SNOW SCIENCE: EXPLORING ECOLOGY AND ENVIRONMENTAL SCIENCE IN THE WINTER WITH OUTDOOR INQUIRY

by

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TABLE OF CONTENTS

CHAPTER 1

Introduction

Stuck Inside

It was early March when I fought my first battle with the climate of Northeastern Wisconsin. I was a first-year Ecology teacher, fooled by the sunshine and the melting snow into thinking we could finally start our long-term coverboard experiments. The ground was not even thawed yet, but that beautiful sunshine whispered promises of soil soon thawed enough for invertebrate collection and analysis. I had my students place small coverboards in locations in accordance with their hypotheses, and we planned to check them weekly for months to measure species richness over time.

Weeks later, our coverboards were covered with a foot of snow. In mid-April, an additional foot fell on the frozen ground. The snow finally began to melt on Earth Day and the ground had completely thawed by May, leaving us just four weeks of outdoor study before graduation; four weeks outside in a sixteen-week course about "outside."

Due to the social, emotional, and academic benefits of quality outdoor education, I strongly believe teachers have a responsibility to provide plenty of time outdoors in high school science courses. And as someone who has experienced the benefit of outdoor education and taught Ecology in the secondary setting, I have seen how students miss valuable opportunities when the ability to study concepts through inquiry (as recommended by the Next Generation Science Standards (NGSS Lead States, 2013)) becomes dependent on the weather. My research question therefore became: “How can I construct curriculum for high school students to study ecology and environmental concepts through inquiry in the winter?” My goal was to construct two units of outdoor education opportunities for the cold months of the year so that midwestern students could study ecology and the environment through inquiry and gain a better appreciation for environmental stewardship.

Why Go Outside?

Outdoor learning has long been established as an invaluable addition to students’ educational journeys. A modern look at the importance of environmental education began in the seventies, when the classic definition of outdoor education was questioned (Hungerford, Peyton, & Wilke, 1980). Until this point, outdoor education had been primarily defined as “Education in, for, and about the outdoors” (Donaldson & Donaldson, 1958, as cited in Priest, 1986, p. 13). Ford (1986) states that this definition was upheld until at least the 1980s. In an article in the 1986 Journal of Environmental Education, Simon Priest argues that the purpose of outdoor education is *relationships*, more specifically, relationships between people and the natural resources that they use. He argued that outdoor education should take place primarily outside, since the outdoor setting is what provides the inspiration for learning (Priest, 1986).

This type of hands-on, minds-on educational experience can be especially beneficial for high school students from a social/emotional perspective and from an academic perspective. Students should feel connected to the world just outside their classrooms before we expose them to tragic stories of environmental disasters. In this way, young people will be more likely to try and prevent those disasters as adults, rather than becoming a hopeless generation disconnected from the environment they need to protect (Sobel, n.d.). In addition, adolescents have been shown to grow in leadership skills and self-efficacy when outdoor learning is emphasized (McGowan, 2016).

As for the academic benefits, the outdoors can provide many opportunities for inquiry. As supported by the Next Generation Science Standards, science learning based on inquiry opportunities increases comprehension of vital science concepts. Teachers are called upon to engage their students in the same practices that real scientists use to conduct investigations (NSTA, 2014). Since most ecologists do not conduct investigations safely behind closed doors, we cannot expect our students to engage in true ecology and environmental inquiry while sitting in a desk.

My Background

As an avid gardener, I’ve always enjoyed the outdoors. My gardening experience began when I was in middle school, gardening in my backyard under my mother’s tutelage. I was fascinated by the idea that I could grow my own food, so vegetable gardening was my unchallenged favorite. This fascination with food production took on a whole new level of importance when I began to study Biology and Ecology in college. Between my junior and senior years, I took part in a research project in which my school built four test garden plots to determine which types of fertilizers produced a high vegetable yield. We worked with a local CSA (Community-Supported Agriculture) to experience first-hand how even a poor community in central Indiana could garner enough interest to make such an environmentally sustainable system possible.

Besides gardening, I also enjoyed learning about the significant biodiversity that exists within the natural world. Armed with a dichotomous key the size of a textbook, we did endless identifications of plant life. Since the school was also running ongoing studies on prairie succession, I helped out with this as well. Yearly burns allowed us to track which species arose first, and which arose only after others were on the scene. Admittedly, this was one of my least favorite jobs, since it required that we spend hours in the hot Indiana sun identifying and counting plants the size of pennies. But we were helping to shed light on the processes of disturbance and succession. And since this was prairie research, changes happened in near-real time.

Rationale for the Project

Through the wealth of opportunities I had, I realized that the best learning that incited the greatest amount of passion (as well as understanding) took place outside. It was only within the context of the outdoors, the natural world, that ecological concepts became concrete; concepts of sustainability, environmental impact, species, niche, disturbance, and succession. If this was true of my own learning journey, how did I expect my students to make some of the same connections, to put the same value in the delicacy of interacting systems if they didn't have the same experience that I had?

This pattern of learning outdoor concepts more effectively while outdoors is supported by Priest (1986), the State Education and Environment Roundtable (1998), and Eaton (1998), even though Dillon et. al. (2006) admitted that comparative studies in this area are rare and difficult to create. Others have shown that outdoor learning can bring about greater knowledge of the environment (Zimmerman & Weible, 2017) and, in some cases, a desire to change environmental behaviors (Breunig, Murtell & Russell, 2014). Students in carefully structured, experiential outdoor or environmental education programs have shown improvements in critical thinking skills (Ernst & Monroe, 2006) and even in standardized test scores (State Education and Environment Roundtable, 1998).

I was determined to bring outdoor educational inquiry to my classroom, specifically in a class I taught called “Biology, Ecology, and Environmental Science”. The class ran from the beginning of February through early June in daily, 90-minute blocks and catered mostly to burnt-out upperclassmen who needed to scrape one last science credit off the classroom floor. My goal was to run literature circles and cover basic Ecology concepts until enough snow had melted. This is when I attempted the aforementioned coverboard experiment and realized just how much weather would restrict the kinds of inquiry activities I would be able to provide for my students.

As a teacher who tries to lead a student-centered classroom, I realized there was a systemic problem that would not be easily solved: How were my students going to study interactions in the natural world (the *definition* of Ecology) without actually *being* in the natural world? And if we couldn’t get into that world until May, what were we going to do for the rest of the term? How was I going to run a fully inquiry-based, student-driven course when the really relevant inquiry could only be accomplished in late spring? We would be able to study Evolutionary Ecology adequately indoors, since single organisms can be analyzed and even brought into the classroom. But how could my students learn about population, community, or ecosystem interactions? How could I teach them about human impact on the environment?

I was not the only one to notice the problem. A group of Michigan teachers, when asked about teaching sustainable agriculture to their students, cited weather as a barrier to meeting proposed curriculum standards (Trexler, Johnson, & Heinze, 2000). Another study, this one of schools in Ontario, revealed that the cold climate was a barrier to outdoor learning in that it restricted the use of outdoor spaces (Dyment, 2005). Although there are many outdoor-education resources for teachers, most of these seem to be designed for more temperate climates. Students in warmer states and countries can cultivate gardens (Ford, 1986; Sobel, 2004) and use transects to measure species density and diversity (Schen & Berger, 2014). Neither of these was available to us throughout the duration of the class.

To be clear, I am not stating that there is an absence of outdoor winter activities for kids, since a Google search would provide ways to engage elementary students in cold-weather learning. However, there is a lack of activities in which *high school age* students can engage in scientific inquiry outdoors in the winter. For example, the National Park Service produced a "Winter Ecology Teacher's Guide" in 2010, but it is specifically designed for elementary-level students and includes materials such as coloring pages and animal cards. I was able to find very few resources, such as "Sampling in the Snow" (Hanson & Burakowski, 2015), that align outdoor winter activities for young adults with national standards.

My goal for this project was to answer the question "How can I construct curriculum for high school students to study Ecology and environmental concepts through inquiry in the winter?". I accomplished this by creating two easy-to-implement curricular units for midwestern high school teachers to bring into their classrooms. My project makes it possible for older students to use inquiry to study Ecology and the environment in the winter. As noted, the literature supports the benefits of outdoor learning, and by participating in units with a cold climate in mind, students will not be limited in their ability to experience and study that world first-hand.

In this first chapter, I have outlined my research question and the rationale for my project, which aimed to create high school curricular units so that teachers can engage students in outdoor education in the winter. I've mentioned the academic and personal value of outdoor education to adolescents as well as the lack of teacher resources that are currently available. Chapter two provides a deeper review of relevant literature, including an analysis of the importance of outdoor education for this age group. I also discuss currently available lessons and curricula I used as resources to build the curricular units. In chapter three I introduce my plan for the project and how it aligns with current national standards. Finally, chapter four will include a reflection on how the curricular units created meet the gap in the current literature.

CHAPTER TWO

Review of the Literature

Introduction to the Review

As I pursued an answer to the question “How can I construct curriculum for high school students to study Ecology and environmental concepts through inquiry in the winter?” several themes continuously arose in the literature. First, it became evident that I needed to specify the meaning of “outdoor education” in the context of my project. Second, “place-based education” surfaced as a necessary concept to pair with outdoor education, since I had decided to provide easy-to-implement lesson plans for rural teachers. Lesson plans that utilize local spaces would make lessons more accessible for teachers and concepts more relevant for students. Third, I sought to establish the research-based benefits of both outdoor and place-based education for adolescents, concluding with a look into available sources. A definite gap exists in teacher resources in this area. There are certainly outdoor education resources for adolescents, and locally-focused winter ecology inquiry resources for younger students, but very little was available for older students that combined these concepts, demonstrating that without some kind of outdoor winter ecology curricular units, older students in the midwest would remain at a great disadvantage. In order for midwestern students to experience inquiry learning in accordance with national standards, some winter ecology and environment units would have to be constructed.

Outdoor Education

A consistent definition of outdoor education is vital to establishing a need for adolescent winter inquiry learning. Consistency is especially relevant since outdoor education has been described as much more in the literature than the name would imply. Jensen (2002) argues that the central focus of outdoor education should be to create in students a desire to care for their environment. This sentiment is supported by Hill (2012), who claims that the need to address environmental issues in education is obvious. In addition, Jensen argues that students should learn about the environment through a problem-solving approach, and that 'hands-on' education is pointless without causal analysis of ways to produce change. Students should be empowered not only with the desire to positively impact the environment, but should also be armed with the intellectual tools to make those positive impacts. This double-edged sword of *desire* for impact and *tools* for impact will serve as the purpose and definition of outdoor education for my capstone project. My research question emphasizes that the curricular units created are to be inquiry-based, and Jensen's work supports the idea that problem-solving is a central part of outdoor education.

Importance of Outdoor Education for All Students

Experts support outdoor education as valuable for students in a variety of ways (e.g. Quay, 2016; Hill, 2012), but of special interest in this work is the research indicating academic benefits. Ernst & Monroe indicated that outdoor learning resulted in increased critical thinking skills (2006) while the State Education and Environment Roundtable (1998) conducted a very detailed study which showed increased test scores in students who participated in outdoor learning in multiple subjects. But without an action-oriented, problem-solving approach to environmental issues, students may be left with a feeling of helplessness in the face of environmental disasters (Jensen, 2002), especially if they learn about these problems before they connect with the world outside their classrooms (Sobel 1996). If the purpose of outdoor education is to inspire social change through learning, what should prevent students from making meaningful connections with their environment while studying it? But again, teachers need to tread cautiously. Hill (2012) and Jensen (2002) remind us that that students should engage in working to solve environmental issues and consequences, not simply participate in a scheduled outdoor adventure to build personal skills (though these benefits are supported by the literature and will be discussed later). The purpose of outdoor education should be to show students how they can change the world around them both on a personal level and at a societal level (Jensen, 2002).

Place-Based Education

David Sobel defines his area of study in “Place-based education: Connecting classroom and community” (2004). He writes: “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” (p. 6.) In the case of my project, I will of course be referring to science education. Sobel goes on to say that this method of education emphasizes learning hands-on, similar to outdoor education. Weise (2012) describes importance of locally-focused education as she relates the process of creating an outdoor play space/learning area for elementary school students. She discusses the role of place-based education in teaching students about environmental issues by first teaching them to value the environment. She emphasizes that this movement does not require that teachers ignore standards, but that they implement them in a local context, using whatever nature is just outside the school to teach students about the value of their environment (Weise, 2012; Sobel, 2004). In this way, students can apply often-abstract ideas about environmental protection to their own communities. As Weise puts it: "Rather than saving a rainforest that most children can only see in pictures, why not save a river or pond near your school?" (Weise 2012, p. 39). Since my research question addresses the creation of winter inquiry, students utilize local spaces and contexts in many of the lesson plans in the project.

Benefits of Outdoor and Place-Based Education for Adolescents

Emotional Growth

Although the curricular units in this project do not utilize adventure programming, analysis of adventure programming studies can be used to gain insight about the emotional benefits gained through outdoor education. McGowan (2016) describes a study in which adolescent students took several outdoor trips while earning high school credits. Student surveys indicate that these experiences outside helped them in identity development. Other programs, whether on or off campus, can help adolescents gain social skills (Fägerstam & Grothérus, 2018; Furman & Sibthorp, 2013) and problem-solving skills (Fägerstam & Grothérus, 2018). McGowan's study specifically indicated growth in situational coping skills, leadership, and self-efficacy, and indicated these skills are retained months after participation in the program (2016). A study of students on a 14-day backpacking trip indicated that the activities, not the duration of the trip, were the main source of growth for the students involved (Furman & Sibthorp, 2013). This indicates that it may be possible to implement these emotionally-beneficial activities locally with similar results.

It must be noted that many studies, including Furman & Sibthorp (2013) and Fägerstam & Grothérus (2018), are prime examples of adventure programs aimed at building social skills, the exact types of programs that Hill (2012) and Jensen (2002) claim do not go far enough and educate students to solve environmental problems. The important detail here is that students in these programs are building connections with the environment, a necessary first step that both Sobel (2004) and Weise (2012) describe as vital to teaching students to care for nature.

Environmental Awareness

This is where we must again make a distinction between teaching students to care *about* something and teaching them to care *for* it. Students who learn about local environmental issues and who also have an appreciation for their local environment do not necessarily go on to suggest and create change (Breunig, Murtell & Russell, 2014; Zimmerman & Weible, 2017). But the literature does indicate that with carefully-structured learning goals, it may be possible to help students develop these skills (Jensen, 2002; Huffling, Carlone, and Benavides, 2017) For example, Jensen offers a four-dimensional strategy for teaching students about ways to address environmental issues at hand. The strategy allows students to focus on analyzing and solving problems discussed in class. Also, in response to Zimmerman and Weible, Huffling et al. (2017) suggest specific classroom and community involvement activities that may help students in rural areas feel that they can and should take action to change the way the environment is handled in their communities. Although major changes were not necessarily found to have occured in students in the Breunig et. al. study, some students did make some changes in habits such as water use and recycling (2014).

In order to address the research question "How can I construct curriculum for high school students to study ecology and environmental concepts through outdoor inquiry in the winter?" I needed to establish the meaning and value of outdoor education for adolescents, as well as the context in which that education would take place. Outdoor education in a local context provides many benefits for high school students. But in order to understand and address the academic needs of the students, I will now discuss the literature on the subject.

Specific Needs of Adolescent Learners in Science Contexts

According to Piaget, adolescence is a distinct state of development characterized by the ability to move beyond the realm of the concrete and engage in hypothetical reasoning (1972/2008). He describes in great detail how the thought processes of younger children differ from those of adolescents. Other characteristics noted about adolescents in science contexts include the elevated importance of peer relationships (Brown & Larson, 2009), the tendency to view arguments as disagreements (rather than a normal part of science) as well as a tendency to discount knowledge claims by saying that all are equal in validity. Due to these characteristics, adolescents need to begin to see scientific arguments as discourse; in addition, claims need to be based on scientific evidence (Anderman, Sinatra, & Gray, 2012). Science in the real world requires group cooperation (Anderman et. al., 2012), so students need to have opportunities to develop stronger social skills (Brown and Larson, 2009).

So how should teachers begin to address these needs in the science classroom? Anderman et. al. suggest that teachers focus on classroom community. If the class is one in which students are cooperative and in which critical thinking and reasoning are encouraged, then they are engaging in activities that take advantage of their developmental potential (Piaget, 2008; Anderman et. al., 2012). Teachers should support learning through inquiry, group assessment, formative assessment, and the combining of various science disciplines to promote higher-level thinking skills (Anderman et al., 2012). Such inquiry learning is the focus of the lesson plans in the curricular units.

Resource Availability: Outdoor/Place-Based Education

Since I was researching how to write curricular units for adolescents to engage in outdoor winter inquiry, I collected information on existing related resources. Much work has been done already in establishing outdoor educational opportunities for PreK-8 students. In addition to scholarly work on the subject, (Weise, 2012; Warner & Dumond, 2004; Strife, no date; Tatarchuk & Eick, 2011; Bourdeau & Arnold, 2008) some local and national non-profit groups offer outdoor education lesson plans for this younger age group (NPS, 2010; NWF; HTFC, 2018). The majority of these activities is marked as being ideal for elementary and middle school aged students. For adolescents, less work has been done to provide outdoor inquiry activities, but a few resources are available

(Zimmerman & Weible, 2017; Schen & Berger 2014). Also, in a movement to jumpstart sustainability education, some organizations offer quality outdoor lesson plans for students related to gardening (Nature Works Everywhere, 2016a; Nature Works Everywhere, 2016b; Nature Works Everywhere and Ch2M Foundation, 2016). This is where the problem emerges. Most resources available have strict seasonal limitations; they can't be accomplished in cold temperatures and heavy snow cover. Just a few authors have published material for high school students to engage in outdoor inquiry during the winter (Hanson & Burakowski, 2015; Schon, Hougham, Eitel & Hollenhorst, 2014). These pieces, from *The Science Teacher* and *Science Scope* respectively, are rare gems, and alone do not provide nearly enough material for the long winters that students in the midwest experience during the school year. However, these sources are distinctive because they provide practical strategies for teachers who do not have hours to hunt down specialized resources. These lessons are age-appropriate and require students build science knowledge by engaging in the content and inquiry. They were used as examples and valuable resources during the lesson-writing process.

The Gap: Winter Outdoor/Place-Based Education for Adolescents

Despite the benefits that outdoor learning offers, cold weather and snow can limit time and scope of outdoor learning. Teachers in northern climates cite weather as a barrier to outdoor learning, whether they refer to the inconvenience of bringing students outside in that weather or to the difficulty it causes in regards to using proposed curriculum (Trexler, Johnson, and Heinze, 2000; Dyment, 2005). Even experts in place-based education such as David Sobel do little to discuss place-based education for cold climates in the winter, though Sobel states that such educational trends are taking root in northern areas as well as southern (Sobel 2004). How are teachers supposed to provide months of high-level inquiry activities in outdoor education without a place to start or a framework from which to work?

What is missing from the literature are comprehensive units that provide practical ways for students to learn by studying Ecology and Environmental Science in the field through cold months. I have made meaningful progress in filling this gap with my capstone project.

Curricular Unit Resources

In order for inquiry to take place in ecology or environmental science units in the winter, teachers will need specialized, climate-specific resources that allow students to engage in outdoor inquiry. My goal was to give high-school teachers two comprehensive curricular units (amounting to roughly two weeks to one month of material depending on schedule style). Themes and lessons will be drawn from the previously unconnected works of experts and will be connected with the appropriate strands of the Next Generation Science Standards (discussed in chapter three). Many of these sources are not written specifically for high-school students, and they may not be based on inquiry. My goal was to use available sources and lesson plan ideas to construct new lesson plans for adolescents that align with national standards.

Some of the resources I have come across contain lesson plans and ideas that are either aimed at or suitable for adolescent learners. Two books, *Life in the Cold: An Introduction to Winter Ecology* (Marchand, 1991) and *Exploring Nature In Winter: A*

Guide to Activities, Adventures, and Projects for the Winter Naturalist (Cvancara, 1992) contain activities and information for unit development. Both include sections about organism adaptations to cold temperatures, animal behavior, and chemical/physical information about snow and ice. Marchand also includes information about conducting experiments outside in cold weather (1991). Strife includes similar subjects in an eight-lesson guide (no date). Some environmental science-focused lesson plans include students comparing biofuel value vs the environmental value of a tree (Schon, Hougham, Eitel & Hollenhorst, 2014) and measuring the thermal heat index and albedo of snow (Hanson & Burakowski, 2015). For the purpose of student formative assessment, older students can create short lesson plans and to teach younger students about environmental issues based on what they have learned in class (Smearsoll, 2017).

I have selected a few resources written for elementary-age students because they contain ideas that are transferable for adolescents and because they might be helpful for students brainstorming possible lessons for their assessment (discussed in chapter three). The National Parks Service has detailed and resource-rich "Winter Ecology Teacher's Guide" (no date). Aimed at very young students, some activities, especially those that focus on animal adaptations and energy flow, would be transferable and usable by older students in creating "these lesson-assessments". The document also contains data tables that students could use as winter Ecology resources. Two other articles, "Winter Treasures" (Warner & Dumond, 2004) and "Enjoying Winter with your Class" (Thomson, 2005) would also provide teaching ideas to students for their assessment project.

Finally, I have included resources to consider as possible supplements to curriculum development. A creative book by Jamie Bastedo titled *Falling for Snow: A Naturalist's Journey into the World of Winter* (2003) includes poetry and literary excerpts relating to winter, as well as narratives and personal accounts of snow-related activities. The selected, short readings could help contribute to the necessary connection with nature that teachers need to encourage in their students (Weise, 2012; Sobel, 2004), especially on days when windchill may not allow students to venture out-of-doors. Another way to engage students in inquiry while the weather is dangerously cold is to run a thermal gradient experiment. Johnson and Tutt (2008) describe how students can build a thermal gradient and use it as an indoor tool to support learning about the importance of temperature on physical and biological processes.

In this chapter I have selected working definitions for outdoor education and place-based education based on expert works. After discussing the importance of each to adolescents, I established that there is a gap in the literature when it comes to outdoor and place-based education for adolescents in the winter. I then summarized some resources that were considered as I prepared to create winter outdoor inquiry curricular units for adolescents into fill this gap. Chapter three will provide a more in-depth description of my capstone project. I will describe the national standards used to construct the lesson plans in each unit, as well as the method of unit and lesson construction. I will also provide the timeline used for project completion as I researched a way to provide midwestern high school teachers and students with outdoor winter inquiry opportunities.

CHAPTER 3

Project Description

Introduction

The verdict is out: inquiry is an effective method of teaching science (Olson & Loucks-Horsley, 2000), and as the research continues to stack up in the favor of inquiry-based learning, teachers need to know how they can provide these learning opportunities to their students. During long midwestern winters, teachers and students alike have been stuck inside when it comes to ecology and environmental inquiry, since true inquiry in these disciplines takes place outside. Only a few resources exist to inspire teachers to engage students in winter outdoor inquiry, and even fewer are written for high school students. In response, I asked how I could construct curriculum for high school students to study ecology and environmental concepts through inquiry in the winter. The winter world is still alive: species still interact with their environment, and the health of that environment can still be investigated. So why *not* go outside, where opportunities for inspiration are just beyond the walls of the traditional classroom? Student interest in a subject matter increases when an activity is done outside (Sadeh & Zion, 2012) and increasing student interest can increase learning (Abrantes, Seabra, & Lages 2007), making outdoor experiences invaluable.

Many educators have joined the movement to include outdoor inquiry in their curriculum (e.g. Weise, 2012; Hill, 2012; Hanson & Burakowski, 2015). And in order to equip teachers with sufficient information to use the new set of national standards known as the Next Generation Science Standards, there have been a rush of resources created for teaching science through inquiry (NGSS, 2018). Many of these resources guide teachers in leading inquiry activities outdoors. As indicated in chapter two, what is lacking from this plethora of ideas, specifically, is winter outdoor inquiry for adolescents. Whether an inconvenience or a struggle due to seasonally-limiting resources, cold weather can be a barrier to outdoor learning (Trexler, Johnson, and Heinze, 2000; Dyment, 2005; Marchand, 1991). By creating curricular units that make outdoor inquiry more accessible for students in the midwest, I hope to add to the growing amount of work that supports teachers in hands-on, minds-on science education.

In this chapter I will describe the two curricular units I plan to build, along with related standards, methods, and instructional strategies that will be included in the lesson plans. A proposed assessment project is included. I also provide a description of desired project outcomes in conjunction with a description of the project audience. I conclude with a proposed timeline for my capstone project completion.

Description of the Project

In order to contribute to the growing need for inquiry-based learning, I created two curricular units followed by a project-based assessment of student learning. The first unit focuses on winter environment, especially the effects of snow and ice on wildlife, as well as how natural insulators provide protection from the cold. An optional lesson in this section includes a way for students to study albedo and the toll that positive feedback loops can have on the environment. The second unit, Winter Ecology, engages students in investigations in plant adaptations and animal behavior. Students learn about changes in the rate of photosynthesis, torpor behavior, and complete a long-term experiment in winter food preferences of local animals. For a final project, students work with a group to prepare a lesson about either winter ecology or winter environment to teach a small group of elementary school students. This final component will serve as a formative assessment of learning for both units.

The focus of these units is learning through guided inquiry. Martin-Hansen (2002) defines guided inquiry as something between “open inquiry” and “structured inquiry.” In guided inquiry, the teacher leads the class in answering a central question. Students choose how they attempt to answer this question and explain a scientific phenomenon with the materials provided, so they have some level of autonomy while working through a specific subject matter. I believe this form of inquiry works well in outdoor learning. Students can plan their investigation of phenomenon, drawing on questions that were brought up in the construction of a Driving Question Board (DQB).

To jump-start student questions about the unit, each unit begins with the teacher and students creating a DQB. Weizman, Shwartz, and Fortus (2008) recommended that teachers start units with this method of question generation. The teacher shows students a phenomenon, and students work together to generate questions about the phenomenon. It is important to note that the students are not determining the subject matter being studied. The teacher provides the central question, and students ask related questions, which are student-organized in the creation of the DQB. The purpose of such an exercise before the planned guided inquiry units is to stir up questions in the minds of students. Without a

DQB (a visual reminder of gaps that they cited in their own knowledge) students may lack the direction and curiosity necessary to participate in guided inquiry to the fullest.

Two final instructional strategies I utilize in these units are called "Think-Pair-Share" (Robertson, 2017) and New American Lecture (Silver, Strong & Perini, 2007). Both can be used in conjunction with each other, as the purpose of both is to help students to stop and think about the subject matter being studied. Think-Pair-Share allows students time to stop and think about the material before they are asked in engage with it. Students discuss their ideas with a partner ("Pair") then have to opportunity to share these ideas with the class. New American Lecture emphasizes frequent breaks, visuals, and memory devices in the lecture to help students engage with the material on a deeper level. Think-Pair-Share can be used as a thinking strategy during a break in New American Lecture. I have selected these strategies because I would like to increase student engagement, especially among students who are not intrinsically interested in science. These methods also provide the teacher with frequent opportunities for informal formative assessment.

The final assessment for the combination of these two units is project-based and provides an opportunity for students to teach younger students about one of the subjects they have studied. According to Anderman, Sinatra, & Gray, teachers should support learning through inquiry and formative assessment (2012), and this project can effectively assess student learning through what and how they decide to teach. The idea is partially based on an article by Smearsoll (2017) describing how high school students learned more about pollution by teaching basic concepts to preschoolers. In this project, students will have the opportunity to develop a five- to ten-minute outdoor lesson for elementary-aged students to do outside in the winter. Older students will be assessed based on both quality and accuracy of content, as well as presentation and student engagement.

By creating two curricular units that allow for student inquiry learning, I hoped to fill students' time outside with active research and thoughtful observations as they engage in outdoor winter inquiry. Surely a beneficial way to educate students about the environment is to guide them in the process of educating themselves, then educating others. Such a process of exploration can be important in helping students meet established science standards.

Researched Rationale for Framework

The standards I will be using for this project are the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). These standards, which were first released in April 2013, have now been adopted and/or used by 35 states for recreating state science standards (Lopez and Goodridge, 2018). Of the 12 states that are considered to be "Midwestern" (the focus of this project) by the United States Census Bureau, eight have used or adopted NGSS in some way as of 2018. It is important to consider that the majority of the midwest uses NGSS, since it is in the midwest that we tend to see the long, cold winters for which NGSS-aligned outdoor inquiry opportunities are limited.

Figure 1: Adoption of NGSS by State (from Lopez & Goodridge, 2018)

Adoption of NGSS

Release	9-Apr-13
Rhode Island (N)	23-May-13
Kentucky (N)	5-Jun-13
Kansas (N)	11-Jun-13
Maryland (N)	25-Jun-13
Vermont (N)	25-Jun-13
California (N)	4-Sep-13
Delaware (N)	19-Sep-13
Washington (N)	1-Oct-13
Illinois (N)	23-Jan-14
Nevada (N)	26-Feb-14
Oregon (N)	6-Mar-14
New Jersey (N)	9-Jul-14
Arkansas (N)	10-Jun-15
Iowa (N)	6-Aug-15
Connecticut	4-Nov-15
Hawaii	19-Feb-16
Wyoming	23-Sep-16
New Hampshire	3-Nov-16
New York (N)	12-Dec-16
Wisconsin	17-Nov-17
New Mexico	Pending (1-Jul-18)

Table 1 - A timeline of the adoption of the NGSS.
(N) indicates NGSS lead states.

Adoption of Standards Based on NGSS

South Carolina	Jan-2014
Oklahoma	Mar-2014
West Virginia (N)	Apr-2015
South Dakota (N)	May-2015
Alabama	Sep-2015
Georgia (N)	Mar-2016
Utah (grades 6-8)	Dec-2015
Missouri	Apr-2016
Michigan (N)	May-2016
Montana (N)	Sep-2016
Tennessee (N)	Oct-2016
Louisiana	Mar-2017
Nebraska	Sep-2017
Massachusetts (N)	Nov-2017
Mississippi	2018

Table 2 - A timeline of the adoption of standards based on the NGSS.
(N) indicates NGSS lead states.

The NGSS are organized into three categories. Disciplinary Core Ideas (DCIs), represent the content standards and are unique to each science discipline. Scientific and Engineering Practices (SEPs) and Cross-Cutting Concepts (CCCs) are not discipline-specific. In order to ensure effective instruction, teachers aim to use all three “dimensions” at the same time, in the same lesson. The purpose of these new standards is to get students “doing” science (exploring phenomena and designing solutions) while learning content at the same time (Krajcik, 2015). The following is a list of the DCIs I cover in my curricular units, as well as the SEPs and CCCs that are the focus of these units (NGSS Lead States, 2013):

Selected NGSS Disciplinary Core Ideas (DCIs) for Unit Focus

Unit One: Winter Environment

LS4.C4: Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.

ESS2.C: The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Unit Two: Winter Ecology

LS2.A: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

LS1.A4: Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

LS4.C2: Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

NGSS Scientific and Engineering Practices (SEPs)

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

NGSS Cross-Cutting Concepts (CCCs)

1. Patterns

2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter
6. Structure and Function
7. Stability and Change

Understanding by Design (UbD) and NGSS

When planning curricular units to help students meet these standards, I utilized the Understanding by Design (UbD) process (Wiggins & McTighe, 2011). UbD closely parallels the goals cited in the NGSS, since the process focuses on communicating big ideas to students, The ultimate goal of both NGSS and UbD is deeper understanding of fewer concepts (NSTA, 2014; Wiggins & McTighe, 2011). Students should also be able to take these deeply-explored ideas and transfer them to other contexts (Wiggins & McTighe, 2011).

Part of UbD is utilizing backwards planning when creating units. Starting with the NGSS standards listed above as each unit's "desired results" (Wiggins and McTighe, 2011, p. 4), I included my expectations for what students should be able to do if they have truly learned the material. Once these expectations (referred to as "Evidence" in UbD) were set, I built a set of activities and instructional strategies that can help students meet this goal (a "Learning Plan") (Wiggins and McTighe, 2011, p. 8).

Learner Outcomes

After these units and assessment, students should have a deeper knowledge of winter ecology and winter-related environmental science issues. My goal is that students' critical thinking and problem solving skills will increase as they engage in guided scientific inquiry. The breadth of knowledge will not be emphasized as much as the depth of knowledge, and through readings, discussions, and outdoor experiments, students will hopefully gain not only an appreciation for the environment, but come away with practical strategies for protecting and maintaining it.

Audience and Setting

The curricular units described above would be written for use in high school Biology, Ecology, or Environmental Science classrooms in the midwest. The author of these units teaches in a rural midwestern high school that had 644 students during the 2015-2016 school year. According to the National Center for Education Statistics, student demographics are: 0.31% American Indian/Alaskan Native, 0.78% Asian, 1.24% Black, 1.86% Hispanic, 0% Native Hawaiian/Pacific Islander, 94.1% White, and 1.71% Two or More Races. Roughly 25% of children in the district live below the poverty line (CensusReporter.org), and about 42% of the students at the high school receive free or reduced lunch (National Center for Education Statistics). Many students in this community spend time outside hunting, fishing, or participating in another outdoor sport, though participation in these activities predictably drops in the winter months. Therefore, the units would be written for students who are used to dealing with cold weather but have very limited life science backgrounds.

The units can be used by any midwestern teacher living in an area where “winter” lasts a significant period of time. In his book *Life in the Cold: An Introduction to Winter Ecology*, Peter Marchand defines his audience using two criteria: 1) geographic areas where temperatures are low enough to elicit adaptive responses and 2) geographic areas where snow lasts long enough to be considered a vital and integral part of the environment (Marchand, 1991). This same criteria will be used to define the audience for these units, though the area may be referred to more generally as “the midwest”.

The project described above can be deemed effective if the activities in the curricular units align with the selected Next Generation Science Standards, and if the curricular units provide ample opportunities for outdoor guided inquiry in the winter. I have discussed the goal statements in these activities with a member of administration who specializes in aligning activities with NGSS. She was able to guide me in making sure that my curricular units mirror the goals of the NGSS. With the feedback of this expert, I made adjustments as necessary to the lesson plans before the presentation of the curricular units.

Timeline for Project Completion

The first three chapters of this capstone were completed by August 2018. I then registered for the final capstone course for Fall 2018. I spent time in September reviewing relevant literature, units, and lesson plans, while working out which main ideas I would cover under the selected standards. I also began creating unit outlines at this time. During the months of October and November, I developed a rough draft of the two units, as well as guidelines for the project-based assessment. I had these units reviewed and completed by the end the month. In November I completed a rough draft of chapter four. The associated project presentation and artifact paper were completed in December.

Summary

Through the development of season-specific ecology and environmental science curricular units, I provide high school teachers with ways to engage their students in inquiry activities outdoors in the winter. The offer a completely different alternative to seeing winter as a “dead time” and a necessary hurdle to jump over. Instead, I hope that teachers and students alike can begin to see winter as an opportunity to learn about how scientists look at different pieces of an ecosystem operating together as a cohesive whole; “and that, of course,” as Marchand puts it “is what ecology as discipline is all about” (1991).

In order to reach this goal, I used NGSS as a framework, building two curricular units (through backwards design) that align with selected standards and engage students regularly in outdoor guided inquiry. Since NGSS is widely used and accepted for science education across the midwest, any midwestern life science teachers can use these units to help their students gain a deeper understanding of the world around them, with the end goal of raising a generation that connects with nature enough to grasp the necessity of taking care of it. In chapter four, I conclude with my reflections on the process of curricular unit construction and literature, as well as some strengths and limitations of the work. I go on to suggest possible areas of future research to continue the process of filling the gap of outdoor winter inquiry for adolescents.

CHAPTER 4

Conclusion

The Writing Experience

The original goal of my project was to answer the question: How could new curricular units enable students to learn about ecology and environmental science through inquiry in the winter? After establishing a need for winter inquiry, I began to look into existing lesson plans and outdoor lab ideas. As I entered into the lesson-planning stage, I used these sources as a bank of valuable ideas. So with the ideas of many experienced educators and scientists in mind, I began the process of building two curricular units, adapting concepts and ideas to fit the needs of rural high school students, and with a focus on inquiry and outdoor learning.

The curricular units in this project were written for use by high school teachers in the rural midwest. The goal was to provide teachers who may see themselves as “stuck inside” during the winter (as this author did) with a resource that allows them to see winter as a unique opportunity. And what an opportunity it is! The more I learned about winter ecology, the more excited I was to teach it. I grew up playing in the snow and yet I barely knew what it was, about its chemical intricacies and its value to wildlife. I now have a gem of knowledge to share with teachers and students, and I want to portray it in the best possible light.

The Process

As a science teacher who was already familiar with the Next Generation Science Standards, the difficulty of this project did not lie in selecting topics that aligned with the NGSS. The content portion of the standards (DCIs) allows teachers to cover a wide range of science topics and still be “teaching to the standards”. The difficult part was tying all three dimensions of the NGSS together into goal statements, and then figuring out how to balance indoor and outdoor time while preserving the integrity of the goal statements. I found that certain Scientific and Engineering Practices (such as “Analyzing and Interpreting Data” and “Using Mathematics and Computational Thinking”) were best done inside, and that some scaffolding of concepts had to take place inside for the outdoor experiences to be relevant and meaningful. Students can cover a concept indoors, then prepare an experiment to conduct outdoors. This pattern of indoor experiment preparation and outdoor experiment completion became a recurrent pattern in the lesson plans, something I did not expect to arise as I considered the scope of the project in the idea phase. But ultimately, I believe that such an arrangement allows for a consistency, which in turn allows students to focus on the new content.

Valuable Literature

Throughout the project process, I was heavily influenced by Marchand’s book *Life in the cold: an introduction to winter ecology* (1991). Even before selecting standards to cover, I used this source to familiarize myself with the content. I now thoroughly believe that every science educator in the midwest should read this book. It is fascinating to learn about a near-alien world that is so close to home, and Marchand is an unparalleled expert in the field. He covers many topics in the short book, so the reader can gain a broad knowledge of winter ecology as a discipline. Another source that was extremely helpful was the National Snow and Ice Data Center website, which provided some easy-to-read articles for both student and teacher reference in lesson one.

A topic that often surfaced in my literature review was the need for place-based education. It makes sense that outdoor education and place-based education would go hand-in-hand, since outdoor education can utilize local spaces. But as I wrote lesson six in the curricular unit, I was forced to consider the importance of localizing climate change education. In lesson six (which I have labeled as optional due to the slightly higher materials costs), students explore possible connections between albedo and snow density. Right outside the school building, students have the opportunity to learn that the more dense the snowpack, the lower the reflectivity, leading to faster melting and, in turn, even lower reflectivity. If students can grasp the concept of dangerous climate feedback loops with this experiment, imagine how much easier it will be to apply the concept to their beliefs about the world. The example used in class is under their feet for months out of every year.

Strengths and Limitations

If midwest teachers would adopt the curricular units created for this project, their students would gain not only an appreciation for climate issues, but also some valuable science skills in the process. I constructed the labs to be "guided inquiry" investigations (Martin-Hansen, 2002) with the students making decisions about how they will conduct their investigations within given limits. This way, students are learning the same inquiry process that scientists use. In my experience, students who are used to “cookbook” labs often become frustrated when asked to do inquiry labs. The labs in my project contain processes that are relatively easy to understand, so students focus on the academic content of the labs and have a much higher chance of being able to participate in the inquiry process.

As mentioned above, nothing could have prepared me to learn about the intricacies of the winter world. I knew that winter environment and ecology was a blind spot in my education, but I did not know how much I had missed until I dove into the sources I needed to complete the lesson plans. The “dead” winter world is so alive, and through a high school education and a bachelors in Biology, I never truly considered the feats that organisms must accomplish to survive the cold. I never once made the connection that cells in all plants, animals, and fungi would freeze and burst were it not for a fascinating set of adaptations, traits as secret and silent as falling snow. Once I learned this, I wanted to find a way to teach this to others.

Difficulty arises when we consider the fickle nature of weather in the midwest. Some years see much more snow than others, and that means that the ability to engage students in the lesson experiments can literally change overnight. A snowpack can all but disappear with a couple of warm, sunny days, and a cold spell could keep students indoors. For the lesson plans to continue uninterrupted for two weeks, temperature and conditions would have to remain within a narrow range. However, such issues could be overcome by rearranging the order of activities in the lesson plans. Teachers can save indoor activities (lab preparation and indoor labs) for days when going outside is not possible.

Teachers may also have to adjust plans to teach struggling readers or students with disabilities. While the content is not difficult for the average high school student to understand, students may need a review of concepts like cell structure and function, energy flow/waves, and basic chemistry. Some of this review can be achieved through discussion of opener questions. However, my experience with students in two midwestern states has indicated that this may not be enough. While the order in the lesson plans is suggested, I understand that this will not always be possible, and teachers armed with the *ideas* for winter ecology inquiry will have the ability to adjust curriculum as necessary for their particular situation. I have used lesson plans from many sources, but rarely do I follow these "to the letter". Instead, they have provided treasure troves of ideas and corresponding resources, which I have in turn used to construct my own related lesson plans based on the source material. I hope that other teachers, who certainly know their local weather patterns and student population, will choose to adjust their lesson plans accordingly.

Possible Future Work

My project detailed just a few of the possibilities for winter science inquiry. As a result, many topics that could have been explored at a deeper level were glossed over, providing a sampling of possibilities to interest students and educators alike. Future researchers may choose to explore the outdoors through a physics or chemistry perspective, spending more time on the chemistry of water and its unique physical properties. Students could also approach animal insulators from a physics perspective, using a similar lab set-up to calculate insulator efficiency. Back in biology, student could investigate photosynthesis in tree bark, spurred along with the carbon dioxide from respiring cells in the trunk.

Beyond the applications in these disciplines, new work could be done to help teachers and students utilize citizen science projects in the curriculum. Projects like CoCoRaHS (Community Collaborative Rain, Hail, and Snow) Network and the Cornell Lab of Ornithology citizen science initiatives provide educators with ways to connect their students to ongoing scientific data collection and analysis. When students learn that their data can be used by a scientist to support a healthy environment, I believe they will be much more engaged in the process.

My hope for this project is that it will provide teachers with tools and ideas to engage midwestern students in inquiry outdoors in the winter. In this way, students will be able to participate in and and ask questions about a world that has been considered “off-limits” to modern education. Teachers can and should bring their students outside in the winter because it is in this season that we can experience unique survival strategies, measure and engage with real issues, and just plain have fun doing science in the snow.

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