathematics? If so, how could this knowledge be used in the development of environmental education programming? If sensitive periods for nature exposure do exist, new curricula and instructional strategies could be employed to maximize the benefits of nature in overall child development.

Finally, I believe some groups of noneducators might find the results of this study valuable. The benefits of high-quality greenspace to environment, health, and even the psyche have been understood for some time, but implications for education are still largely unexplored. Arming land use experts, planning officials, and policymakers with evidence linking greenspace and learning could positively influence the planning of neighborhoods, schools, and cities.

Impact of Action Research on the Author

There are many ways to know a student. Through this Action Research, I've discovered new ways to know mine. The project was inspired by classroom observations. It was clear to me all students could learn the standards and pass the tests but there was considerable variation in how students effectively assembled concepts to create a meaningful big picture. Nature provides great examples of how the pieces fit together and perhaps a lack of exposure to nature was one factor contributing to the observation. This research plan required me to interview students, examine their academic records, and visit the neighborhoods in which they live. These steps

made me a better listener, an acute observer of landscapes and behaviors, and a more accommodating facilitator.

Shortly after earning my undergraduate degree, I decided to continue my education with a master's degree in environmental science. I couldn't have made a better choice. The discipline fits me. And this Action Research allowed me to blend environmental science and education in a unique way. The work reminded me of the reasons I chose the discipline way back then. I'm fortunate to have found a teaching position that encourages me to continue that path. And I appreciate the challenge of teaching environmental science in the city, working with kids that commonly present the disconnect from nature discussed in this paper. The Action Research process allowed me to advance two passions at once.

Many hours of reading studies in environmental psychology and discussing nature with students encouraged me to revisit my own environmental identity and positive experiences in nature, some of which were life changing. And ironically, the many hours of work on this project required a home-based lockdown, limiting my nature exposure to views out the sunroom window. The positive benefits of nature have been established in study after study. These were useful reminders and have encouraged resolutions to get outside in the interest of my own well-being. Visiting residences through satellite imagery and finding correlations with student perspectives confirmed my intuition that neighborhoods with trees are better neighborhoods. These many images even provided inspiration for how I might improve my own plot of land.

And for me, this Action Research reinforced the importance of science as a way of knowing. I'm reminded of an online discussion post from a Montana middle school teacher while taking my first course in the MSSE program: "When it comes to ways of knowing, science

is the best thing going." Even with its flaws, frustrations, sticking points, blind alleys, and constant course corrections, scientific research remains our most reliable tool in understanding nature. Recent attacks on the scientific endeavor underscore the importance of demonstrating its relevance and importance to students daily through high quality science education. Science does not always go as planned or as shown in *Chapter 1: Scientific Methods* of any high school textbook. But this teacher-researcher is thankful for the many challenges presented during this project, from research question to conclusion. In each, an opportunity for growth.

REFERENCES CITED

Barrera-Hernández, L. F., Sotelo-Castillo, M. A., Echeverría-Castro, S. B., & Tapia-Fonllem, C. O. (2020). Connectedness to nature: Its impact on sustainable behaviors and happiness in children. *Frontiers in Psychology*, *11*. https://10.3389/fpsyg.2020.00276

Berkes, F. (2009). *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Cambridge University Press.

Berman, M. (2014). The restorative benefits of interacting with nature. *PsycEXTRA Dataset*. https://10.1037/e578192014-337

Capaldi, C. A., Dopko, R. L., & Zelensky, J. M. (2014). The relationship between nature connectedness and happiness: A meta-analysis. *Frontiers in Psychology, 5*. https://10.3389/fpsyg.2014.00976

Clayton, S. (2003). "Environmental identity: a conceptual and operational definition," in *Identity and the natural environment: The psychological significance of nature*, eds S. Clayton and Opotow (Cambridge, MA: MIT Press), 45-65.

Engemann, K., Pedersen, C. B., Arge, L., Tsirogiannis, C., Mortensen, P. B., & Svenning, J. C. (2019). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. *Proceedings of the National Academy of Sciences*, *116*(11), 5188–5193. https://10.1073/pnas.1807504116

Ernst, J. A., & Monroe, M. (2006). The effects of environment-based education on students' critical thinking skills and disposition toward critical thinking. *Environmental Education Research*, *12*(3-4), 429–443. https://10.1080/13504620600942998

Ernst, J., & Theimer, S. (2011). Evaluating the effects of environmental education programming on connectedness to nature. *Environmental Education Research*, *17*(5), 577–598. https://doi.org/10.1080/13504622.2011.565119

Heimer, H. (2005). Topophilia and quality of life: Defining the ultimate restorative environment. *Environmental Health Perspectives, 113*(2). https://10.1289/ehp.113-a117

Kals, E., Schumacher, D., & Montada, L. (1999). Emotional affinity toward nature as a motivational basis to protect nature. *Environment and Behavior, 31*(2), 178-202. https://10.1177/00139169921972056

Kellert, S. R., & Wilson, E. O. (2013). *The biophilia hypothesis*. Island Press.

Kesebir, S., & Kesebir, P. (2017). A growing disconnection from nature is evident in cultural products. *Perspectives on Psychological Science, 12*(2), 258-269. https://10.1177/1745691616662473

Kondo, M., Fluehr, J., McKeon, T., & Branas, C. (2018). Urban green space and its impact on human health. *International Journal of Environmental Research and Public Health*, *15*(3), 445. https://10.3390/ijerph15030445

Lankenau, G. R. (2016). Fostering connectedness to nature in higher education. *Environmental Education Research*, *24*(2), 230–244. https://10.1080/13504622.2016.1225674

Leopold, A., Schwartz, C. W., & Kingsolver, B. (2020). *A Sand County almanac: And sketches here and there*. Oxford University Press, 203-204.

Lieberman, G., & Hoody, L. (1998). Closing the achievement gap: Using the environment as an integrating context for learning. https://digitalcommons.unomaha.edu/slcek12/64/

Louv, R. (2008). *Last child in the woods*. Algonquin Books.

Mayer, F., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology, 24*(4), 503-515. https://10.1016/j.jenvp.2004.10.001

Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2008). The nature relatedness scale. *Environment and Behavior, 41*(5), 715-740. https://10.1177/0013916508318748

Nisbet, E. K., & Zelenski, J. M. (2013). The nr-6: A new brief measure of nature relatedness. *Frontiers in Psychology, 4*. https://10.3389/fpsyg.2013.00813

Public School Review. (2022). https://www.publicschoolreview.com/martin-luther-king-jr-school-profile/37203

Renz, H., & Skevaki, C. (2020). Early life microbial exposures and allergy risks: Opportunities for prevention. *Nature Reviews Immunology, 21*(3), 177-191. https://10.1038/s41577-020-00420-y

Simms, W. (2020). Bringing environmental identity research into the classroom context: Examining the theoretical foundations influencing its current use in the literature. *Studies in Science Education*, *56*(1), 35–76. https://10.1080/03057267.2020.1736379

Semken, S., & Freeman, C. B. (2008). Sense of place in the practice and assessment of place-based science teaching. *Science Education, 92*(6), 1042-1057. https://10.1002/sce.20279

Smith, G. A. (2002). Place-based education: Learning to be where we are. *Phi Delta Kappan, 83*(8), 584-594. https://10.1177/003172170208300806

Sobel, D. (2017). *Place-based education: Connecting classrooms and communities*. Orion Magazine.

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human-nature interactions. *Frontiers in Ecology and the Environment*, *14*(2), 94–101. https://10.1002/fee.1225

Tabraiz, S., Ahmad, S., Shehzadi, I., & Asif, M. B. (2015). Study of physio-psychological effects on traffic wardens due to traffic noise pollution; exposure-effect relation. *Journal of Environmental Health Science and Engineering, 13*(1). https://10.1186/s40201-015-0187-x

Tugurian, L. P., & Carrier, S. J. (2016). Children's environmental identity and the elementary science classroom. *The Journal of Environmental Education*, *48*(3), 143–153. https://10.1080/00958964.2016.1191415

Williams, D. R., & Vaske, J. J. (2003). The measurement of place attachment: Validity and generalizability of a psychometric approach. *Forest Science. 49*(6), 830–840. https://www.fs.usda.gov/treesearch/pubs/23746

Walker, T. D. (2016). *The cognitive benefits of kindergarten in the forest*. The Atlantic; The Atlantic. https://www.theatlantic.com/education/archive/2016/09/kindergarten-naturally/500138/

Wells, N., & Lekies, K. (2006). Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. *Children, Youth and Environments*, *16*(1), 41663. https://naaee.org/eepro/research/library/nature-and-life-course-pathways

Wu, C. D., McNeely, E., Cedeño-Laurent, J. G., Pan, W. C., Adamkiewicz, G., Dominici, F., Lung, S. C. C., Su, H.-J., & Spengler, J. D. (2014). Linking student performance in Massachusetts elementary schools with the "Greenness" of school surroundings using remote sensing. *PLoS ONE*, *9*(10), e108548. https://10.1371/journal.pone.0108548

Zylstra, M. J., Knight, A. T., Esler, K. J., & Le Grange, L. L. L. (2014). Connectedness as a core conservation concern: An interdisciplinary review of theory and a call for practice. *Springer Science Reviews*, *2*(1-2), 119–143. https://10.1007/s40362-014-0021-3

APPENDICES

APPENDIX A

MUIR MAP

Muir Map **Name _____**

"When we try to pick out anything by itself, we find it hitched to everything else in the universe"

-John Muir

1. Create a concept map, using water as a central theme.
2. Build a structure around the theme using concepts you've learned in Environmental Science.
3. Extend your map to show how water is connected to other disciplines (sociology, health, law, history, geography, economics, etc.).
4. Write your name somewhere on the map to show one way you're connected to the theme.
5. Personal Connection: At the bottom of the map, write 2-4 sentences to describe/explain this connection.

APPENDIX B

METRO NASHVILLE SCHOOLS RESEARCH APPROVAL

November 1, 2021

Mr. Scott Carter
2807 Barclay Dr.
Nashville, TN 37206
Scott.carter@mnps.org

RE: Connectedness with Nature and Implications for Learning in Science

Dear Researcher:

Your action research proposal has been reviewed by MNPS through our expedited review process and has beenapproved. This pathway is open to master's-level students conducting research within their normal scope of professional practice and reviews only for the potential of student harm. Please note that projects limited in scope such as yours lack generalizability. In other words, you may discover an instructional impact within your classroom's context and with your participating students, but the study's limited nature inhibits one from making broader claims about whether this impact would occur within other contexts. You are likely aware of this limitation, but we want to re-iterate the distinction between the type of action research you are undertaking and generalizable research. A more rigorous research design would need to be implemented in order to know whether an educational technique/initiative is effective.

We do hope that your investigation proceeds smoothly and that your research questions are answered conclusively. We encourage you to amend your consent forms and communications to include a notification ofMNPS central office approval of your study. As a reminder, participation within external research projects is always optional for students, parents, and teachers. Additionally, the school principal has complete discretion to allow or disallow research projects to occur within his or her school.

MNPS is pleased to approve proposals that are protective of MNPS instructional time, attentive to privacy issues, and aligned with current district instructional efforts. We hope your action research study leads to improved practices and outcomes in your classroom or school. In future correspondents with us please includereference code **Approve_21_*11_1_Carter.***

Respectfully,

Nécole Elizer

Nécole Elizer
MNPS Research, Assessment, and Evaluation

APPENDIX C

MONTANA STATE UNIVERSITY IRB EXEMPTION

Dear Scott,

Thank you for your application. This email acknowledges receipt of the request for IRB Review and serves as the Approval Letter for your research. Your new **IRB Exempt Protocol # is SC110821-EX**. Please find your approved/stamped Consent Form attached.
Study Title: **Connectedness with Nature and Implications for Learning in Science**
As the PI, it is your responsibility to facilitate subject understanding by informing subjects of all aspects of the project, providing an opportunity to ask questions, and describing risks and benefits of participation. Submit any new changes to the research protocol to the IRB via Amendment Form prior to implementing.
The research described in your submission is exempt from the requirement of additional review by the Institutional Review Board in accordance with 45 CFR 690.104(d). The specific paragraph which applies to your research is:

(1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Thank you,
Kelly Beiswanger

IRB Administrator & Program Manager
Office of Research Compliance
Hamilton Hall 114
Montana State University
kelly.beiswanger@montana.edu
406-994-4706
https://www.montana.edu/orc/irb

APPENDIX D

PARENT/GUARDIAN PERMISSION FOR PARTICIPATION

Parental/Guardian Permission for Research Participation

Dear Parents and Guardians,
Permission is being sought for your child's participation in educational research to be conducted at Martin Luther King Academic Magnet during the 2021-2022 school year. Please read the following information carefully before deciding to give your permission.

Title of Project: Connectedness with Nature and Implications for Learning in Science

Researcher: Scott Carter, Environmental Science Instructor

Purpose of the research: This study aims to discover relationships between student perceptions of nature and learning in science. The researcher hopes to identify variables that influence student-perceived connectedness with nature and to explore teaching strategies that enhance connectedness with nature.

Procedure to be followed: Your child will take a survey to assess his/her perceptions of nature. Following the survey, each participant will engage in a short interview with the researcher. Results from survey and interview will be compared to semester averages in previous science courses (biology, chemistry, and physics) to examine possible associations between these variables. The researcher will also collect residence data (zip code) to determine if relationships exist between the greenspace surrounding a participant's home and their perceptions of nature.

Risks: There are no foreseeable discomforts or dangers to either you or your child in this study.

Incentives/benefits for participation: There are no direct incentives for student participation. Participants will explore and discuss their own learning however, and the results of the study will help us enhance science instruction to better meet the needs of students.

Time requirements: Your student will complete three surveys (5-10 min each) and will participate in one interview (5-7 minutes).

Statement of confidentiality: All records will be kept confidential and will be available only to the researcher. If the results of this study are published, the data will be presented in group form and individual participants will not be identified.

Voluntary participation: Your child's participation is voluntary. At the time of the study, your child will be reminded of this by the researcher. You or your child may terminate participation in the study at any time.

Questions: Questions or concerns regarding participation in this research should be directed to Scott Carter at scott.carter@mnps.org. This research has been reviewed and approved by the Metro Nashville Public Schools Research Review Committee. If you have questions about the study or its outcomes, please contact the MNPS Department of Research, Assessment, and Evaluation at mnps-rae@mnps.org.

Parent Signature
I, the parent or guardian of _____, a minor _____ years of age, permit his/her participation in the program of research named above.
Signature _____ Date _____

Student Signature
I, _____, agree to participate in the program of research named above and understand that my participation is voluntary.
Signature _____ Date _____

APPENDIX E

NATURE RELATEDNESS SCALE

Nature Relatedness Scale

Directions: For each of the following, please rate the extent to which you agree with each statement, using the scale of 1 to 5 as shown below. Please respond as you really feel rather than how you think "most people" feel.

1 Disagree Strongly

2 Disagree a little

3 Neither agree nor disagree

4 Agree a little

5 Agree strongly

1. _____ I enjoy being outdoors, even in unpleasant weather.
2. _____ Some species are just meant to die out or become extinct.
3. _____ Humans have the right to use natural resources any way we want.
4. _____ My ideal vacation spot would be a remote, wilderness area.
5. _____ I always think about how my actions affect the environment.
6. _____ I enjoy digging in the earth and getting dirt on my hands.
7. _____ My connection to nature and the environment is a part of my spirituality.
8. _____ I am very aware of environmental issues.
9. _____ I take notice of wildlife wherever I am.
10. _____ I don't often go out in nature.
11. _____ Nothing I do will change problems in other places on the planet.
12. _____ I am not separate from nature, but a part of nature.
13. _____ The thought of being deep in the woods, away from civilization, is frightening.
14. _____ My feelings about nature do not affect how I live my life.
15. _____ Animals, birds, and plants should have fewer rights than humans.
16. _____ Even in the middle of the city, I notice nature around me.
17. _____ My relationship to nature is an important part of who I am.
18. _____ Conservation is unnecessary because nature can recover from any human impact.
19. _____ The state of non-human species is an indicator for the future of humans.
20. _____ I think a lot about the suffering of animals.
21. _____ I feel very connected to all living things and the earth.

APPENDIX F

STUDENT INTERVIEW

Student Interview

Researcher: This interview is an important component of my research into how connectedness to nature affects learning in science. I will write down key points during our discussion. Your name will not be used in the study and your responses will never be shared. Please try to answer the following questions as honestly as possible.

Question 1:
In a normal week, how much time do you spend outside? In what outdoor activities do you participate?

Addresses: Research Question, Sub-question 1

Question 2:
How would you describe the greenspace near your home? About how close is the nearest park?

Addresses: Sub-question 1

Question 3:
Identify regular interactions you have with plants or animals (EX: watering plants, fishing, pets).

Addresses: Research Question, Sub-question 1

Question 4:
Describe 1-2 positive experiences in nature. Who was involved? How old were you?

Addresses: Research Question 1, Sub-question 1

Question 5:
Did these experiences make you feel more connected to nature? If so, how?

Addresses: Research Question 1, Sub-question 1

Question 6:
Have your experiences outdoors helped you better understand concepts and skills taught in science class? If so, provide an example.

Addresses: Research Question 1

Question 7:
When taking a science class, do you have an interest in understanding the deeper meaning behind scientific concepts?
Or do you just study the vocabulary and concepts required to pass?
Does this vary depending on the class/content?

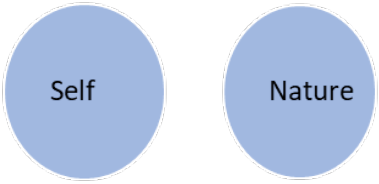
Addresses: Research Question 1

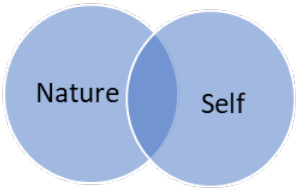
Question 8:
Your score on the Nature Relatedness Scale was _____. The class average was _____. Do you think your score accurately represents your feelings, beliefs, and attitudes toward nature?

Addresses: Research Question 1

Question 9:
Examine the three visuals below. Which most accurately describes your relationship with nature? Why did you choose this visual?

Addresses: Research Question 1





APPENDIX G

MUIR MAP RUBRIC

Muir Map Rubric

Category	Excellent (4 pts)	Good (3 pts)	Emerging (2 pts)	Needs Improvement (1 pt)
Environmental Science Content	Includes 6+ environmental science concepts	Includes 5-6 environmental concepts	Includes 3-4 environmental concepts	Includes 1-2 environmental concepts
Interdisciplinary Content	Includes 6+ interdisciplinary concepts	Includes 5-6 interdisciplinary concepts	Includes 3-4 interdisciplinary concepts	Includes 1-2 interdisciplinary concepts
Organization	100% logical connections between central theme and concepts	76% -99% logical connections between central theme and concepts	51-75% logical connections between central theme and concepts	50% or less logical connections between central theme and concepts
Personal Connection	3-4 well written sentences describing direct/indirect personal connection to the central theme	2-3 good sentences describing direct/indirect personal connection to the central theme	1-2 sentences describing direct/indirect personal connection to the central theme	1 or less sentences describing direct/indirect personal connection to the central theme