Summer 2023

Utilizing Storytelling in a High School Ecology and Cell Energy Unit

Katherine Shealy
Hamline University

Utilizing Storytelling in a High School Ecology and Cell Energy Unit

by

Katherine Shealy

A capstone submitted in partial fulfillment of the requirements for the degree of Master of Arts in Teaching

Hamline University

Saint Paul, MN

August 2023

Primary Advisor: Jana Lo Bello Miller
Content Reviewer: Charles Johnson
Peer Reviewer: Chris Cudnowski, Sarah Graham, Isaiah Ripley, and Allie Brown

DEDICATION

To my family who supported me through this teaching program and creation of this project. Thank you to my professors that guided me through this Capstone project, Trish Harvey and Jana Lo Bello Miller. Special thanks to my friends and classmates, Isaiah, Sarah, and Chris, for making this time in my life full of laughter, support, and commiseration.

TABLE OF CONTENTS

CHAPTER ONE

Introduction

Science has been and will continue to be studied by a multitude of different people from varying cultures. Due to this, people study and conduct science in unique and diverse ways. In the United States, the predominant mode of delivering and assessing science curricula is through lectures and memorization (Buxton & Provenzo, 2007). However, in other cultures, science knowledge is taught and absorbed through storytelling, discovery, projects, and more (Nelson-Barber & Estrin, 1995). As we evolve and aim to improve our science pedagogy, it is crucial to look at other ways of teaching science.

I created a Capstone project which involved the formation of an ecology and cell energy unit that follows the story of the reclamation and restoration of land in Minnesota back to its original form. This chapter provides both rationale and context for this question. It touches on my personal journey that led to me this question as well as how this question fits into my role as a science educator. Additionally, it explains how different stakeholders, such as students, their families, the community at large, and fellow educators, can benefit from the research and unit created through this Capstone project. My experiences and witnessing those of others in the science classroom have led me to develop the Capstone research question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?*

My Journey

In every course I took as a graduate student working towards getting my teaching license, I imagined what I would be like as a teacher. Would I be someone students could learn more than just science from? Could I show students that science is a fascinating topic? I had and still have big hopes for the impact I can have on students and their relationship with school and science specifically.

I have seen the impact I can have on students in my current role working as an educational assistant at an online school. Students who have not connected with anyone else connected with me instantly and their improvement was noticeable. It was hard to see what I did to help them. Was it my patience? My encouragement? My ability to explain information in a more digestible way? I wondered how I was getting through to these students because it was not anything I was doing intentionally. Rather I was trying to be the person I would want if I were the student in that situation.

It was not until I went through student teaching that I truly understood what it took and meant to be an impactful teacher. One day about halfway through my student teaching I received an email from a student who had to practice sending a professional email for one of her classes. She chose to email me and she started her email by saying that I do a good job of providing clear instructions and being patient. However, how she ended her email brought tears to my eyes. She said that she loved how open I was with them, sharing about myself, but also that I was genuinely interested in hearing about them outside of just who they are as students. This student said she has had teachers who just see their students as bodies in a seat and their grades as the only thing that matters. But I was not one of those teachers.

At the end of student teaching, the students wrote me notes as a going away present. They were vulnerable and compassionate. I still have them to this day and look at them when I need a boost of encouragement. The email along with the notes made me realize that a big part of teaching is about connecting with students. The traditional way of teaching science does not allow for this because it focuses primarily on facts and knowledge acquisition rather than students connecting with what they are learning. That is why I desire to find a more meaningful way to create units and teach scientific ideas.

One reason I believe that students learned and enjoyed science while I was teaching it is that I strayed away from the traditional way of lecturing and memorization. Instead, I used many hands-on activities, labs, and projects to aid students in learning. One technique I did not use but am interested in learning about is storytelling. Storytelling is the art of narration to describe events and experiences using vocalization, gestures, and other forms of communication (Gürsory, 2021). It can be used in science as a unique form of pedagogy to explain and help students visualize the events of a scientific discovery or phenomenon.

Science educators can utilize storytelling to create a common thread throughout an entire unit which helps students understand how what they are learning about is connected. That is why I used this project as a chance to explore what it would take to build a unit using storytelling. When I was thinking about what I wanted to do for a project, I thought back to my methods classes for my teaching program. Through these classes, I learned about using a story to teach a unit.

I thought this was such a unique teaching method that had the potential to be effective. Then, I had to think about what unit I could use this story technique for. My first instinct was to create a genetics unit as my Bachelor's degree is in genetics. However, genetics is quite a common unit for storytelling. There are already stories that have been created. For example, there is a story that follows a family with albino children to help teach about inheritance, mutations, meiosis, and so on.

I was discussing with my grandfather and he suggested that I look into a land site in Minnesota that has been reclaimed and restored to its original state. I could use this land site to create an ecology and cell energy unit. This was a great idea because I will be teaching in Minnesota so this will make the story even more meaningful as the story will take place near where students live. Also, one of the standards for Minnesota is to include knowledge and information about Native American tribes found in Minnesota. Not only will this unit include a personal touch in that it is found in the student's home state, but it will also bring a diverse lens to students' learning.

Once I was able to focus on what the story could potentially be, it made me very excited to use the storytelling technique. Storytelling might be a new technique used in Western science classrooms, but storytelling has been a teaching method used by all people for hundreds of thousands of years. I believe that using storytelling and making personal connections will not only make learning science more meaningful, but it will make students feel more connected to what they are learning and where they are learning.

The Rationale

Science standards tend to be rigid barriers to teaching science outside the traditional Western way. This is because many standardized tests require students to memorize terms and equations in order to do well on them. Breaking from this would also require breaking away from traditional standardized tests. Additionally, scientific ideas and concepts are not uncovered by knowing a multitude of facts or the right equation. Scientists learn through experimentation, trial and error, and discovery. Therefore, it would make more sense to teach science in the way that it is done in the real world instead of through lectures and strict memorization.

Minnesota has recently adopted new science standards that align more closely with how science is done in the real world. They are called the New Generation Science Standards (NGSS). Each NGSS standard includes three important domains. The first is crosscutting concepts which aim to help students explore connections between all the different sciences. This area helps students form a scientific worldview. The second domain is the science and engineering practices domain. Within this domain, students learn how to scientifically investigate the world around them and apply their knowledge. Finally, the third domain, disciplinary core ideas, are the key ideas found in science and these are built on throughout the grade levels (*Three Dimensional Learning*, n.d.). Together these three domains help students form a scientific view of the world around them by using different concepts and tools that encourage inquiry and discovery.

One of the new state life science standards requires Minnesota science educators to teach how Native American tribes in Minnesota, as well as other cultures, create explanations of phenomena and design solutions to problems (Minnesota Academic Standards in Science: 9L.4.2.2.1). Therefore, I want to create a high school ecology and cell energy unit that focuses on a habitat in Minnesota that has been reclaimed and restored to its original state. I believe that this will allow me to pull in stories and knowledge from Native American tribes as their knowledge of the land in Minnesota and how to care for its ecosystem goes back hundreds of years.

Some stories have been created by the organization that created the NGSS as well as by other educators. However, I have not found one for an ecology and cell energy unit that incorporates Minnesota. Therefore, between using NGSS standards and storytelling, I hope to create a meaningful and informative unit that answers the question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?* I will create a seven-week Minnesota-inspired ecology and cell energy unit that will bring in students' personal experiences and knowledge. The unit will encourage inquiry and provide students a chance to learn about a culture that may be outside their own.

Context

As of now, I do not work in a school where I will be for the long term. Therefore, I will be using data from the Minnesota Student Survey Interagency Team (MSSIT) 2022 Student Survey that I feel is important to create context. According to the MSSIT student survey, 70% of public schools chose to participate in this survey and together those that did participate constituted 51% of those enrolled in Minnesota public schools (Burton et al., 2022).

First, it is important to know what identities students associate with as this shapes who they are and can inform educators about what type of cultures they should try to include in their curriculum. For race, on average: 1.5% of students identified as American Indian or Alaskan Native; 6.25% as Asian or Asian American; 8.75% as Black, African, or African American; 6.5% as Hispanic or Latino/a; 0.5% as Middle Eastern/North

African; 64% as White; 9.5% as multiple races; and 2.25% did not answer. For sexual orientation, on average: 88% of male-identified students identified as straight, 3.3% identified as Bisexual, and 1.3% as Gay or Lesbian; 65% of female-identified students identified as straight, 14% as Bisexual, and 4% as Gay or Lesbian. For gender identity: 91.5% identified as cisgender, 1.2% as transgender, 2.5% as genderfluid, 6% as non-binary, and 2.7% were questioning/unsure (Burton et al., 2022). When considering the kind of teacher I want to be, I consider this information. Because even if there is one student who falls outside the White, Straight, Cisgender norm, I want them to feel seen and included in the classroom and content. As a queer cis-woman, I have experienced a disconnect with some of my science courses because I did not see myself represented in the curriculum. There are plenty of scientists I have learned about as an adult whose identity aligns with my own. It would have benefited me greatly to learn about these people in my science classes as a younger person. Science has been and continues to be formed and shaped by people from all walks of life and this will be shown in my classroom.

Next, it is important to consider students' attitudes and feelings surrounding the school. The survey asked students if they missed school, then why were they absent. On average, 5% of fifth and eighth graders said they were absent because they were bored with or not interested in school while 12.25% of ninth and eleventh graders said this response (Burton et al. 2022). I found it interesting that this number increased for high school-age students as my license is for grades 9-12. The survey asked students if something interests them, then will they try to learn more about it. On average, 60% of all students surveyed said they agreed with the statement (Burton et al., 2022). This is key to making a curriculum that incorporates students' interests and choices.

When asked if they feel their teachers at school care about them, 32.5% of fifth graders said very much, 9.5% of eighth graders said very much, and 7.5% of ninth and eleventh graders said very much (Burton et al., 2022). This concerns me because students in high school feel less often that their teachers care about them very much than those in elementary school. It intrigues me to know why this happens. Finally, about 16% of all students surveyed have been treated for a mental health, emotional, or behavioral problem in the last year (Burton et al., 2022). Mental health is finally something that schools are taking into consideration with some even treating mental health days with the same importance as sick days. Mental health can take a real toll on students and people in general. With the COVID-19 pandemic, I only see this number increasing because people's lives were changed immensely and so much grief occurred.

Stakeholders

Several people would benefit from the creation of this unit and Capstone project and are therefore stakeholders. They include fellow educators, curriculum creators, students, and the community at large. Not only would life science educators benefit from the creation of this unit, but all educators and curriculum creators would benefit from incorporating more storytelling into their curriculum. Every subject area could create a unit or lesson that involves the techniques used in the creation of this unit. Additionally, this unit will focus on Native American teachings and practices which could also be taught about in a historical context. Furthermore, this unit will closely follow and align with the NGSS guidelines and concepts which all science educators in Minnesota had to adopt by 2023. Therefore, this provides a framework for one approach that encapsulates and strongly builds on these principles.

Students and the community at large would benefit from the creation of this unit as well. For many students, the traditional way of teaching science is not an effective teaching model. This unit creates a series of lessons that will incorporate students' real lives and knowledge. Additionally, it allows students to make a personal connection to what they are learning and learn in more meaningful ways. For the community, one of the main focuses of the NGSS is that students become more aware of the world around them and use their knowledge to question and inquire about phenomena. Instilling this concept into students creates citizens that make better-informed decisions and think critically about the consequences of their actions as well as about solutions to world problems. Overall, the creation of this unit and project should have many positive outcomes and impacts.

Summary

In chapter one, I introduced the topic and research question of this Capstone project. The research question is: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?* Once the question had been introduced, I provided an overview of the journey I took to get to this question. I provided information on my background and why this is an essential topic to me.

Next, I went into the rationale for the research question and project. I discussed how the traditional way of teaching science is not necessarily the most effective. Additionally, I discussed the New Generation Science Standards which are built around bringing more inquiry teaching into the science classroom. Then, I discussed the important context of the project. I took data from a survey given to Minnesota students in 2022 to better understand demographic information such as race, sexual orientation, and more. Finally, I ended the chapter with an overview of the stakeholders for this project. The people who would benefit from the creation of the unit within this project include fellow educators, students, and the community at large.

In chapter two I conducted a literature review about three subtopics that helped to develop the necessary rationale and background information needed for the creation of the ecology and cell energy unit for the Capstone project. The subtopics include an examination of the best scientific teaching techniques, an evaluation of the effects of standards on student learning, and an investigation into equity and diversity within science. In chapter three I discuss the who, what, when, where, why, and how of the project by describing the project, the setting and intended audience, the timeline of the project, and how the effectiveness of the project will be assessed. Finally, in chapter four I concluded the project and reflected on the process of creating the project as well as the project itself.

CHAPTER TWO

Literature Review

The following literature review discusses relevant research and sources that relate to the research question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?*

The chapter starts with a review of science teaching. Science teaching of the present is different from science teaching of the past (Buxton & Provenzo, 2007). This is due to science educators taking a different approach to teaching science. This section provides an overview of how traditional ways of teaching science differ from inquiry-based learning and culturally different ways of teaching and learning science, specifically Native American ways of teaching and learning. Additionally, it examines the usefulness of utilizing storytelling in science. Finally, it also aims to compare and contrast student achievement and connection with learning science through traditional techniques versus inquiry-based techniques.

The next section of the literature review addresses the New Generation Science Standards (NGSS). One of the keystones of education is the standards teachers must build their curriculum around. In science, standards have been subject to change with the most recent change being the NGSS. In Minnesota, all science educators had to adopt the NGSS by the year 2023. These standards are meant to help students build a scientific worldview that helps them interact with and explore the world around them. This section provides an overview of the use of standards in science education, specifically breaking down and analyzing the NGSS. It also examines the positive and negative aspects of using standards in education and the effect they have on students' learning.

The last section examines the history and experiences of women, people of color, and other marginalized groups in science. Although science books in the United States may not make it seem this way, science is done and has been done by people of all backgrounds. It is important to acknowledge this and incorporate this into the science curriculum. Students have a right to see themselves and people who are like them reflected in their education. This section examines the effects students from marginalized groups have experienced due to their lack of inclusion in the curriculum. It also looks at the effects that inclusion can have on marginalized students as well.

Science Teaching

There are varying beliefs and opinions about the most effective way to teach science. However, there is one form of teaching that has dominated science classrooms for many years. Buxton and Provenzo (2007) stated, "When science has been taught at all, it has generally been presented as a collection of vocabulary and facts, read from a textbook, then memorized for a test" (p. 1). There are many ideas and concepts to be learned in science, nevertheless, this does not mean that the most effective way to teach students about these is through rote memorization. Buxton and Provenzo (2007) went on to say, "Memorizing scientific vocabulary without understanding what science is or how it is practiced will not prepare students for the scientific and technological world in which they will live" (p. 1).

Real scientists do not practice science by relying on memorization. Instead, they ask questions, conduct experiments, rely on their own as well as others' experiences and funds of knowledge, and learn from failure. Klopfer and Aikenhead (2022) pointed out that "A conventional approach [*to science teaching*] is to give emphasis to decontextualized scientific knowledge, on a need-to-know-for-a-test basis" (p. 491). Furthermore, Klopfer and Aikenhead (2022) stated:

> Conventional high school science curricula today are mainly about the world of abstract categories, laws, theories, models, and calculations…However, these curricula do not answer two fundamental questions that many learners pose: How is it used? How does it connect with me? (p. 491)

Science teaching tends to depersonalize and separate students from the science itself. Students are not encouraged to question theories or facts but instead accept them and be able to recall them for long enough that they can do well on an exam. According to Buxton and Provenzo (2007), "The most innovative approaches of people such as Dewey (1907) and Vygotsky (1987), in which students were involved in an active process of discovery and reflection, continue to be the exception rather than the rule" (p. 47).

It is not entirely the fault of the science teacher that science has been taught in this manner. Grimber and Gummer (2013) acknowledged that "The organization of the school day using limited time periods, and the authoritarian structure of schools, constrain the open-ended activity of science" (Theoretical Practices). Science is a process that requires time and repetition. However, the current educational system limits teachers' ability to allow students to learn science as it should be learned. Additionally, Grimber and Gummer (2013) stated, "Similarly, the dynamic nature of scientific knowledge characterized by the practice–knowledge cycle is at odds with teacher-centered instruction" (Theoretical Practices). In science classrooms, the students should be partners in the knowledge acquisition process. They should be able to ask questions and guide their learning. However, that goes against the current structure of the United States educational system where the norm is that the teacher is the one responsible for the transferring of knowledge.

Finally, one last aspect that is missing from science education is the history and context of scientific concepts. Rowcliffe (2004) said in a study that a high proportion of postgraduate students “felt that ‘absence of history or context’ had been one of the reasons that they had found science insufferable” (p. 122). In my experience, theories and facts in science are taught in a way that explains the theory but neglects to explain how the scientist(s) were able to discover and definitively support their theory. Therefore, there is a lack of understanding from students as to why that theory matters to them and their own lives. Throughout the creation of the unit for this Capstone project, I pushed against traditional forms of science teaching and incorporated new approaches to make science learning more meaningful and impactful. These new approaches are discussed next.

Changes to Science Teaching

Students finding meaning within science is one of the ways science educators are changing how science can be taught. As Buxton and Provenzo (2007) said, “Science is much more than definitions: science is an integral part of our daily lives. In modern society, it surrounds us in everything we do” (p. 6). Allowing students to view science as something that they experience every day instead of simply as a school subject can change how students view science. One way to incorporate science into students’ everyday lives is to teach science using inquiry-based learning. Inquiry-based learning is defined as “a learning process that engages students by making real-world connections through exploration and high-level questioning” (Santa Ana College, n.d., Inquiry-Based Learning). Staver (2007) explained the role inquiry learning can have, “Today’s students must learn how to do scientific inquiry and use scientific information to make decisions that will affect their personal lives, careers, and societies” (p. 9). Students are using science and scientific concepts every day, however, there tends to be a disconnect. Buxton and Provenzo (2007) pointed out where this disconnect likely comes from, “Memorizing scientific vocabulary without understanding what science is or how it is practiced will not prepare students for the scientific and technological world in which they will live” (p. 1).

Therefore, there must be a conscious effort on the part of the teacher to create better and more meaningful learning opportunities for students. It is not enough to have content knowledge of the subject they are teaching. “There is more to being an effective teacher of science than having a firm grasp of the relevant science content… to be an effective science teacher you must master appropriate forms of pedagogy” (Buxton & Provenzo, 2007, p. 2). Klopfer and Aikenhead (2022) described an appropriate form of pedagogy:

> An effective case history of science is: a story; accompanied by activities, investigations, conversations, and arguments; to learn: the scientific content, who the people are, how they know what they know, their assumptions, their passion, and rational ways they decide what to believe as a tentative truth; and the ways science affects society's political–industrial–military–environmental–economic complex, and vice versa; as well as affecting students’ personal lives. (p. 493)

Essentially, students should be able to see how science connects to themselves and the world around them through learning activities the teacher creates. Students should also be able to see themselves reflected in these activities and the teacher should create a curriculum with their students in mind. This is important not only for students but also for society as a whole. As Buxton and Provenzo (2007) stated, “Continued scientific progress, in turn, requires satisfactory science education” (p. 41).

Another way to make science learning more meaningful for students is to use a teaching technique broadly known as culturally responsive teaching. Grimberg and Gummer (2013) explained how one can teach in such a way, “Culturally congruent instruction intends to bridge the cultural differences between school, and homes and communities of non-mainstream students” (Theoretical Perspectives). Educators can bridge the gap by not only understanding but also valuing students’ cultural backgrounds. Additionally, teachers who can connect students’ experiences to science continue to bridge the gap (Grimberg & Gummer, 2013).

Culturally Responsive Teaching

Unfortunately, the gap for students from certain ethnic groups remains and results in people from these groups being under-represented in careers that require both mathematical and scientific knowledge (Nelson-Barber & Estrin, 1995). Therefore, science educators must turn their attention to finding ways that make science accessible to all students. One theory is to use a constructivist framework where “the child's personal experience and knowledge base become keys to instruction and to understanding how children construe new information and experiences” (Nelson-Barber & Estrin, 1995, p. 175). It cannot be overstated that including students’ identities in their curriculum improves the learning experience immensely.

As Aikenhead (2001) explained, “For the vast majority of students, however, enculturation into Western science is experienced as an attempt at assimilation into a foreign culture” (p. 2). Science has a culture of its own and any student who enters a science classroom is entering a new culture. Therefore, teachers must act as culture brokers for students which means they help students go between their own culture and that of Western science (Aikenhead, 2001).

One way we can view how culture and science are at odds is by looking at the experience of Native American students. Nelson-Barber and Estrin (1995) explained that “American Indian ways of teaching, such as modeling and providing for long periods of observation and practice by children, are quite harmonious with constructivist notions of learning” (p. 175). However, these ways of teaching tend to run counter against Western science ways of teaching. One example of this is, “In tribal science, the observer is not separate from the observed; and Western science, itself, is slowly coming to recognize such separation as impossible” (Nelson-Barber & Estrin, 1995, p. 177). Western science tends to take concepts out of their context and displays them in a very linear time frame. However, Native American ways of thinking focus on the interrelationship of concepts and view time as more circular (Nelson-Barber & Estrin, 1995).

Some believe it is not feasible to include a student’s culture in science because “cultural considerations do not determine the truth claims of science” (El-Hani & Mortimer, 2007, p. 661). They believe that science is supported by unbiased evidence and that someone’s personal beliefs or opinions cannot change the truth of scientific ideas and concepts. However, this does not take into account the students who are learning science.

Believing that Western modern science is the only way of knowing and putting it above other cultures' scientific thinking is harmful to students from other cultures (El-Hani & Mortimer, 2007). As El-Hani and Mortimer (2007) pointed out, "Knowledge is a social construction, but this construction operates within a limited territory, constrained by an independent reality" (p. 666). Students' realities and backgrounds will influence their acquisition of science knowledge. This means students may find themselves in a difficult position, especially if their disbelief prevents them from understanding the science. Therefore, a science teacher should aim for students to understand the science, but not necessarily believe in the science (Staver, 2007). For example, students should be given all the tools and information necessary to understand evolution, but not necessarily required to believe in evolution, especially if it conflicts with their personal beliefs.

It only means so much to say that incorporating students' identities and using inquiry-based learning will increase student engagement with science. It is important to also observe what effects this has on students once put into practice. Grimberg and Gummer (2013) aimed to study the effect culturally-relevant professional development teachers underwent had on the science learning of Native American students in Montana. They found that the professional development increased the teacher's effectiveness at implementing pedagogy that was culturally inclusive and responsive to students which in turn improved student learning of the content. By relying on students' cultural banks, teachers were able to make meaningful connections. In fact, they found that:

> Gains in teacher beliefs about their ability to implement equitable strategies and the increase of teaching strategies that prompt students to make connections between science and their real-life issues significantly explained the 36.7% of the

> variance of student science test scores gains in treatment classrooms. (Grimberg & Gummer, 2013, Abstract)

This means that when teachers improve their culturally responsive teaching strategies, they also have significant effects on student achievement. Furthermore, Grimberg and Gummer (2013) observed that “Teachers' implementation of equitable instruction…prompted students to make connections between science topics, issues relevant to their lives, and hands-on experiments” (Discussion). To summarize, incorporating outside cultures and culturally responsive teaching techniques allowed students to make more connections with the science they were learning and how it reflected in their lives outside of school (Grimberg & Gummer, 2013).

Storytelling in Science

One last teaching technique that will be discussed in this section is the use of storytelling in science. Gürsory (2021) described storytelling as “the art of narration of the experiences, traditions, or the culture of ancestors using language, vocalization, and gestures to simulate the scenes of an event” (p. 97). For science, this could mean teaching a specific concept through the use of a story, such as a story of how James Watson and Francis Crick used data from Rosalind Franklin without her permission when teaching about the structure of DNA. Another option would be to teach an entire genetics unit through the lens of a single story, such as the story of an Albino family while teaching a genetics unit.

In science, educators can use storytelling to make students more excited, engaged, and emotionally involved in the content they are learning (Rowcliffe, 2004). Storytelling can be useful in science in many different ways. One way is it can give students a historical context of the science they are learning. Another is to provide students with more entertainment and therefore get them more fired up about learning. A third way storytelling can be useful is to provide students with mental triggers to bring what they have learned to the forefront of their minds (Rowcliffe, 2004). In this day and age, digital storytelling (DS) is a tool many educators can use. Gürsory (2021) conducted a study to determine the effectiveness of digital storytelling in the 21st-century classroom. According to Gürsory (2021):

> The pre-service teachers mostly considered the advantages of DS since it led to meaningful and permanent cognitive learning and allowed students with different learning styles to learn, it was fun, motivating, and attractive in the affective dimension, and facilitated the adoption of daily life in the psychomotor skills dimension. (p. 109)

Storytelling has many positive effects on students and with the continued adoption of technology into the classroom, teachers must find a way to utilize the technology positively and beneficially (Bilen et al., 2019).

Bilen et al. (2019) also conducted a research study on digital storytelling for 6th-grade science students. They found that the use of digital storytelling not only improved students' academic performance but also their attitudes toward learning science. Bilen et al. (2019) stated, "These activities give children the opportunity to solve problems, use their imagination, develop their creativity, and reflect their inner Earth" (p. 1). There were some downsides to storytelling and they are that creating stories can be time-consuming and that creating digital stories requires access to and knowledge of technology (Gürsory, 2021). Overall, the benefits of storytelling outweigh the negatives.

Throughout my Capstone project, I will be sure to rely on culturally responsive teaching techniques as well as inquiry-based learning when creating the unit within the project. In the next section, I examine and discuss the use of science standards, specifically, the New Generation Science Standards (NGSS). I break down the different components and aspects of the NGSS as well as the effects using standards has on student learning.

Science Standards

Educators are well aware of the importance of standards for shaping and guiding their instruction. Standards are a key component in education and they were developed for a reason. They were developed with a positive outcome in mind, however, many teachers and administrators are aware that there are also negative consequences that go along with implementing standards and evaluating the usefulness and effectiveness of these standards using standardized tests.

The Effects of Using Standardized Tests

The No Child Left Behind (NCLB) Act was implemented as a way to hold schools accountable for student learning (Aydeniz & Southerland, 2012). NCLB utilized standardized testing as a way to evaluate student learning and achievement which in turn reflected on the effectiveness of the teacher and school that students attended (Aydeniz & Southerland, 2012). Proponents of standardized testing argue that:

> Assessment can support students' learning and improve the quality of instruction when used formatively. When used summatively, it can help monitor the effectiveness of a particular curriculum, help evaluate the quality and effectiveness of instruction, and enhance the efficiency of the school system.

(Aydeniz & Southerland, 2012, p. 234)

Therefore, the proponents of standardized testing believe that standardized tests are an effective way to hold teachers accountable as well as improve the quality of the curriculum. They also view standardized tests as reliable indicators of student learning and a way to ensure students achieve “minimum academic competencies” (Aydeniz & Southerland, 2012, p. 235).

Opponents of standardized testing argue that emphasizing “the results of one single test does not necessarily ensure the quality of science education delivered in nation’s science classrooms as well as address equity issues in our schools” (Aydeniz & Southerland, 2012, p. 235). Additionally, standardized tests “were found to fail to adequately sample higher order thinking, high-level conceptual or high-level procedural knowledge in either subject” (Lomax et al., 1995, p. 171). Furthermore, opponents of standardized tests believe that these tests pressure educators into reducing their curriculum solely to knowledge and skills that will help students pass the test (Aydeniz & Southerland, 2012). Therefore, teachers are pinned into a corner that does not allow for inquiry learning and exploration which are important components of science learning. Another negative aspect of standardized testing is that:

> Teachers do not differentiate instruction to address the learning needs of students who need additional assistance (i.e., underachievers) or those who need further challenge (i.e., gifted students). Rather, they cater instruction to the learning needs of average achieving students—who have the greatest likelihood of making gains on these assessments. (Aydeniz & Southerland, 2012, p. 235)

As personalized learning and instruction become more prominent in schools, standardized tests make it harder for teachers to adjust and adapt their curriculum which is required for personalized instruction (Aydeniz & Southerland, 2012). This personalization is especially important for students with learning disabilities, English language learners, and students with specialized learning plans such as 504s.

Another group that has been negatively impacted by the use of standardized testing are students from high poverty and minority students (Aydeniz & Southerland, 2012). This is contrary to why the NCLB Act was put into place as one reason for the NCLB Act was to close the achievement gap between students from advantaged and disadvantaged backgrounds (Lomax et al., 1995). This inequity and unfairness for students from marginalized groups have significant implications. For example, poor results on standardized tests make marginalized students ineligible to participate in courses needed for higher education (Lomax et al., 1995). It also tracks these students into remedial courses that focus on test preparation instead of higher-order thinking skills and causes them to drop out of school in larger numbers (Lomax et al., 1995). Therefore, the "mandated standardized tests in mathematics and science not only have significant impacts on classroom teaching and instruction, but these impacts are even more substantial in high-minority classrooms" (Lomax et al., 1995, p. 183).

A study conducted by Geier et al. (2008) found that standard-based, inquiry science curricula can improve underserved urban students' achievement on standardized tests. However, Geier et al. (2008) emphasized that this is only achieved when "the curriculum is highly specified, developed, and aligned with professional development and administrative support" (p. 923). Additionally, Geier et al. (2008) pointed out that research consistently proved lower achievement by urban minority boys compared to urban minority girls. They say this is due to “a number of contextual factors that limit or discourage learning for boys” (Geier et al., 2008, p. 934). However, with the use of their standard-based, inquiry curriculum they found it “essentially eliminate the boy-girl difference in science achievement, allowing this often at-risk group to catch up with their peers” (Geier et al., 2008, p. 934). Therefore, it is possible to use inquiry-based learning and still have positive student outcomes on standardized tests. However, it requires better resources and more prepared teachers (Aydeniz & Southerland, 2012).

One last downfall in regards to standardized testing is the design and creation of the exams themselves. Visone (2009) conducted a study to examine if there is a relationship between how students perform on science standardized tests and their reading ability. Visone (2009) stated that:

> The inability to insure that items are readable by and understandable to the students taking the test leaves open the possibility that the test is not only assessing its intended concepts, but reading proficiency and reading comprehension, as well. (p. 47)

This means that students are not only being tested on their scientific knowledge but also on their ability to read and comprehend in general. Through their study, Visone (2009) found that “both science knowledge and reading comprehension skill displayed statistically significant correlations greater than .50 when compared to science achievement” (p. 50). Visone (2009) also found that reading comprehension had a greater effect on student performance on a science comprehension passage than the student’s science knowledge had. Creators of science standardized tests should take this into account along with the open-ended nature of science.

There are many positive intentions that come along with the use of standards and standardized testing. However, it is also important to consider the pressure they put on educators and the limiting effects they can have on students' learning (Aydeniz & Southerland, 2012). In order for science standards and standardized tests to be effective, they must start taking into account the nature of science and the best approaches for learning science. This is something that the New Generation Science Standards are trying to be conscious of so that the science curricula can be more equitable and meaningful.

The New Generation Science Standards

Science standards have continually been undergoing reforms since the late 1980s in the United States (Bybee, 2013). There are many reasons for this, however, Bowman and Govett (2015) explained that "science changes every day and with it the skills necessary to understand its increasing complexity change" (p. 1). Due to the ever-changing nature of science, which is a core value of science, educators and members of the scientific community decided there needed to be science standards in primary and secondary education that reflected this (Bowman & Govett, 2015).

Therefore, in July 2011, the National Research Council (NRC) developed *A Framework for K-12 Science Education* (Achieve, n.d.). According to Achieve (n.d.), "The *Framework* provides a sound, evidence-based foundation for standards by drawing on current scientific research—including research on the ways students learn science effectively—and identifies the science all K–12 students should know" (Resources). Additional key features of the framework are expressed by Penuel et al. (2015):

> The *Framework* also called for a sharper focus on equity and diversity in science education. All students should be expected to reach high academic standards and

> also have adequate opportunities to learn science. Science educators should identify interests, experiences, and cultural practices relevant to young people's everyday lives, and instruction should make use of these to support science learning. (p. 3)

This *Framework* was used to create the New Generation Science Standards (NGSS) which are the new science standards that have been adopted by many states, including Minnesota (Achieve, n.d.).

Penuel et al. (2015) described the difference between past science standards and the NGSS, "Where past standards separated content from process, the NGSS expect students to develop an integrated understanding of science both as a body of knowledge and a set of practices for developing new knowledge" (p. 3). The National Research Council (2015) also acknowledged that standards alone do not accomplish much, but standards can "drive improvements when they are informed by all aspects of the education system, including curriculum scope and sequence, curriculum resources, instruction, assessments, professional development for teachers and administrators, and state policies" (p. 9). Therefore, there has been a great need for standards like the NGSS in science education.

The NGSS categorizes learning goals for students into three dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas (National Research Council, 2015). The first dimension, scientific and engineering practices, describe the skills and practices scientists utilize when investigating the natural world as well as what engineers do when they create systems (Achieve, n.d.). This dimension reflects what science educators mean when they describe inquiry learning. It is through this dimension that students are not only developing and building their scientific knowledge, but also applying and deepening their knowledge of core science concepts (Achieve, n. d.).

The second dimension, crosscutting concepts, utilizes concepts that allow students to see connections between the four scientific domains which include Physical Science, Life Science, Earth and Space Science, and Engineering Design (Achieve, n.d.). Some of the crosscutting concepts that are included in the NGSS are cause and effect, observing patterns, recognizing the scale, proportion, and quantity of phenomena, and understanding how the structure of an object can determine its function (Bybee, 2013). In addition to connections between the four science domains, the NRC *Framework* also "outlines coherent trajectories for students' learning in science that span grades K-12" (National Research Council, 2015, p. 10). Therefore, students are building on their crosscutting concepts and skills, such as cause and effect, throughout every grade level of science and in every science domain. By establishing these crosscutting concepts in every aspect of science learning, students are able to use these concepts to develop a scientific worldview that extends beyond the classroom (Achieve, n.d.).

The last domain, disciplinary core ideas, are simply "the key ideas in science that have broad importance within or across multiple science or engineering disciplines" (Achieve, n.d., The Three Dimensions). These are typically part of standards people tend to think of when they think of standards. They are the core scientific ideas students will learn throughout their science education. However, the NGSS builds on these core ideas as students progress from grade to grade (Achieve, n.d.). This means students will encounter and have the opportunity to learn about these scientific concepts and ideas more than once.

This idea of focusing and building on specific core ideas is also one of the perceived downsides of the NGSS. Since the NGSS focus on the most important scientific concepts students should be able to master before graduating, they tend to be seen as having more depth and less breadth (Bowman & Govett, 2015). This creates issues for science educators when it comes to time management because the NGSS requires teachers to spend more time on core ideas than they normally would with other standards (Bowman & Govett, 2015). Due to this, science teachers can find it difficult to create lessons, activities, and assessments that go along with the NGSS (Penuel et al., 2015). However, as the standards become more established and adopted by more states, there are more resources available to aid educators (Penuel et al., 2015).

Lastly, since the Capstone project I created was about ecology, I looked specifically into the NGSS in regard to ecology. Bowman and Govett (2015) explained that “recent climate change events make changes in ecology, evolution, and biodiversity findings and their subsequent standards changes especially relevant” (p. 12). Ecology is a key unit in biology and the effect ecological change has on students is more important than it ever has been (Bowman and Govett, 2015). In fact, Bowman and Govett described how important this is:

> The ability to predict the subsequent responses is an unavoidable consequence of anthropogenic climate change, and as an inclusion of this standard in the NGSS speaks directly to the need to develop the young scientists’ ability to think about questions such as biodiversity and survivability. (p. 13)

Students must develop the ability to understand and visualize how humans impact the environment which is a core idea throughout the unit I created for my Capstone project. It is crucial for the future of this planet that students learn to scientifically evaluate and approach real-life issues. However, it is difficult to get students to buy into learning when they do not feel connected to the content they are learning, which is described in the next section.

Equity and Diversity in Science

It is well known and apparent that an opportunity and achievement gap exists between students from the majority culture and students from minority cultures in the United States. Within science specifically, the majority culture has been white males and this has caused a gap in scientific opportunities and representation between white men and people who are not white nor men (Hall, 2011). The United States is diverse and the lack of diversity within educational institutions has harmed the learning and achievement of students who identify as female and/or students of color. Within this section, I discuss the experiences of girls and women in science as well as students of color. I especially focus on the experiences of Native American students and how we can learn from Native American teaching practices to make science curricula and pedagogy more equitable and welcoming to all students.

Supporting Girls and Women in Science

Hall (2011) researched why girls and women have traditionally been under-represented and experienced unequal treatment within science. Hall (2011) explained that the "inequality in science instruction is a crucial component to the under-representation of females in science and "the existing literature suggests that the competitive nature of traditional science classrooms and the view of science as a male field of study inhibit female scientific performance" (p. 3). Essentially, the culture of science and traditional science classrooms does not align with how female-identified students tend to learn and creates an unsupportive and difficult environment for girls and women (Hall, 2011).

Inequality within the science field such as within scientific jobs all starts in the science classroom (Hall, 2011). Under-representation continues throughout a woman's secondary and university education and can even be compared to a leaky pipe. As women move through their education, they lose interest in science careers at a higher rate than men do, leaking out of the pipe, and this leads to an under-representation of women in science careers (Clark, 2005). Additionally, Hall (2011) explained how the "conventional science-learning environment is competitive and individualistic" (p. 12). Furthermore, the gender disparity within science classrooms is also due to male students verbally dominating discussions and answering questions (Hall, 2011). Not only is the inequality maintained in the classroom from teaching practices and teacher biases, but, the stereotype that science is a male-only field is reinforced in "a science curriculum base of materials, which provide biased language, content, and illustrations of science as primarily a male endeavor" (Hall, 2011, p. 13). This does not only influence girls' perceptions of themselves in science but it also influences boys' perceptions as well. Hall (2011) stated "Having minimal female representation in science curriculum and materials, female and male students come to the conclusion that science is a male subject of study and career path appropriate only to males" (p. 26).

Hall (2011) suggested that "methods, such as creating a collaborative learning environment and increasing inquiry-based opportunities…effectively counteract the disempowerment of females in science" (p. 3). Therefore, a move from traditional science teaching to inquiry-based science teaching helps to close the gender gap between students. Hall (2011) also suggested "that science classrooms be restructured to provide a safe and nurturing collaborative learning environment" (p. 15). Creating safer classrooms that value collaboration will help all students, but especially those who have been under-represented and underserved in the classroom.

Supporting Students of Color in Science Classrooms and US Schools

Mensah (2013) explained that students who come from diverse cultural backgrounds have academically lagged behind students who come from the majority culture. This is partially due to the fact that students from culturally diverse backgrounds do not share the same culture that schools and science classrooms were built on (Mensah, 2013). Additionally, within US schools and science classrooms, there has been a history of "segregation, policed language, and rote curricula" (Shea & Sandoval, 2020, p. 24). These have resulted in a lack of awareness of all students' identities and a lack of inclusion of multiple perspectives in the classroom which can enhance student learning (Mensah, 2013). Due to racism and a lack of inclusion, educators have developed "deficit thinking and negative views of students and their communities" which in turn affects how they treat and teach students from diverse backgrounds (Mensah, 2013, p. 71). Something must be done to help all students achieve academically.

Emdin (2016) described pedagogy techniques and strategies teachers can use to teach all students in his book *For White Folks Who Teach in the Hood and the Rest of Y'all Too*. The strategies he described should especially be used while teaching indigenous students as well as students of color, however, all students benefit from the strategies. Emdin (2016) discussed the seven C's that educators should use as tools while creating and delivering content to indigenous and nonindigenous students. The seven C's are as follows: "cogenerative dialogues, co-teaching, cosmopolitanism, context, content, competition, and curation" (Emdin, 2016, p. 60). By using these seven C's, educators can create a classroom that best serves all their students. I touch on only a few of the seven C's that I feel are most important and relevant for this literature review.

One of the most important themes Emdin (2016) explores is how a student's reality does not match up with the reality of their teachers. Therefore, when teachers do not acknowledge this, the student feels invisible and rightfully frustrated (Emdin, 2016). Many urban educators and experts do not live in their students' communities so they do not know about their students' realities (Emdin, 2016). This led Emdin (2016) to reality pedagogy which is a way of teaching students that allows each student to learn on their own emotional and cultural ground. In this way, teachers are learning from their students about how they can best deliver and teach them the content. The teacher and student are co-constructing a supportive classroom that allows for differences to be overcome (Emdin, 2016).

One of Emdin's (2016) strategies that worked well for students of color is co-teaching. He did not mean co-teaching between two teachers or between a special education and general education teacher. He meant letting students take over and teach content to their peers (Emdin, 2016). The students do all the tasks a teacher would do in lesson prep including making a lesson plan as well as planning many activities to engage the class (Emdin, 2016). This method allows the teacher to learn from the students and see what type of teaching, activities, and examples work best for indigenous and nonindigenous learners (Emdin, 2016). By engaging students on both sides of the learning process, you give them the tools they need to take control of their learning and realize that education is worth putting effort into (Emdin, 2016).

Another one of the C strategies that Emdin (2016) presented was cosmopolitanism. Cosmopolitanism is a method for creating community and respect in a classroom that is based on the values and culture of the indigenous and nonindigenous (Emdin, 2016). In a cosmopolitan classroom, students are given roles, such as class leader or organizer, they must perform to ensure a functional classroom environment (Emdin, 2016). This gives students a new way to view their relationship with one another as well as gives them the desire to support one another and their community (Emdin, 2016). Cosmopolitanism takes away the idea that there is a model student (Emdin, 2016). Instead, all students are valued and shown that they are good students. Additionally, it builds a classroom environment where both the teacher and the student can be vulnerable (Emdin, 2016). This vulnerability and the lack of shame given to it allows for so much growth from everyone involved.

Lastly, Emdin (2016) explained that the culture of competition and having an "ideal" student in schools goes against what the indigenous and nonindigenous believe and grow up with. Science has traditionally been taught in a competitive manner instead of a collaborative manner (Hall, 2011). Therefore, Edmin (2016) suggested fostering a classroom with healthy engagement and motivation that is not based on competition. This mindset is a best practice for all students who do not come from the typical background and identity that has dominated science for a long time.

Learning From Native American Students' Experiences

Laubach et al. (2012) conducted a study to explore how Native American students perceive scientists and to determine if their perceptions differed based on gender, grade level, and level of cultural tradition. The authors found that overall, the Native American students did not view themselves as scientists (Laubach et al., 2012). This is also a common feeling found among students of color as well as girls and women as mentioned above by Mensah (2013) and Hall (2011) respectively.

Another important concept to remember about Native American students is that they are living bi-culturally (Cajete, 1999). They must switch and integrate between their Native culture as well as the American culture they are in while at school (Cajete, 1999). Cajete (1999) explained that the Native worldview and American worldview are very different from one another. Native Americans hold a mutualistic, holistic worldview whereas the American worldview is rationalistic and dualistic (Cajete, 1999). The American worldview is what is found in science and it makes science a field that divides, analyzes, and objectifies which contrasts with how Native American students learn (Cajete, 1999). Living bi-culturally is common for any student who is not a white American and it is something that must be taken into account. If a student can see their culture in the classroom and curriculum, it will make school better for them.

Mihesuah and Wilson (2004) pointed out that educators and schools must create a space where Native American values and traditions are respected. Additionally, schools must push for an institutional response to Native American issues, concerns, and communities (Mihesuah & Wilson, 2004). Teachers can do so much to help their students. However, when a group has been harmed by an entire institution, then the institution must have a part in the reparation process as well.

According to Morgan (2010), many Native American students have problems in traditional American high schools. One reason Morgan (2010) suggested for this is the lack of acknowledgment of the learning style and culture of Native American students. Morgan (2010) acknowledged that not all Native American students will learn in the same way. However, due to their culture, there are learning similarities for most Native students. One value common in Native American cultures is harmony and humility (Morgan, 2010). This value may lead some Native students to underachieve because they do not want to be viewed as superior or better than their classmates (Morgan, 2010).

This is quite different from the competitive nature found in traditional science classrooms where students are fighting to be the best and are pressured to do so by many sources including grades, teachers, and parents (Hall, 2011). Another learning style of Native American students is that they learn by observing (Morgan, 2010). Native students are more visual learners and learn best by demonstration and this is likely due to the fact that many Native American children are taught by watching their parents or elders (Morgan, 2010). Therefore, Native American students do better in classrooms that offer many opportunities for visualization (Morgan, 2011). Demonstrations and modeling are effective strategies to use, especially with Native American students (Morgan, 2010).

A third learning style Morgan (2010) mentioned was that Native American students prefer to work together and as a group instead of alone. This again speaks to the large difference seen in traditional American science classrooms where competition leads to students who are detached from one another (Hall, 2011). Native American students look at things holistically and in relation to a whole (Morgan, 2010). They look to authority figures for guidance and have difficulty separating themselves from their environment (Morgan, 2010). Therefore, when teaching Native American students, it is important to consider activities that reflect the learning styles of Native students. The strategies an educator uses should focus on group work and group discussions since mutual collaboration is so embedded in Native American culture and learning style.

A fourth and final learning style that Morgan (2010) mentioned about Native American students is their way of answering questions. Native students tend to be more reflective and take time while answering questions (Morgan, 2010). In addition to this, there is a strong emphasis in traditional Native American homes that one must perform an activity correctly (Morgan, 2010). Therefore, Native American students may be hesitant to participate or answer questions out of fear of not performing well (Morgan, 2010). Some educators may view this as these students having a lack of interest or motivation (Morgan, 2010).

However, this is not the case and is another example of why it is so important to learn about the cultural background of all students. Since Native American students have a different way of answering questions, this is something to consider when planning a lesson or exam. The anxiety of performing poorly due to not knowing all the answers means that traditional written exams may not be the best way to evaluate Native students (Morgan, 2010). Also, using a call-and-response lecture style may not be the best way to get Native students to participate during class (Morgan, 2010).

The lack of Native American culture and history included in traditional American schools also leads to future educators who have misconceptions about Native Americans

(Morgan, 2010). By being more inclusive and aware of Native students, schools create better future educators and citizens who hold fewer misconceptions and stereotypes. Additionally, by incorporating Native American culture and history into the curriculum and schools, Native students will feel more respected and less alienated by schooling (Morgan, 2010).

Nelson-Barber and Estrin (1995) explored how to bring Native American students' perspectives to science. They also explained how this is important because science has been a field where Native American students have done poorly and it is largely due to how it is taught in American schools (Nelson-Barber & Estrin, 1995). Based on the naturalist traditions and experiences found in Native American communities, science should be a field that Native students do well in (Nelson-Barber & Estrin, 1995). However, that has not been the case (Morgan, 2010).

Science teachers must draw on the experiences and existing knowledge of Native American students and use that to build on their current knowledge (Nelson-Barber & Estrin, 1995). By not doing so, Native American students may be confused by science approaches that are not grounded in experience (Nelson-Barber & Estrin, 1995). This may lead the teacher to assume that Native students are not knowledgeable about science when that is not the case (Nelson-Barber & Estrin, 1995). Another aspect to consider is that student understanding of science should be based on concepts instead of memorizing specific skills or knowing specific facts and formulas (Nelson-Barber & Estrin, 1995). This means allowing students to be hands-on in the learning process by being active and exploratory, and taking on a strong role in constructing their own knowledge (Nelson-Barber & Estrin, 1995). This also means that students must be able to take what they learn and connect it to examples and experiences in the real world (Nelson-Barber & Estrin, 1995). By doing this, students will be able to go back and forth between the concepts and the real world and in doing so will be constructing their own knowledge (Nelson-Barber & Estrin, 1995).

Another teaching strategy that science teachers should use when teaching Native American students is a more complete approach that includes the ethical and historical elements of science (Nelson-Barber & Estrin, 1995). Nelson-Barber and Estrin (1995) explained how this approach to science is reflective of the Navajo approach to science. They also explain that using this approach to science will allow everyone to be better equipped to recognize the Western values embedded in science (Nelson-Barber & Estrin, 1995).

As humans, our diversity and uniqueness allow us the opportunity to learn from one another. The United States is a nation of multiple cultures and identities and it is time we acknowledge this in our education and bring in ideas from non-dominant cultures. In the creation of the ecology and cell energy unit for this Capstone project, I incorporated Native American teachings, knowledge, and traditions. There are only benefits when we allow ourselves to learn from one another and learn in different ways. This is a core value I held with me when creating the lessons, activities, and curriculum for the ecology and cell energy unit.

Conclusion

I started this chapter by discussing traditional science teaching and changes to science teaching followed by the use of standards in science teaching. Making connections and personalization are two newer learning strategies in science teaching that

I strongly believe in and that are featured heavily in the unit for this Capstone project. Science can be so hard to grasp because it requires higher-level abstract thinking. We cannot visualize an atom or what is happening in a chemical reaction because these are oftentimes invisible to us. Therefore, the best way to teach these hard-to-grasp concepts is by connecting them to something students already know and understand.

Next, I discussed the history and experiences in science learning of students from traditionally marginalized backgrounds. I strongly believe in bringing more diversity into my science classroom. Throughout the ecology and cell energy unit I created through the Capstone project I made sure to acknowledge the great diversity of scientists who have made contributions to science. Additionally, I also acknowledged that science has done harm and has contributed to racism, sexism, ableism, and more oppression. Science has been used as a field to do harm, but by showing students the ethical challenges in science, they can learn and do better in the future. We cannot fix past wrongdoings if we refuse to acknowledge they happened and commit to never letting them happen again.

Furthermore, students who come from identities that have traditionally been locked out of the science field cannot be expected to see themselves as scientists if educators do not show them how they are connected to what they are learning. In the next section, I provide a detailed explanation of the science ecology and cell energy unit project I created that is guided by the research question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?*

CHAPTER THREE

Project Description

Science curriculum and teaching have gone through changes frequently. There is no one way to teach science. However, science educators have learned there are positive ways to teach science that allow for increased interest and learning by students. Additionally, there are not-so-positive ways that only benefit a very small number of students and unfortunately, those have been the predominant modes of teaching in science education for decades upon decades (Buxton & Provenzo, 2007). Therefore, I wanted to explore a different style of science teaching. To do so, I based my Capstone project around creating an ecology and cell energy unit that focused on a specific land site in Minnesota and utilized storytelling as a teaching method. The aim of the project was to answer the question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?*

Throughout this chapter, I explain the who, what, when, where, how, and why of this question. First, I provide a project description that gives a detailed explanation of the project and the research that supports the curriculum models and theories utilized in the unit. Next, I describe the setting and intended audience for the unit created in the project to explain who the project is meant for and who may find it useful. Finally, I explain the timeline for the creation of the project and how the project's effectiveness will be assessed.

The project involved the creation of an ecology and cell energy unit that can be used in a general-level high school biology or environmental course. The unit was created based on a trimester schedule. For this unit specifically, fifty-one-minute class periods were used, with thirteen lessons that span over a time period of twenty-four school days.

Inquiry-Based Learning

While creating the lesson, several components of curriculum design and development were considered and implemented. Firstly, inquiry-based learning is a strongly supported teaching method utilized more recently in science learning. Buxton and Provenzo (2007) explained that inquiry-based learning allows students to authentically explore science concepts which in turn develops the students' problem-solving and reasoning abilities. Therefore, when designing the unit I ensured students had the opportunity to guide their own learning and to uncover concepts through their inquiry. Buxton and Provenzo (2007) also commented on the traditional "Science Method". They said there "is largely a misconception (or at the very least an oversimplification)..." about the scientific method because "science sometimes advances in part through taking leaps of faith, and sometimes discovery is even a result of pure accident" (Buxton & Provenzo, 2007, p. 16). Throughout the unit, I allowed for more fluidity of learning and for trial and error as this is a better way of learning science rather than following strict rules.

The Learning Cycle

Another teaching method I considered and implemented throughout the unit was a concept known as the learning cycle. According to Marek (2008), the learning cycle is a way to structure the inquiry-based learning mentioned above and involves sequential steps. Furthermore, Dass (2015) explained that the learning cycle is a form of organizing teaching that:

> Establishes the purpose and usefulness of lesson content early in the lesson with real-life contexts, involves students actively in the learning process, provides opportunities for connecting lesson content to real-life applications, and gets students to "experience" science the way real scientists do and problem-solving the way real engineers do. (p. 5)

There are two different versions of the learning cycle, one involving five steps and one involving only three steps, however, they both involve the same process (Marek, 2008). Due to what I learned throughout my science teaching methods courses in my teaching program, I used the three-step learning cycle as this is what I learned and practiced in my courses.

The first step of the learning cycle is known as the exploration or discovery phase (Marek, 2008). This is the first step to inquiry learning where students are investigating and building their own evidence around a certain concept or topic (Dass, 2015). For example, in one of my lessons on food webs, I provide students with cards that have different components within an ecosystem including the living and nonliving components. Then, I ask the students to group the different components in a way that makes sense to them and explain why they grouped them in that manner.

The second step of the learning cycle is known as the concept development or clarification stage (Marek, 2008). This stage is when the teacher introduces the students to the scientific concepts and terms that go along with the learning they did in the exploration or discovery phase. The aim is to allow the students to build and engage in the scientific concepts that explain the observations and evidence the students collected in the first step (Dass, 2015). Using the food web example above, this is when I lead a discussion to explain important concepts related to the food webs such as the different ways organisms obtain energy (ex: herbivores and carnivores) and introduce the important scientific vocabulary.

The last but very important step is the expansion or application phase of the learning cycle (Marek, 2008). This is when students apply their newly formed knowledge to a new situation or problem to reinforce the learning of the topic and ensure students have a solid understanding of the topic (Dass, 2015). Going back to the food web example, this is when I lead another activity on food webs to check for student understanding and allow for more practice with the newly learned concepts and vocabulary. Overall, the learning cycle is utilized in many of the lessons I planned for the unit in this Capstone project.

Backward Planning

One last curriculum technique I utilized while creating the unit within this project is called backward planning. Wiggins and McTighe (2005) created the idea of backward design. The goal of backward planning or design is to focus on understanding-based goals with the hope that this will then eliminate some of the common weaknesses found in many lesson plans (Wiggins & McTighe, 2005). The stages of backward planning start with identifying what a teacher hopes students will accomplish, the essential learnings, then determining what evidence, usually through formal and informal assessments, will show evidence of this accomplishment, and lastly, the teacher can plan learning activities and experiences (Wiggins & McTighe, 2005).

Oftentimes educators will start with the content and activities and end with the assessments while planning. Additionally, they will have a goal in mind for what skill they want students to gain from the lesson but leave out the point of learning that skill (Wiggins & McTighe, 2005). Therefore, Wiggins and McTighe (2005) provided a useful template for the first stage of backward planning which I adjusted for my own purposes: I want students to learn (content) so that they will be able to (justification for learning). While planning and creating the lessons throughout the unit I used backward planning and always started with the learning goals and assessments and then planned activities around these.

Summary

Science units are involved and complicated to plan at times due to the massive amount of information and scientific vocabulary that students are expected to learn. Therefore, it is important to have curriculum tools and techniques that simplify the planning process and also ensure better engagement and understanding for students. Inquiry-based learning, the learning cycle, and backward planning are a strong combination of tools for science educators and ones featured heavily in the creation of the unit for this Capstone project.

Setting and Intended Audience

While designing and creating the unit, I did not have a science teaching position. Therefore, I used the location where I completed student teaching as the setting for the unit and project. I completed my student teaching at a suburban high school which is located in a larger suburb about twenty miles west of Minneapolis, Minnesota. According to U.S. News and World Report (2023), as of the 2021-2022 school year the school had 2,876 students. Around 44% of students came from a historically marginalized background, 95% of students graduated, 16% of students were economically disadvantaged, and 65% of students obtained science proficiency on the Minnesota Comprehensive Assessments (U.S. News and World Report, 2023).

The school is a larger school and more well-off than others in the state of Minnesota. I have been in high schools in other cities and comparatively, the school where I did my student teaching is very fortunate. For example, the science department has an entire lab room and there are a plethora of supplies, while in other school districts I have been in, the science teacher has to buy the lab supplies using their own money. Furthermore, while student teaching, I learned every student receives a Macbook for school purposes and there is an abundance of resources for students, such as free college preparation help.

The reason I bring this up is that although I created the unit based on the school where I completed my student teaching, I also kept those other school districts in mind who do not have many resources at their disposal. I chose to do this because I want this unit to be used by biology teachers in all educational settings from rural to urban. Therefore, the school where I completed student teaching was a good basis for student demographics and the schedule the school uses, however, not for other markers such as a school with a large population of students from economically disadvantaged backgrounds.

Lastly, the unit created for this project involved following the story of restoration at a land site in Minnesota. I wanted to find a location that was not too far from the Twin Cities and involved the restoration of both plants and animals. Therefore, I chose Minneopa State Park located in Mankato, Minnesota. This state park has not only had its native wild grass population restored, but there has also been a continued effort to restore and revive the bison population. It was an excellent choice for the project and visitors are allowed to drive through the range where the bison free-roam so it also made for a good location for a field trip.

Timeline

The creation of all the materials and content required for the unit in this Capstone project was developed over a three-month period. I started developing the project by finding a land site to base the story on. Once I settled on the location mentioned above, I researched the history of the land site, the different organisms that live at the site, and how it all connected to the necessary ecological and cell energy terms and concepts students need to learn. Next, I planned out different types of assessments and learning objectives followed by activities which I then grouped into eighteen different lesson plans. Once I knew the assessments, learning objectives, and activities I would use for the unit, I created the necessary directions, worksheets, and so on that accompanied the activities and assessments. Finally, I made a rough outline of a plan for a field trip to the land site. As for implementing the project, I plan to implement it in the fall of 2023 when I have a science teaching position, and once I have taught with it once I plan to then make it available to other educators on teaching websites such as Teachers Pay Teachers.

Assessment

To evaluate the effectiveness of the unit created for this Capstone project I will make sure to include both formal and informal assessments throughout the unit to check for student understanding. The main assessment I will plan for checking effectiveness is an end-of-the-unit project where students create some form of presentation that requires them to investigate and research an endangered organism. The project requires students to demonstrate their knowledge of different ecological and cellular energy topics such as energy pyramids, food webs, nutrient cycles such as the carbon and water cycle, carrying capacity, the effects of invasive species, and the impact of human activities on ecosystems.

I also used this end-of-unit project assessment in student teaching, however, the students I taught during student teaching learned the information needed for the project in a different way than the students who will have learned through the unit created for this Capstone project. Therefore, in order to assess the effectiveness of the unit I created, I will compare how students who learned through my unit did compared to the ones I taught during my student teaching program. I will use the same rubric I used while student teaching to grade the projects completed by students who learned using my unit. The rubric will assess students' effectiveness and grasp of different concepts within ecology and cell energy as mentioned above (see Appendix A).

Conclusion

This chapter provided an overview of the who, what, when, where, how, and why of the project and research question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?* First, I gave a description of the ecology and cell energy unit that was created for this Capstone project and explained three curriculum methods I used while creating the unit: inquiry-based learning, the learning cycle, and backward planning. Next, I described the setting and audience for the unit followed by a timeline for creating the project as well as implementing the project. Finally, I finished this chapter explaining how the effectiveness of the unit will be measured. In the next chapter, I reflect on the Capstone project and what I learned from completing it.

CHAPTER FOUR

Introduction

The purpose of this Capstone project was to create a curriculum for a high school ecology and cell energy unit that focused on using alternative ways of teaching science. One of these alternative methods was to incorporate the story of Minneopa State Park, located in Southern Minnesota, throughout the entire unit. The ultimate aim of the creation of the project was to answer the question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?*

To start, chapter one of this paper provided my own personal experiences that led me to this project as well as the professional rationale and context behind the project. As someone whose identity is not always represented in the science field, it was important to me to create a curriculum that reflected more students' identities and backgrounds. Additionally, it was critical to consider alternate ways of learning since it is well known in general that people have different ways of learning best.

Next, chapter two provided an in-depth and extensive literature review of sources that related to and provided support for the Capstone project and question. The literature review first examined how science teaching has been done historically followed by a discussion about changes in science teaching, culturally responsive teaching, and storytelling in science. The literature review then discussed science standards and in particular the effects of using standardized tests on teaching and learning. This part of the literature review also discussed the New Generation Science Standards that the state of Minnesota officially adopted in 2023. Lastly, the literature review examined equity and diversity in science with a particular focus on supporting girls and people of color in science.

Then, chapter three provided the intended audience, setting, frameworks, and theories of the project. The aim of chapter three was to provide the who, what, when, where, and why of creating the project. This project was created with a focus on diversity, however, it could be used in any type of school setting. All students would find value and benefit from the use of the curriculum created for this project.

Finally, in chapter four I reflect on the process of creating the Capstone project. I discuss the major learnings I had through the capstone project as a researcher, writer, and learner. Then, I revisit the literature review and examine the parts that were most influential and helpful for my work. Next, I determine what implications and limitations this project has. Finally, I discuss potential future research opportunities in relation to this project, how I will communicate the results of this project, and what benefits this project provides to the teaching profession.

Major Learnings

As someone who has been in school and learning without a break for 21 years, I have learned it is very important to take time to reflect on what you have learned. Especially after a large and major learning experience such as writing a Capstone paper. Therefore, I can say with confidence that I have learned a lot as a learner, writer, and researcher. The most important thing I learned throughout this process is that I am capable of more than I give myself credit for. I tend to downplay my capabilities and underestimate what I can do and achieve. Creating this Capstone project not only gave me confidence in my ability to research and write long papers, however, it also gave me confidence in my ability to plan meaningful lessons for students in the future.

Another important thing I learned is that this project really helped me grow and advance as a writer. I have mostly only ever written papers that had deadlines and guidelines. For example, when I was completing my undergraduate degree, I always had strict deadlines and detailed rubrics when writing papers or lab reports. I did well on these and never had issues completing them on time. However, writing this Capstone paper was a struggle at times as the deadlines were pretty open as well as what to write. Since the guidelines were more open-ended, that made it hard for me to start, especially with the literature review in chapter two. However, this process taught me the value of creating my own deadlines and the freedom of having more open-ended guidelines. I feel as though I am now on an elevated level of writing and I can see how much I have progressed from the hamburger style of writing taught in high school to this Capstone project I have now completed as a graduate student. I used to really struggle with writing so to complete such a large writing endeavor has been an eye-opening experience.

Revisit of Literature Review

In all honesty, my entire literature review was very important and helpful while creating my Capstone project. However, the sections about science teaching and culturally responsive teaching were most helpful in particular. This is due to the fact that I was creating a unit that aimed to push back and against traditional ways of science teaching. Therefore, I needed to establish a basis for what has been done in order to know what needed to be changed. One source that was helpful in establishing a basis for what science teaching has been and what it could be was from Buxton and Provenzo (2007).

Buxton and Provenzo (2007) explain how the predominant mode of teaching science in the United States has been lecturing and memorization. However, they also explain the importance and usefulness of using inquiry-based, hands-on learning in science. Therefore, they provided support and guidance in the creation of my Capstone project by showing me what alternative science teaching methods look like.

Another source that was particularly helpful was from Nelson-Barber and Estrin (1995). Although this source is quite dated, Nelson-Barber and Estrin (1995) provided an effective overview of how to make science teaching more meaningful for students. They particularly explained how students need to see how science is used in the real world and how what they are learning is connected and useful to them. I kept this in mind while creating the unit and it was a big reason as to why I chose a local state park as the focus. When students can see their learning reflected in the world around them, it makes the learning all the more meaningful. Additionally, Nelson-Barber and Estrin (1995) also described how educators can be culturally responsive to their students. They do so by looking specifically at Native American students, however, their findings and explanations are applicable to all students.

There are many more sources that I came back to often while creating my Capstone project. It was important to me to keep students in mind while not getting too bogged down in the science. As someone who enjoys science and has learned it at a higher level of education, it can be hard to remember that not everyone feels the same way or has the same level of knowledge. Therefore, the literature review sources helped to keep the curriculum student-centered.

Implications

I strongly believe in the curriculum I created for this project and feel proud of how it could be used by others and myself in the science classroom. One implication that can be made from the creation of this project is that it is possible to create science learning experiences that are meaningful and incorporate alternative learning methods. Additionally, it is not any more difficult to plan or implement these types of experiences than it is with the traditional lecture and memorization learning methods. In fact, it was more enjoyable to plan the alternative learning experiences found in the curriculum of this project. Another implication that can be made from this project is that there is value in using non-Western forms of learning and that there is much Western societies can learn from non-Western societies and cultures. For example, storytelling may seem childish or unrelated to science, however, it can make learning more memorable and interesting to students.

One possible policy implication this project could have is that it shows how standards and education policies should focus on incorporating alternative learning methods, testing methods, and curriculum knowledge. For example, if standardized tests are going to be used, they should be more reflective of how people conduct science which is through trial and error, exploration, and inquiry. Another possible policy implication this project could have is to show the value of incorporating people from underrepresented backgrounds into the curriculum. Therefore, instead of banning culturally responsive teaching, we should encourage and promote teaching about other cultures and the experiences and contributions of people from the multitude of cultures we have in this country and world.

Limitations

A limitation that occurred with this project was a time limit. If I had more time, there would have been more that I would have liked to do. The way this project is as of now is usable and ready to implement, however, if I had more time I would have liked to create some alternative learning experiences to coincide with the ones in this project for students with Individualized Educational Plans (IEPs) and students with English as a second language. Additionally, I would have liked to have some of the activities translated into other languages common in Minnesota such as Somali, Spanish, and Hmong. Finally, since this is such a large unit, I was able to create lessons and activities for each day, however, I feel some were slightly rushed and less in-depth than I would have liked them to be.

Future Research or Projects

The next steps in regard to this project would be to explore more alternative teaching methods that can be utilized in science teaching. As for future research, researching the effects of these alternative methods on student learning would be beneficial. Additionally, researching how standardized testing for science in particular could be adapted or changed to better reflect these alternative learning methods would be important. This would allow for us to truly examine and analyze the effectiveness of the alternative methods.

Some future similar projects would be to create other units with different topics that use alternative teaching and learning methods. One recommendation I have is to create some type of professional development guide work or framework that assists science educators in learning and implementing these alternative methods. It is hard to start when there is no true guidance or recommendations. Another recommendation I have is to create a resource that lists and describes different ideas of alternative learning and teaching methods that can be used in science. These do not have to be specific, however, more broad so educators can apply these methods in whatever way they see fit. All in all, there is so much more that can be created and researched in this area.

Communicating Results

First and foremost, I plan to share this project with any teacher I know that would be interested in the curriculum. I feel this could be adapted for middle and elementary school science as well, therefore, I would not only share it with high school teachers. Additionally, I plan to share the project on websites such as Teachers Pay Teachers. I strongly believe in collaboration and sharing within the field of education and therefore I would be more than willing to share my project with anyone.

Benefit to the Profession

This project is beneficial to the field of education, specifically to the field of science education, because it provides an alternative way to teach ecology and cell energy that strives away from the traditional lecturing style of science teaching. While researching, I found very few resources for a unit that is similar to the one I created. Therefore, this provides a curriculum for a field and form of teaching that is new and underdeveloped. Additionally, I believe this helps others to see that teaching in this way is possible and worth it because it makes science learning more meaningful and interesting for students. This in turn helps students who may not be interested or believe they are capable of learning science and enjoying it due to past experiences where science was taught more traditionally. Overall, I think this project could have many meaningful and helpful benefits.

Summary

Throughout this chapter I reflected on my experience of writing and creating the Capstone project as well as what I learned from the experience. In particular, this experience was especially helpful in allowing me to see how much I have grown as a writer. It also gave me more confidence as a teacher and my ability to create meaningful learning experiences for students. Overall, there is much more to be done in this area as this was only one unit in one field of science. Hopefully, this project inspires others to continue the work that was started with the research question: *How is student learning impacted when storytelling and knowledge from Native American tribes are used to create a high school biology unit on ecology and cell energy?*

REFERENCES

Aikenhead, G. (2001). Integrating Western and Aboriginal sciences: Cross-cultural science teaching. *Research in Science Education*, *31*, 337-355.

Aydeniz, M., & Southerland, S. A. (2012). A national survey of middle and high school science teachers' responses to standardized testing: Is science being devalued in schools?. *Journal of Science Teacher Education*, *23*, 233-257.

Bilen, K., Hoştut, M., & Büyükcengiz, M. (2019). The effect of digital storytelling method in science education on academic achievement, attitudes, and motivations of secondary school students. *Pedagogical Research*, *4*(3), 1-12.

Burton, L., Rosas-Lee, M., Helgertz, S., Kuziej B., Bengston, P., Loew, M., Maruska, M., Phelps, M., & Clark, V. (2022). *2022 Minnesota Student Survey.* Minnesota Student Survey Interagency Team. https://www.health.state.mn.us/data/mchs/surveys/mss/statewidetables.html

Buxton, C. A., & Provenzo, E. F. (2007). *Teaching science in elementary and middle school: A cognitive and cultural approach*. Sage.

Cajete, G. A. (1999). The Native American Learner and Bicultural Science Education.

Clark Blickenstaff*, J. (2005). Women and science careers: leaky pipeline or gender filter?. *Gender and education*, *17*(4), 369-386.

Dass, P. (2015). Teaching STEM effectively with the learning cycle approach. *K-12 STEM Education*, *1*(1), 5-12.

El-Hani, C. N., & Mortimer, E. F. (2007). Multicultural education, pragmatism, and the goals of science teaching. *Cultural studies of science education*, *2*, 657-702.

Emdin, C. (2016). *For White folks who teach in the hood... and the rest of y'all too:*

Reality pedagogy and urban education. Beacon Press.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay‐Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry‐based science curricula in the context of urban reform. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *45*(8), 922-939.

Grimberg, B. I., & Gummer, E. (2013). Teaching science from cultural points of intersection. *Journal of Research in Science Teaching*, *50*(1), 12-32.

Gürsoy, G. (2021). Digital Storytelling: Developing 21st Century Skills in Science Education. *European Journal of Educational Research*, *10*(1), 97-113.

Hall, J. R. (2011). Gender Equity in Science Education. *Online Submission*.

Klopfer, L. E., & Aikenhead, G. S. (2022). Humanistic science education: The history of science and other relevant contexts. *Science Education, 106*(3), 490–504. https://doi-org.ezproxy.hamline.edu/10.1002/sce.21700

Lomax, R. G., West, M. M., Harmon, M. C., Viator, K. A., & Madaus, G. F. (1995). The impact of mandated standardized testing on minority students. *Journal of Negro Education*, 171-185.

Marek, E. A. (2008). Why the learning cycle?. *Journal of Elementary Science Education*, 63-69.

Mensah, F. M. (2013). Theoretically and practically speaking, what is needed in diversity and equity in science teaching and learning?. *Theory into Practice*, *52*(1), 66-72.

Mihesuah, D. A., & Wilson, A. C. (Eds.). (2004). *Indigenizing the academy: Transforming scholarship and empowering communities*. U of Nebraska Press.

Morgan, H. (2010). Teaching Native American students: What every teacher should know. *The Education Digest*, *75*(6), 44.

Nelson‑Barber, S., & Estrin, E. T. (1995). Bringing Native American perspectives to mathematics and science teaching. *Theory into practice*, *34*(3), 174-185.

Rowcliffe, S. (2004). Storytelling in science. *School science review*, *86*(314), 121.

Santa Ana College. (n.d.). Inquiry-Based Learning. Retrieved March 20, 2023, from https://www.sac.edu/AcademicAffairs/TracDat/Pages/Inquiry-Based-Learning-.aspx

Shea, M. V., & Sandoval, J. (2020). Using historical and political understanding to design for equity in science education. *Science Education*, *104*(1), 27-49.

Staver**,** J. R. (2007). *Teaching Science.* International Academy of Education.

Three-Dimensional Learning. Next Generation Science Standards. (n.d.). Retrieved February 10, 2023, from https://www.nextgenscience.org/three-dimensional-learning

U.S. News and World Report L.P. (2023). *Eden Prairie Senior High School in Eden Prairie, MN - US news best high*...Eden Prairie Senior High School. Retrieved April 16, 2023, from https://www.usnews.com/education/best-high-schools/minnesota/districts/eden-prairie-public-school-district/eden-prairie-senior-high-school-10840

Visone, J. D. (2009). The validity of standardized testing in science. *American Secondary Education*, 46-61.

Wiggins, G., & McTighe, J. (2005). Understanding by design (2e). *Alexandria, VA: Association for Supervision and Curriculum Development (ASCD)*.

APPENDIX A

Rubric for Ecology and Cell Energy Unit Final Project

Ecology Final Project Grading Rubric Name ___________________________

Criteria	1 point	3 points	5 points
Ecosystem Description	No description is provided	Description is provided but does not address the required topics	Description is provided and all requirements are included in detail
Food Web	-Food web is missing or incomplete -Arrows are either missing or incorrect -Trophic levels are not identified	-Food web drawing does not include 3 food chains -Arrows are not accurate -Trophic levels are not accurate	-Diagram of food web includes 3 food chains. -Arrows in food web are accurate -Trophic levels are correctly identified
Energy Pyramid	-Energy pyramid is not included OR amounts and/or organisms listed in each level are incorrect -Trophic levels are not identified	-Energy pyramid does not include correct examples or energy amounts -Trophic levels are not accurate	-Energy Pyramid correctly lists examples of organisms from the food web AND amount of energy for each level -Trophic levels are correctly identified
Nutrient Cycle	-No cycle diagram/drawing is given -Explanation of the role your species plays in the cycle is missing	-Cycle diagram is incomplete -Explanation of the role your species plays is not complete or inaccurate	-Cycle diagram is included and accurate -The role your species plays in the ecosystem is accurate and detailed
Carrying Capacity	-Definition of carrying capacity is not included or is inaccurate -3 factors that cause changes to your specie's population are either missing or not all provided	-Definition of carrying capacity is lacking detail -3 factors that cause changes to your specie's population are identified BUT the explanation is lacking detail	-Carrying capacity is defined -3 factors that cause changes to your specie's population are identified AND thoroughly explained
Invasive Species	-Definition of invasive species is not included or is inaccurate -No invasive species are listed for your ecosystem -Impact of 1 invasive species on your food web is not described	-Definition of invasive species is inaccurate -The invasive species for your ecosystem are either incorrect OR less than the requirement -Impact of 1 invasive species on your food web is not fully described	-Definition of invasive species is included and is accurate -2 to 3 invasive species are listed for your ecosystem -Impact of 1 invasive species on your food web is described in detail
Human Impact	-1 way humans are impacting your ecosystem is not included OR only partially present -2 solutions to reduce the impact of this issue are not provided OR explained	-1 way humans are impacting your ecosystem is not described in detail -2 solutions to reduce the impact of this issue are included but lack an explanation	-1 way humans are impacting your ecosystem is thoroughly described -2 solutions to reduce the impact of this issue are explained in detail
Graph	A graph is included but is not accurate OR does not explain a component of the project	Includes a graph that is accurate, labeled, and is visually clear in explaining a component of the project	
Sources Cited	At least 1 reference is given and uses correct citations	At least 3 references is given and uses correct citations	

Your score (out of 40 points):