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Increasing High School Students' Environmental and Scientific Literacies Through Outdoor Investigations

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Increasing High School Students' Environmental and Scientific Literacies Through
Outdoor Investigations

by

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A capstone project submitted in partial fulfillment of the requirements for the degree of
Masters of Arts in Education: Natural Science and Environmental Education.

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CHAPTER ONE

Introduction

Introduction

The goal of this capstone is to assist in solving the question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* As an environmental science educator, I wholeheartedly believe that it is our duty to foster a connection between nature and our students. Often have I seen a lack of understanding of the world around us online and even from my own AP environmental students. We are at a critical time period in human history where the decisions we make within the next five to ten years can impact the climate and landscape of the Earth for generations to come. To me it seems like there is an apathetic viewpoint of the environment with people because they simply do not understand how humans can influence and affect something as complex as the environment. To alleviate this pandemic of environmental misconceptions; we need to show our students the beauty of nature and teach them how humans have impacted the entire planet while thinking critically. Achieving this goal requires students to get outside in nature and conduct hands-on research and investigations.

From my experience as an educator, I have noticed that students work best in engaging environments that provide hands-on learning experiences. It is equally important for students to have dedicated classroom and instructional time to learn important environmental concepts, but they also need to get outside in nature to fully grasp and comprehend the intricacies of their ecosystem. Not only does getting the

students outside help develop scientific literacy by conducting field investigation, but also helps to promote a passion for nature and the world around them. With the newly developed understanding of nature, the students will be more inclined to make informed decisions regarding the health of the environment and also become advocates for its protection.

My overarching goal of this project is to create different outdoor investigations for educators to help provide the first steps in getting the students out of the classroom and into nature. The activities listed will be about three main systems of Earth; air, water, and soil. With these three, the students will have adequate information about how these processes function, how anthropogenic activities affected them, and most importantly, ways we can preserve and restore them.

For the next section of this chapter, I discuss the experiences that led me to become an educator, and how my passion for the environment influences my teaching and desire to promote scientific/environmental literacies. Lastly, I summarize my capstone goals and provide an overview of the remaining chapters in this project.

My Background

I was lucky to have been exposed to nature early on in my childhood. One of my favorite memories growing up was spending time at my grandpa's lake house on the shores of Lake Michigan. I remember one particular aspect of visiting the beach every summer was the differences in how far the beach would extend and retreat. Although I had no idea why this was happening, it was always interesting to me to see what would happen next year. I remember seeing these small wooden fences with around 2-3 inch

gaps between the stakes all around the beach. Little did I know, but that would be my first experience with a technique used to protect the environment.

All throughout high school, I knew I wanted to be a teacher. The only issue was I had no idea what subject I wanted to teach. During my junior year, I started to lean towards being a history teacher, but that changed when I took Earth Science with Mr. Pedersen. This class was different for me. I found myself actually trying to learn as much as possible about the subject. It was fascinating to start to achieve just the basic understanding of our Earth and how it functions. The standout topic for me during that class was geology. There was a rock and mineral identification lab that became such a core memory. I remember conducting different mineral identification tests and determining which unknown mineral our group was given. I have always been a big fan of puzzles and turns out mineral and rock identification is a puzzle in itself. Even to this day this lab is even my favorite to teach to my students now. Nonetheless, this was a class special to me and I instinctively knew I wanted to become an Earth Science teacher.

Flash forward three years and I am starting my sophomore year majoring in earth and space science education. During my fall semester, I had two classes that stood out to me, sedimentology and mineralogy. In sedimentology, we took a deep dive into weathering and how different rocks are formed, and in mineralogy, well I am actually still confused on that topic to this date, but these classes stood out to me for a reason. I spent countless hours in the lab classroom trying to figure out and identify different rock samples, but I enjoyed every minute of it. These were the first classes in college that required me to do hands-on investigations. I realized that in order to have the material meaningful and impactful, a hands-on approach is often the best way to achieve this.

In college, I learned two valuable lessons about teaching that will stick with me forever. We discussed the first, but now let's discuss the second lesson. In my second semester during the same year, I had my first college field trip. We visited the Garden of the Gods in Shawnee National Forest in Southern Illinois. This trip was exciting to me because this was the first time ever in my life I was conducting field investigations outside in a brand new environment. We would draw our own cross-sections of different outcrops we investigated and the structure of the overlaying rock strata. While investigating an oil field, I found a sample of shale that formed with gas bubbles trapped inside. Even now when I would chip off a piece of the rock; you could still smell the gas. This whole trip meant a lot to me. I really discovered that getting outside in nature was a true passion of mine, and that field trips are a great way to build memories and get students engaged in scientific practices.

After graduation I was ready to start teaching and utilize the two key lessons that I discovered through my major classes, hands-on activities help build understanding and field trips/outdoor opportunities reinforce the content and promote ways for the students to get immersed in nature. Unfortunately, my first two years of teaching I did not have a class that would allow me to get the kids outside, but that all changed when I had the opportunity to teach AP environmental science. The current AP teacher was retiring and my school needed someone to fill in; all I had to do was pass the content test. During my college courses, I rarely looked into the impact that humans have caused on our environment. However, this test gave me the chance to actually have a deeper understanding of anthropogenic climate change and how devastating humans are to our planet. I feel like my background in earth science allowed me to see the content in a

different light. I had a fairly good understanding of all the systems that make Earth habitable, and honestly I started to get terrified after realizing how fragile our ecosystem actually is with all the damage we are causing.

This process was my first glimpse into environmental science and where my passion started. I am nowhere close to mastering the content, and every year I learn more and more about the intricacies of our Earth and absolutely love it. Getting the opportunity to teach AP environmental really changed my life. It is an absolute joy to teach this content to my students. In the past couple of years while teaching this subject I have incorporated fun hands-on activities for my kids. My next step is to develop field trips and outdoor investigations that not only develop the students' environmental literacy and critical thinking skills, but also a fun way for the students to get involved and connected to the material. All of this will help me achieve my goal of creating environmentally literate students that will fight for ecojustice and will fix the environmental mess that individuals before them have caused.

Professional Application

As mentioned above, I am currently an AP environmental teacher in the Chicago suburbs, and just started my fourth year teaching this subject. Every single year, I feel that I am getting stronger and stronger with the material and am currently at a place to really achieve my goals. I have three goals that I want to accomplish with teaching this course. First, I want my students to improve their environmental/scientific literacy. Luckily, I teach in a state that has standards that include environmental education. However, from a study conducted with elementary schools, they found that students on average are only exposed to about 20 to 100 minutes of environmental education a year

(Young & LaFollette, 2022). From an educator standpoint, that is not enough time to fully teach the complex concepts that are included in environmental education. Second, I hope to instill a passion for nature and create advocates for its protection, and lastly, I just want my students to have fun and enjoy the content. With the ideas I have for this capstone project, I think I will definitely be one step closer to achieving this dream; it all starts with getting the students involved and outside.

The outdoor opportunities that I will create for this capstone project will allow my students to get the outdoor experiences that will build everlasting passion. I know I may not be able to achieve the passion part with every student, but if I can just increase their knowledge of their own ecosystem then maybe they can make the right decisions in their life to help decrease their own ecological footprint. In a study conducted by the National Environmental Education and Training Foundation, they found that environmentally literate individuals are more likely to make environmentally friendly decisions during their daily routines (Coyle, 2005). In order to accomplish this, I need to create three field trips that promote scientific investigations that allow the students to get into the field and see the systems of nature first hand. I plan on hitting the three of the main systems/resources that we take for granted every single day; water, soil, and air.

For my water quality outdoor investigation, the students will be conducting water quality samples of a nearby stream. During the activity, the students will be right in the field conducting different tests to see how healthy the water in the stream is, and how that will impact the overall health of the ecosystem. The students will learn that without water there is no life, so the protection of our most sacred resource is extremely important. My second lesson will be more of an ongoing outdoor investigation where I plan on having

the students look into the quality of soil around the school, their homes, and the community. Perhaps at the end of this investigation, the students could even share their data with city hall to help increase soil awareness with the rest of the community. However, if they just discover that soil is the foundation for life on land, and how to maintain it then I will at least be happy with that outcome. My last investigation will involve my students testing air quality. I am still working through the details on this activity, but my outcome is for the students to understand how air quality is directly related to human health.

All in all, I will use the information that I will learn and resources that I create to help pass on my passion to my students. My goal is to build a new generation of environmental advocates that will fight for an environmentally literate society that values science and exploring all possibilities. On a more personal and professional level, I am excited to achieve the missing piece of the two teaching lessons I discovered during my undergrad. The students need field experience to not only learn more about scientific investigations, but just to get outside. Often I hear my students talking about their weekends that just involved being inside watching tv or playing video games. I want my students to become inquisitive and start to question how everything is interconnected, and how one grain of sand in the hypothetical gears of Earth could throw the whole system out of balance. Selfishly, with getting my students outside to conduct outdoor investigations, I also get to get outside of the classroom and experience nature. Everyone needs to go out and explore nature to fully get a grasp on how important and surprisingly frail it really is.

Positionality

It is important to note that my own experiences with the environment will be different than many of my students and colleagues. I am a white middle-class male in my late twenties that grew up in a diverse suburb of Chicago. I have had the opportunity to travel around the United States visiting various state and national parks along with traveling out of the country to Panama. When approaching the topic of environmental education, I realize my biases towards Illinois' continental climate which experiences all four seasons.

My environmental lens has also been shaped by my experiences as an able-bodied person who has plenty of chances growing up to explore the outdoors. I acknowledge that not every student or individual I encounter will have the same life experiences and perspectives regarding nature and environmental education.

Summary

Throughout this chapter, my capstone project has been focused around the question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* A brief overview of the following things were discussed, the three outdoor field trips I plan to create, how I got into environmental education, my passion for the environment, and my goals for my future students. As previously stated my overarching goal is to create resources for educators to help provide the first steps in getting the students out of the classroom and into nature.

Moving forward, Chapter Two will take a deeper dive into the reasons students need outdoor education and how that can help facilitate passion. This chapter will also

contain different techniques that teachers have used to increase environmental and scientific literacies with a hands-on approach, and also present the background knowledge of why learning about water, soil, and air are important pieces of the ecosystem that every student should have a basic understanding of. Chapter Three will provide my step-by-step process for the creation of the field trips/scientific investigations that my students will be conducting. Another important part of this chapter will be how these investigations could fit into anyone's environmental curriculum. Lastly, Chapter Four will include a reflection piece on the field experiences for the students, and how I could possibly make them more effective in the future. Also, I will include any limitations and difficulties I had while creating the activities while explaining the most effective ways to utilize the documents that will be included.

CHAPTER TWO

Literature Review

Introduction

“Acts of conservation without the requisite desires and skill are futile. To create these desires and skills, and the community motive, is the task of education.” (Leopold, 1944, as cited in Coyle, 2005, p.ii) This is a quote from one of the leaders of the conservation movement. Even in the 1940s, people knew that one of the only ways to protect the environment is through education. In the past 80 years, the world has drastically changed from overpopulation to overconsumption. Something has to be done to fix this problem and education is the answer. Due to population growth and the resulting need for additional resources, it is even more crucial to foster appropriate environmental education and raise individual awareness for the consequences of our everyday choices that influence our ecological footprint. (Bissinger & Bogner, 2017)

Below will be a review of literature that helps answer the research question, *how can high school science teachers improve students’ environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?*

The following literature review discusses how outdoor hands-on investigations can increase student’s environmental and scientific literacies, along with digging into the benefits of getting students outside out of the classroom and into nature. Lastly, this chapter will give a basic understanding of three different environmental science concepts that any environmental literate individual should understand.

Techniques to Improve Environmental Literacy

In environmental education, an important objective has been the promotion of environmental literacy with an idea that environmentally literate citizens would be able to behave in a responsible manner, respecting the environment. As a whole, environmental literacy has various definitions but is commonly described as carrying environmental knowledge, awareness and concern (Hares et al., 2004). All in all, environmental literacy is knowing how humans have impacted the ecosystem and understanding how economics is one of the greatest determinants in how society advances – for the good of the environment or not. With proper environmental education, people can begin to grasp the notion that our everyday actions can be detrimental to our planet. One example of environmental literacy is knowing that the combustion of fossil fuels releases carbon dioxide as a by-product. Since carbon dioxide is a greenhouse gas that acts by trapping and reflecting heat as it gets radiated out into the atmosphere from the Earth; more carbon dioxide means an increase in global temperatures. Knowing how Earth's systems function is a fundamental part of environmental literacy. The University of Connecticut's School of Education identified the five steps of becoming an environmentally literate person termed the environmental literacy ladder is as follows...

- 1) Awareness of the relationship between the environment and human life
- 2) Attitudes of appreciation and concern for the environment
- 3) Understanding of human and natural systems and processes
- 4) Problem solving and critical thinking skills
- 5) Capacity for personal and collective action and civic participation (DeFelice et al., 2016, p.1).

Environmental literacy has been identified as the point of inception to bring a change and form a positive and close nexus between environment, education and health (Biswas, 2019). With proper environmental education, individuals can begin to develop a deeper understanding of the world around them and make informed decisions about its protection. In a research study done by the National Environmental Education and Training Foundation using the same definition of environmental literacy as previously stated, they found that environmental literate people are 10% more likely to save energy at home, 10% more likely to purchase environmentally friendly products, 50% more likely to recycle and 50% more likely to avoid using chemicals in yard care (Coyle, 2005). These numbers are not where they should be, but it goes to show that having environmental knowledge does lead to more environmentally friendly decisions. Real change usually emerges from educational strategies that give the learning a sense of involvement and ownership (Coyle, 2005). This idea follows the second step of environmental literacy with getting students outside into nature to create the human-nature connection and building the next generation of environmental advocates.

An emerging practice to help students understand the world around them while completing the five steps of environmental literacy is place-based education. According to David Sobel in his book published in 2005:

Place-based education is 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 subjects across the curriculum. Emphasizing hands-on, real-world learning experiences, this approach to education increases academic achievement, helps students develop stronger ties to their community,

enhances students' appreciation for the natural world, and creates a heightened commitment to serving as active, contributing citizens. Community vitality and environmental quality are improved through the active engagement of local citizens, community organizations, and environmental resources in the life of the school (Sobel, 2005, p. 7).

Place-based education has incorporated almost all of the five steps of the environmental literacy ladder. One of the biggest pushes in environmental education is just getting the students outside. Students that spend more time outside in their own communities more often become more responsible and active citizens towards its protection (Palmberg & Kuru, 2010; Hungerford & Volk, 1990). Place-based education is about getting students connected within their own communities, physically and culturally (Gruenewald & Smith, 2014). Another framework of environmental education is environment as an integrating context (EIC), is about getting students outside in nature and having them construct their own learning using the environment as a medium (Lieberman & Hoody, 1998). Even though EIC is not directly about increasing environmental awareness or learning about the environment like place-based education, the principle of getting students out of the classroom can still be applied. There is no one size fits all approach when it comes to environmental education. Different bits and pieces from different frameworks can be applied to achieve the same end result of getting students outside into nature in their own communities. Combining both traditional settings and outdoor classrooms is one way to increase environmental awareness and literacy. Children have to be exposed to a variety of environmental education materials and strategies in order to improve environmental literacy (Chu et al., 2007). This could look like learning a concept

in the classroom and then using that new knowledge to conduct outdoor investigations. Not only can outdoor investigations increase students' environmental literacy which has been described as increasing an individual's knowledge, awareness, and concern for the environment, but also students' scientific literacy as well. The programme for international student assessment (PISA) defined the three competencies of scientific literacy as

- 1) Explaining phenomena scientifically
- 2) Evaluating and designing scientific enquiry
- 3) Interpreting data and evidence scientifically (OECD, 2018, p.99)

What does it mean to explain or interpret something scientifically? According to Merriam-Webster the meaning of scientifically is to conduct in a manner of science or according to results of investigation by science; practicing or using thorough or systematic methods (Merriam-Webster, 2022). Scientific literacy problem solving and investigating everyday phenomena using the scientific method. A scientific literate person should be able to question the world around them and make informed decisions about what has been investigated (Pereira et al., 2019). Science education helps promote the development of scientific skills such as observing, predicting, and explaining. These are essential for one to be considered scientifically literate. Science education promotes the development of scientific reasoning skills and early exploration of scientific phenomena helps promote more scientific understanding later on in life (Eshach, 2006). From the reason above, getting students outside of the classroom and into nature to conduct scientific investigations is a great technique for high school environmental teachers to increase their students' environmental and scientific literacies.

Outdoor Experiences for Students

In our current day of age, students are consistently using their phones or other electronic devices instead of actively engaging in the world around them. Students are moving indoors at a vital time in their growth and development when the evidence-based suggests they would benefit from time outdoors (Mann et al., 2022). Not only does phone use limit the opportunities for children to get outside and play, but it is also causing issues with social interactions. Frequent cell phone use is likely to increase children's social isolation and hinder opportunities for social interaction, both of which promote social development (Hosokawa & Katsura, 2018). In a study done in 2019, researchers found that there is an indirect relationship between cell phone use and outdoor exposure. They found that 75% of the participants from different backgrounds in 6th to 8th grade had 30 minutes of screen time each day, with 43% having more than two hours (Larson et al., 2019). It is evident that students are not spending enough time outdoors to learn and discover the beauty and benefits of getting outside (Stiglic & Viner, 2018; Paulich et al., 2021; Soga & Gaston, 2016). Students need outdoor opportunities implemented in their everyday lives. Having access to open and natural spaces supports improved physical health and beneficial effects on cognitive and mental health (Mann et al., 2022). Not only does getting students outside help to alleviate the ongoing health issues of chronic electronic use, but it engages them in a world they are not familiar with. Since students have spent so little time outside, they have begun to develop a view of the outdoors as being remote, mysterious and frightening (James & Williams, 2017). Outdoor opportunities for students are a great start to get students off of their electronics and out into the natural world. They will begin to learn new skills, explore new areas, and just

overall establish a sense of peace and belonging. As another benefit, the students get to experience nature instead of being confined to a classroom. An outdoor field-based study involving middle school students had positive experiences about being outside instead of a classroom (James & Williams, 2017). A couple quotes from the students themselves, “It is a wonderful way to learn because you get fresh air and you’re not cooped up in a classroom” and “We didn’t just get data from some worksheet; we saw how the data was collected, and that makes it much more meaningful” (James & Williams, 2017, p.64). Getting students outside has immense benefits such as building a sense of identity, life ownership, stress relief and beneficial impacts for mental health and well-being to name a few. (Mann et al., 2021). Besides the added social-emotional well-being, field trips also break up the mundane routine of students going from classroom to classroom.

Getting students outside of the classroom and into nature can have many positive health and mental benefits like mentioned above, but another positive outcome is getting students connected to nature. There is a term called “biophilia” which was coined by the biologist Edward O. Wilson in his book *Biophilia*, which is the urge to affiliate with other forms of life (Wilson, 1984). Getting students outside is important because they get to learn and experience a whole other world that kids nowadays are not experiencing. Humans have evolved from nature and need to keep harmonic balance with it. Unfortunately, students spend more time inside and living in urban areas than previous generations (Capaldi, 2014). This is detrimental to understanding how the natural world works. Living in urban areas, society is closed off from nature and experiences just a fraction of what is actually out there. People who do not spend time in nature will not understand the intricacies of the environment. They will not feel like it is their

responsibility to do anything to protect it. The more time people spend in natural environments, the more they will have an increasing sense of connectedness to it (Berto, 2017). Getting students outside in nature should be the number one priority of any environmental class. Most environmental programs put emphasis on environmental problems like pollution and climate change rather than letting learners appreciate the beauty (Cho & Lee, 2017). It is extremely important to learn about the anthropogenic issues that are plaguing the world, but it is even more important to get out into nature and learn from hands-on experiences how nature actually works. It is one thing to learn about concepts from a textbook, but to see the cyclical patterns in person makes one understand so much more than a book or lecture could provide. With the outdoor experiences, the students begin to develop their environmental literacy by seeing the world with their own eyes (Soga & Gatson, 2016).

All in all, outdoor experiences are a must for any environmental student. A study completed within the past couple of years concluded that natural environments have a medium to large effect on increasing positive emotion and decreasing negative emotions (Gaekwad, 2022). That in itself should be a deciding factor for any educator that is on the fence about conducting field experiences with their students. Not only will teachers be increasing the mental health of students, but also getting them outside can help promote more environmental literacy. Hands-on outdoor fieldwork investigations are effective especially since they reinforce what students have been learning in class (Fuller et al., 2006). When immersed in nature, individuals more fully attend to the characteristics of their surroundings, they recognize and contact more aspects of the natural environments (Berto, 2017). There are a lot of positives about getting students outdoors, but there are

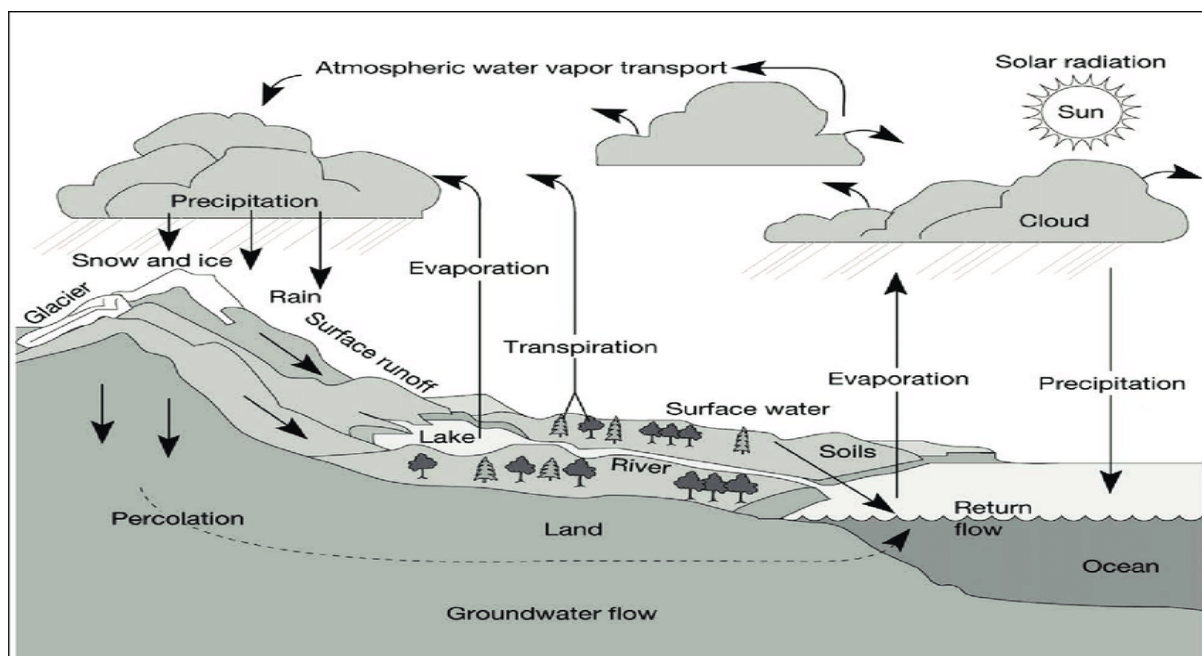
also some downsides that might steer teachers away from implementing outdoor investigations in their curriculums. For starters, outdoor investigations can be time consuming and costly (Prince, 2020). Field trips are a great way to expose students to different aspects of nature that they normally would not see, but the cost of these trips are increasing. With increased costs due to inflation and time requirement to plan field trips many teachers have shifted towards other resources to help students instead (Kenna, 2019). However, a teacher does not need to take their students to a different location just to conduct outdoor investigations. Outdoor investigations or just simply getting the students out of the classroom can be done anywhere. They could be as simple as walking around the school or conducting biodiversity research on school grounds. Overall, the positives mentioned above outweigh the few negatives that are associated with outdoor investigations. Increasing student performance and socio-emotional health are worth all the time in the world for teachers.

General Background on the Water Cycle, Soil, and Atmosphere

Before students increase their environmental literacy there has to be some previous environmental knowledge. “Knowledge is a critical tool for understanding and investigating environmental and sustainability issues as well as providing a foundation for decision-making and problem solving. As a dimension of environmental literacy, environmental knowledge represents the cognitive elements of environmental literacy” (Green & Baek, 2022, p. 8). Below will be three different Earth’s systems that students should have a basic understanding for in order to achieve better environmental literacy.

The first system that will be looked at is the water cycle. The water cycle is a worldwide system that is powered by solar radiation from the sun (Tarbuck & Lutgens,

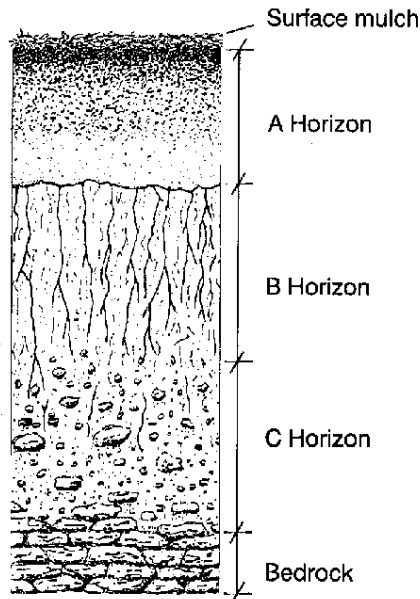
2017). Water will continuously flow and recycle throughout this whole cycle, there is no beginning or end (see Figure 1). Students need to know three main pieces of the water cycle puzzle, with evaporation and transpiration being the first. Evaporation is defined as the process by which liquid water changes into water vapor; surface water enters back into the atmosphere. Transpiration is when the water the plants take in through their roots is exited back into the atmosphere as well. Runoff is the next important concept and the simplistic definition is the flow of water on the surface back to the oceans. The last big concept is how water enters into the ground. Groundwater is one of our most important freshwater sources and is essential for irrigation (USGS, 2018). When water first reaches the ground from precipitation, some of that water will infiltrate into the soil. Infiltration is when water will seep through pervious surfaces, such as grass, dirt, and other porous material. This allows water to enter back into the ground and help recharge aquifers that have been used to provide drinking water and irrigation for people all around the world. One of the biggest anthropogenic (man-made) issues that affect the water cycle is urbanization. With the increase of built-up land, especially non permeable surfaces such as blacktop, asphalt, concrete, etc. water cannot infiltrate into the ground. Non permeable surfaces instead increase the amount of runoff especially in urban areas which can lead to flooding and increase pollution (Marsalek, 2007). With having a basic understanding of the water cycle, students can conduct different water quality tests to make different hypotheses on what could be affecting water quality. However, understanding the flow of water above and below Earth's surface is essential before any proper field investigations can be properly implemented.

Figure 1*Water Cycle*

Note: This illustration shows the flow of water above and below the ground. (Berg et al., 2007).

The next essential concept that will be explored is soil and soil conservation. Soil is vital for agriculture as well as preserving our forests. Soil is not just lifeless dirt, but an interconnected system of weathered rock, organic matter, water, air, nutrients, and microorganisms (Withgott & Laposata, 2014). Soil is a renewable resource, but if not maintained properly could cost humans billions of dollars (Thaler et al., 2021). Soil takes hundreds to thousands of years to form depending on the environmental conditions. The formation of soil first must begin with the weathering of parent material. This is the breakdown of the bedrock that can be shown in Figure 2. Overtime organisms die and decompose which deliver nutrients that are essential for microorganisms and the growth of any plant. To fully understand soil, one needs to understand soil horizons (see Figure

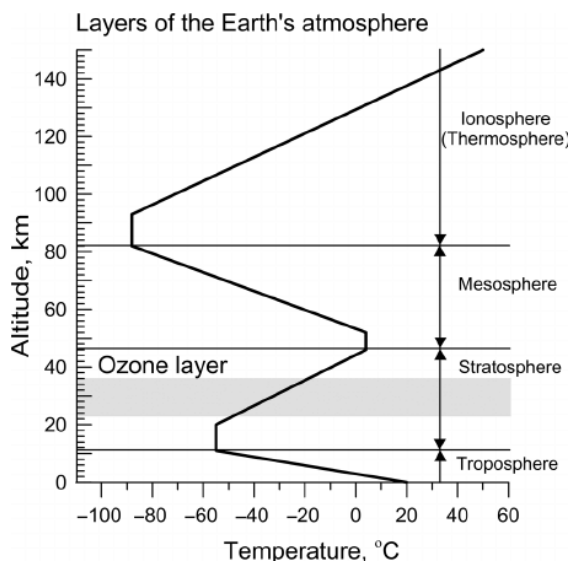
2). Each layer represents different components of soil. The first layer, O-horizon/surface mulch, is the organic layer of soil such as leaf litter, and other organics deposited by organisms. Below that is the A-horizon, this layer is the topsoil. Fundamentally the most important layer because it is home to the majority of the nutrients and mineral components that healthy soil requires. Organic material and nutrients can be leached from the A-horizon to the B-horizon subsoil. Lastly, above the bedrock (parent material) is the C-horizon. This layer holds remnants of partially weathered parent rock. An important soil quality test for students is figuring out the soil texture. Soil texture is determined by the size of particles (sand, silt, and clay). Each of these particles have different qualities that can either benefit or hinder the growth of crops. Sand, the largest sized particle, does not hold water easily which explains why not a lot of vegetation can grow in sand. However, topsoil loss is a growing issue in America. Soil erosion, the wearing away of soil by water, wind, and other forces is a natural process that is being accelerated by human activities (Magleby et al., 1995). One of these processes is tilling. Tilling refers to the process that cultivates the land for crops. This process breaks down root structures that are in the soil which act like anchors to trap the soil in place. Without this support system the soil is prone to erosion (Withgott & Laposata, 2014). With having background knowledge on the basics of soil, students will be able to conduct different soil quality tests along with hypothesizing while different soils are more effective for producing crops.

Figure 2*Soil*

Note: This image displays the different layers of the soil. This cross section would only be around a meter deep (Hendrickx et al., 2003).

The third system that will be looked at is the atmosphere. The atmosphere is essentially a blanket of gas that protects us by trapping heat and making liquid water possible (Buis, 2019). The atmosphere retains solar heat, protects us from deadly radiation in space, and distributes the water that makes up the majority of our bodies (Cunningham & Cunningham, 2018). The atmosphere is divided into four distinct layers, with the closest to the Earth's surface being the troposphere and the farthest being the thermosphere. The layers are separated by changes in temperature (see Figure 3). In the troposphere, temperature decreases as altitude increases which is exactly opposite to the stratosphere where temperature increases as altitude increases. All weather occurs in the troposphere due to convection. Convection is a transfer of energy by the flow of a heated

substance (Hess et al., 2005). As air near the surface gets heated it begins to rise just like water in a boiling pot. However, since the temperature in the stratosphere is warmer than the troposphere the rising air from the surface cannot pass the boundary between the two layers. This phenomenon is the reason the troposphere accounts for essentially 100% of all water vapor (Cunningham & Cunningham, 2018). This movement of air is how pollutants and greenhouse gases that are released during the combustion of fossil fuels enter into the atmosphere. Gases like carbon dioxide and methane are two of the main byproducts of fossil fuel combustion which enhance the greenhouse effect. The greenhouse effect is the natural heating of Earth's surface by certain gases, which helps keep the Earth warm enough to sustain life (Hess et al., 2008) The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases (NOAA, 2022). These increases can be attributed to our natural lifestyle of burning fossil fuels for transportation, electricity, and industrial processes. With understanding the different layers of the atmosphere and the fluctuations in temperature, students will be able to conclude how pollution from one general area can transport to various different regions. Another aspect of the atmosphere that will help students improve their environmental literacy is convection currents and how weather does not take place above the Troposphere. With all this known beforehand, students' investigations will be more about problem solving instead of learning the fundamental concepts.

Figure 3*Layers of the atmosphere*

Note: This figure shows the different layers of the atmosphere. The Y axis represents altitude from the surface and the X axis represents temperature. Notice that the different layers are influenced by if the temperature is either increasing or decreasing (Kalita & Titlyanov, 2013).

Summary

The literature reviewed in this chapter provided context for the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* This chapter began by reviewing what environmental and scientific literacy is and how there is a direct link between knowledge of the environment and stewardship. Students also need access to outdoor places to improve their socio-emotional health and to see the world in a different perspective besides just being

stuck in a classroom. Lastly, general scientific information was shared about the three main concepts, water cycle, soil, and the atmosphere.

The following chapter will go into detail on the project description that aims to help solve the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* A timeline, target audience description, outdoor investigation incorporation, and main takeaways will be discussed in detail.

CHAPTER THREE

Project Description

Introduction

In the previous chapter, I discussed the importance of environmental literacy and getting students outside of the classrooms along with basic information on science concepts that students need to know. The purpose of this capstone project is to develop different outdoor field investigations that high school environmental teachers can use with their classes to get them outside into nature conducting hands-on experiments while increasing their environmental literacy. Environmental literacy has been identified as the part of inception to bring change and form a positive connection between the environment, education, and health (Biswas, 2019). The resources created will help answer the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?*

The chapter begins by describing the guiding principles behind the rationale for the creation of the project focusing on the importance of environmental literacy and how getting students outside can increase their stewardship towards the environment. This is followed by the project description, the grade level this project is designed for, a timeline for teachers to follow for proper implementation, and an assessment piece to make sure that students' environmental literacy has actually increased.

Guiding Principles

Rationale for this project came about during the literature review in chapter two. There are two themes behind the designs of the outdoor research investigations that the

students will be conducting; how to increase the environmental literacy of students and how to increase the human-nature connection. Environmental literacy has been defined as having knowledge, awareness, and concerns about the environment (Hares et al., 2007). In order to achieve this goal students are getting out of the classroom and into nature to conduct hands-on investigations. This opportunity allows the students to be exposed to environmental education material inside the classroom and out. The more time students spend in nature can help improve their environmental literacy (Chu et al., 2007). The hands-on investigations are designed to have the students think critically and develop a sense of the world around them. Also, another goal of the project was to get students outside in nature at a time of their life when kids are spending more and more time indoors compared to other generations (Capaldi, 2014). Spending time inside and learning from a textbook or watching a documentary is one thing, but experiencing nature firsthand is essential. Outdoor exposure is essential to help foster the human-nature connection (Berto, 2017). The design of the project includes both of these themes to help improve the environmental literacy of high school students.

The next part of this chapter describes the three different investigations that were created to help solve the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?*

Project Description

The project was broken down into three different outdoor investigations that are focused on different systems of our natural world including the water cycle, soil, and the atmosphere. Each of the different outdoor investigations described below will contain

lesson description, type of tests, setting, and can be done at any time in the curriculum. The timeframe for each outdoor investigation is around five 50-minute class periods.

Water Cycle

The first investigation is focused on determining water quality. During this outdoor investigation, students will be conducting various water quality tests on a stream or river that is on campus or classes can take a field trip to a local body of water. Once the students arrive at the stream they will begin by taking field notes and documenting their observations. After that the students will begin conducting their water chemistry tests by looking at the pH levels, nutrient levels of nitrates and phosphates, dissolved oxygen amount, temperature, etc. The next set of tests the students will be conducting are geology based with looking at the stream flow, discharge, turbidity, etc. The biggest part of the outdoor investigation is seeing if their initial hypothesis of if the water is safe for aquatic organisms and human consumption were correct.

Soil

The second outdoor investigation that the students conducted is a soil quality experiment. The purpose of this experiment is to determine the soil quality on school grounds. This can help implement future programs such as the potential to have a school garden. The first couple of class periods were used in class to teach the students the basics of soil, and focusing on how important soil health is for human life. After the students got their understanding, we went outside on school grounds to take different soil samples. Students took two different samples of soil from two different ecosystems to find differences. Students conducted various

different tests on-site such as soil temperature, pH, and nutrient levels. Students also drew field sketches to remember exactly where they got their soil samples from. The next couple of class periods the students conducted in class soil tests using the samples they gathered the previous day. Students were looking at the porosity, permeability, and soil textures to help determine soil quality and if the soil is adequate for growing any plants.

Atmosphere (Air Quality)

The last outdoor investigation that was designed had students conduct two different air quality tests. This is the shortest of the three outdoor investigations with only four class periods. The first day was spent in the classroom going over important information. General information about the atmosphere was already taught towards the beginning of the year. The outdoor investigation took two class periods. The first class period, the students set-up their air quality test kits which included two petri dishes with a small amount of vaseline to collect air particulates. After the students constructed their apparatus, they placed them around the school grounds. The second air quality test was conducted the following class period. This investigation was different from the other because all students were working together as one big group. They had sealed ziplock bags of BromoThymol Blue, which is an indicator solution for carbon dioxide concentration. The students put these bags on the exhaust pipes of cars to record which vehicles produced the most carbon dioxide emissions.

Setting/Audience

The setting for my project is a high school in the suburbs 30 miles west of Chicago. The school is decently sized and has 1,750 students ranging from 9th to 12th

grade. Fifty percent of the students considered low income and on free or reduced lunch. The demographics of the school are 65% Hispanic, 17% White, 8% Black, and 10% other/two or more races. On average there are about 20 students per adult at my school. I designed this project for my advanced placement environmental science students that are juniors and seniors. At my high school, there are about 500 students that are enrolled in one or more AP classes.

Timeline

The duration of my project will cover the course of the school year. The first and second investigations will take place during the fall while the last outdoor investigation covering air quality will be conducted in the spring. I selected this timeframe to match the already established AP curriculum from Collegeboard that I use for my class.

Implementation of the different outdoor investigations could be completed at any time.

Assessment

There are two pieces of information that I tested for during this project. Tested the overall improvement in environmental literacy and tested to see if outdoor experiences did change students' perspective on the environment. To test environmental literacy, I used the scores of the AP test that my students take at the end of the school year. The AP test is a standardized test created by Collegeboard to determine how well students understand the concepts they have been learning all year. To test the overall perception and opinion of the environment, I did that in class at the beginning of the year and at the end of the year with interest surveys. Each student was surveyed at the start before any outdoor investigations took place and then at the end to see the students' thoughts and perception about the environment has changed. Earlier in chapter two, I mentioned the

definition of environmental literacy that I used through this project. I stated that environmental literacy is having knowledge, awareness, and concern about the environment. The two assessments that were used covered all three of these. The Collegeboard AP test looked at students' environmental knowledge while the interest survey collected data and students' awareness of anthropogenic issues and concern for the environment. This data helped me figure out if the outdoor investigations made an impact on environmental literacy.

Summary

This chapter covered the project details that helped answer the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* The outdoor investigations that were discussed are designed to increase students' environmental literacy and overall appreciation for the environment by getting them outside into their local environment performing hands-on experiments. Additional details of the project were also discussed such as the target audience, setting, timeline, and different assessments that are used.

Chapter four will summarize various findings from the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* It will provide personal and professional reflection on the outdoor investigation design process, and as well discuss key resources used. Chapter four will also identify limitations, implications, and discuss future projects and questions.

CHAPTER FOUR

Reflection

Introduction

The overarching goal of this project was to design different outdoor investigations that high school environmental science teachers could use to help promote the human-nature connection with their students to help answer the research question: *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* Throughout this capstone process, I have discovered many different techniques that teachers can utilize to help their students understand the world around them. Also, I found out ways that I can help my own students learn more effectively, and always ways I can improve my own environmental literacy.

In chapter one, I shared my background with how I became interested and involved with understanding the environment. It was extremely beneficial to look back at some of my personal and professional experiences, and think of ways I could have done something different to better support my students.

In chapter two, I read a plethora of academic articles to discover and learn more about different techniques high school environmental teachers can promote a better understanding of our world while increasing environmental and scientific literacies. Later in this chapter, I will discuss the key resources that were extremely beneficial to the creation of my project.

In chapter three, I provided an explanation of the project that I created. In this chapter, teachers can read about the intended audience, evaluation, and just general aspects of the different lesson plans that will help students understand their Earth.

In this following chapter, I will discuss the resources that were beneficial to me while creating this project. After that I will mention the limitations I discovered while constructing the project. The next portion of this chapter will cover the implications and how students could potentially benefit from outdoor investigations. The final two sections will include future work that students could utilize after performing the investigations, and questions I thought of while working on this capstone. These components will provide a reflection on what I have learned during this project, and how it will impact my professional development as an educator.

Creating the Project

While developing the three different outdoor investigations, there were a couple of resources that really stood out to me and helped shape the design of my project. The first one being guidelines for an individual to become more environmentally literate created by the University of Connecticut School of Education. The environmental literacy ladder goes as follows..

- 1) Awareness of the relationship between the environment and human life
- 2) Attitudes of appreciation and concern for the environment
- 3) Understanding of human and natural systems and processes
- 4) Problem solving and critical thinking skills
- 5) Capacity for personal and collective action and civic participation

(Defelice et al., 2016, p.1)

When creating my three different outdoor investigations, I made sure to focus on the first section of the ladder which is essential for building the human-nature connection. All of the investigations focused on the students getting out into their particular ecosystem and learning the essentials of soil, water, and the atmosphere. With understanding the main components of nature, students are able to understand how their actions can impact the environment around them. After the students begin to understand how the environment works from the outdoor investigations then the students will have more concern and awareness for their actions. In David Sobel's book, he discussed the importance of place-based education. In place-based education, students become familiar with their surroundings and local environments (Sobel, 2005). All of the outdoor investigations can be completed at or near school grounds with the exception of the water quality testing which may need student transportation if a stream or river is far from school grounds. With having the outdoor investigations take place near the school, the students will start to become familiar with the environmental aspects of their own community. This is one of the first fundamental ways to increase one's environmental literacy, get them immersed in nature in a region they are familiar with. According to Berto, when immersed in nature, individuals more fully attend to the characteristics of their surroundings, they recognize and contact more aspects of the natural environments (Berto, 2017). Hands-on labs conducted in the classroom are also essential, however the students need to be physically outside to start to connect all the various intricacies in an outdoor environment. With the immersion of being out in the field, the students start to make observations and connections using all five of their senses that they normally would not be able to experience with classroom investigations alone.

Limitations

There are a couple limitations with the three outdoor investigations. The first being that three investigations alone are not enough to increase the students' environmental literacy. In 2007 Chu stated that students need to be exposed to multiple different environmental education materials in order to improve ones' environmental literacy (Chu, et al., 2007). Additional outdoor investigations are necessary to help increase students' environmental and scientific literacy, but these three outdoor investigations are a great place to start to begin getting students comfortable and familiar with their own surroundings.

Another limitation is weather. In the water quality investigation, there needs to be flowing water to take various tests. A frozen stream or river will not be ideal and would limit the amount of tests the students can actually conduct. Plus, if the weather is too cold, it could be potentially dangerous for the students and safety is the biggest priority. Same situation with the air quality test and soil investigation, if the ground is frozen then the students cannot dig and collect a proper soil sample to conduct the necessary tests. Also, with snow on the ground, water could get into the petri dishes of the airborne particulate matter investigation. Ultimately, any type of precipitation on the forecast would cause this study to become inconclusive. Also, some schools may not have adequate ecosystems on campus to conduct these investigations, so some teachers may have to take the students to an alternate site. By doing this the teacher will have to plan and organize a field trip while following the field trip policy created by their district.

Implications

After conducting these three outdoor experiments, the students will begin to understand the environment around them. In combination with the investigations with additional resources, the students will have an increased environmental literacy that they then can share with their friends and family with the hopes of creating more awareness for the protection of the environment. Another implication is the increase in critical thinking skills and problem solving. Even if the students that are enrolled in my AP environmental class do not plan on pursuing a career in any scientific field they can still learn lifelong skills. Every field and college major requires some sort of critical thinking. Besides the environmental knowledge the students will receive, they will also strengthen their problem solving and critical thinking that will have endless applications and benefits that will be with them throughout their lifetime.

Future Work

There is no “one size fits all” type of lesson in education. Every outdoor investigation, project, experiment, etc. needs to be altered to best fit your particular students. Same goes for the three different outdoor investigations that I created. Depending on the resources, certain aspects of the investigations may need to be changed in-order to achieve the best results for the students and community. After conducting any type of lesson there will be parts that need to be refined and altered. These investigations have not yet been conducted in the field yet with students, so the revisions that need to be altered are not yet known. However, these investigations are just the tip of the iceberg with what environmental teachers can utilize to provide the best experience to our students. I plan on sharing these three investigations with the other environmental science

teachers at my school and in my district. We can all work together to brainstorm the different issues or changes that we will need to make to the investigations to ensure that we are promoting the most environmental growth and challenge for the students as possible. Another plan in the future is to provide and create more outdoor investigations that get the students outside more often and can help promote an even greater understanding of the world around them.

Summary

This capstone project was designed to begin the process of increasing students' understanding of their particular ecosystem by answering the research question, *how can high school science teachers improve students' environmental and scientific literacy and help them understand their environmental impact through outdoor investigations?* I began this chapter by discussing the techniques that I have learned to help effectively teach my students and also different resources that I can use to increase my own knowledge of the environment. I also did a quick recap of the previous first three chapters. After that, I explained the resources that I thought were essential to the creation of my project, and how I used them to help increase the environmental and scientific literacy of my students. Another part of this chapter was discussing the limitations and implications of the three different outdoor investigations that were created. Lastly, I mentioned future work that will be necessary to promote the most environmental knowledge to students and how these investigations may need to be altered to best fit students in different environments and regions. Overall, these investigations in addition to other resources are a great step for any environmental science teacher to utilize with

the goal of creating environmentally literate students that will understand the importance of protecting our only planet.

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