TEACHING CHEMISTRY THROUGH AN ENVIRONMENTAL SCIENCE LENS AND THE EFFECT OF STUDENT UNDERSTANDING AND MOTIVATION IN LEARNING HIGH SCHOOL SCIENCE

by

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

Hamline University

Saint Paul, Minnesota

August 2019

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DEDICATION

To my parents for their continual investment, support, and encouragement through the frustrations of word selection, times of low motivation, and celebrations of small completions. To my coworkers who have full confidence in my vision. To my friends who had no clue what I was doing, but listened to my rants anyway and provided endless coffee. Finally, to my students who listened to my ideas and gave me honest opinions. This would not have been possible without everyone's support. Thank you.

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Introduction

A Journey

My goal as a science teacher is to provide students with useful knowledge to make important, life decisions. These decisions can influence lifestyle, political, and community choices. In order to nudge students in the direction of applying said knowledge to said choices, I feel it is also my responsibility to show them how specific content can be related to real-life situations. Of course, I want students to make connections on their own, but by giving them a primary connection, they can complete that secondary connection independently. The primary connection relates to real-world examples that pique their interest, and the secondary connection relates to the choices students will eventually make about those examples. Examples would ideally be those that are relevant to student interest and include connections to current environmental, social issues. Water is a great model to use when teaching introductory chemistry. There are a lot of future choices that students will need to make around water for example, household consumption, product choice and use, and conservation. My question is: *How does teaching Chemistry through an Environmental Science lens affect the level of student understanding and motivation in learning high school science?*

My motivation for teaching students this way relates back to my own student experiences. In high school, my teachers were blasé about not only the application of science to everyday experiences and choices, but about the subject in general. Many of the topics were surrounded solely around note-taking and even comments about not wanting to teach the content. Of course, as the only scientific role models available to me, I took their attitudes with me throughout high school.

I would never wish or want any of my students to have the same science education experience I had in high school. By creating a curriculum in the fashion explained above, I hope to reduce, if not eliminate, the negative stigma associated with science in high school and create a positive, applicable experience.

My Scientific Revelation

I remember going to orientation week at North Dakota State University (NDSU) to find my dorm, wander the campus, and register for classes. I sat at the computer staring at a list of hundreds of classes available to me. I had never been able to choose classes on this level. My high school was small and my path was pre-determined by my parents and teachers. A woman, whose identity is still a mystery to me, came over and suggested I take Introduction to Anthropology to fulfill credits in the Social and Behavioral Sciences category of my general education requirements. I can never thank her enough as this class forever changed my outlook on science and the natural phenomenons that encompass everything. It gave me a new perspective on evolution. I had never had a true explanation of it before. I always had a preface of disbelief before any conversation about evolution, even from teachers. Once I had the experience of a teacher who felt passionate about the topic explain it in its factual, rather than belief system based form, I started to dive deeper into different topics of science.

Since that first Anthropology class, I have had a great interest in the environment. Climate change, with its political fire, has pushed me to fight for the beauty that I have seen and experienced around the world. My initial declaration of a pre-optometry major soon morphed into a general zoology degree with an emphasis in ornithology. Post graduation, I traveled to Wellington, New Zealand for two months, where I volunteered at both the Wellington Zoo as well as the world's first fully-fenced urban ecosanctuary, Zealandia. At the time I was interested in education, but not in the traditional "students in a classroom" sense. I was more interested in education via conservation programs.

I was in awe every day at my volunteering jobs. Even though it was technically winter, it was not like the winters at home. Everything was still lush and colorful. I would catch myself standing in the middle of the trail at Zealandia just staring, not knowing how long I had actually been stationary. Mesmerized by the beauty of New Zealand and packed with the knowledge I had received from my advisor and professors at NDSU, I knew my path was about to change again; although, I did not quite know how.

When I returned, I decided to rescind my invitation to the Masters program I had been accepted to at the University of West Georgia. I took a year off to reflect and worked to build my savings. Finally, I decided to go back to NDSU to obtain my educator license. Children are the future, and although they are young, they can have a great impact on their surroundings through parents and schools. I wanted my students to feel the same joy, beauty, and passion that I felt when walking the trails in Wellington. I wanted to make sure my students got the full picture of science to make future choices that would impact their environment, community, and home.

NDSU welcomed me back for another year and a half of my life. They applied my previous degree of general zoology courses to my additional degree of biology education.

Soon, I was student teaching at a high school in the West Fargo Public Schools district and then applied for an open science teaching position for Biology and Physical Science. I had fallen in love with teaching. Even though I felt so passionate about the content, I never realized I could build such strong connections with students. I cared about not only their success in the classroom, but about them as individuals. While Fargo had been my home for almost ten years, it was time to move on to a bigger city. I needed to bring my passion somewhere I was needed. West Fargo had a great staff already, and even though I gained more than I can ever imagine from that staff, I had my eye on the horizon.

After a year at West Fargo Public Schools, I submitted my resignation and moved to the Twin Cities and accepted a position as a science teacher at a performing arts charter school located in downtown St. Paul, to develop and teach the Physical Science curriculum. Since working with the charter school, I have taught Chemistry for two years, and now have the opportunity to create the curriculum for Advanced Placement® Biology, all while continuing to teach and modify Physical Science at the on-level and advanced-level.

Finding My Stride as a Science Teacher

Although this is only my fourth year teaching, I feel as though I have grown leaps and bounds in my overall philosophy of teaching. I have had wonderful mentors and coworkers who have fully supported me in my journey. They give me advice and drive to be the best teacher I can. I owe who I am as a teacher to each person I have come into contact with throughout my career. The greatest lesson I have learned throughout my few years of teaching is to determine what drives students to learn. By maintaining a scope of what is relevant to student interest, I can hope they will not only understand the material at a more proficient level, but also use what they have learned in their future consumption, political, and daily choices.

While developing and teaching the physical science curriculum in Saint Paul, I have found that students tend to get confused with so many examples being used for different concepts. Also, a lot of the examples used seem to not apply or interest the fourteen year olds that occupy my classroom. By far, my students find their passion for the arts through activism. By using their drive for social justice, I can infuse the curriculum with examples that are focused on environmental issues to help them better understand and motivate them to succeed in physical science and potentially carry that passion to other secondary science courses. Many students choose the performing arts charter school because they do not feel supported in a traditional school setting due to unfounded perceptions of specific learning styles, lifestyles, and cultural differences. By applying the content consistently to topics they truly care about and understand, I hope to see not only an increase in classroom engagement, but also an increase in their overall interest of the sciences while still adhering to state standards.

New Minnesota state standards for grades 9-12 include similar categories as grades 6-8 for Earth Space Science: Earth's place in the universe, Earth's systems and processes global, weather and climate, and human impacts and sustainability in Earth's systems (Minnesota Department of Education). With these similar categories, I tend to get complaints from students about having already learned the material, even though it is at a different level. By using their "already learned knowledge," as real-life application for Physics and Chemistry, I am giving them the confidence they need for the perceived difficult science classes ahead. The confidence to, “do science” is very important to instill in students right away in high school as I feel it increases the probability of students taking science courses all four years of high school. On average, students show a decline in intrinsic motivation from ages nine to seventeen for science subjects, specifically, chemistry and physics due to a perceived lack of connection to the content (Gottfried, Marcoulides, Gottfried, & Oliver, 2009). Also, our school depends upon enrollment to continue our programs and if students decide to continue to take science courses beyond their required three credits, it benefits the school greatly.

This St. Paul charter school is well known for its artistry programs and sometimes is perceived as an “easy academic” school to attend. Our academic staff, administration, and school board are very aware of this and we would really love to be known for having great artistry and academic programs. Creating a reputation of high academic success would potentially increase enrollment with the school which would allow us to continue to provide extended academic programs to students, like Advanced Placement® programs. I would also hope parents would feel more comfortable with the knowledge of their students being able to follow their passion in the performing arts, while obtaining a solid, college preparatory, academic program.

Summary

All good teachers have a goal of preparing their students for postsecondary challenges, whatever they may be. For our students, it could include conservatory, college, work force, or even show business. Students know these are just some of their options and they are so focused on these things that sometimes they forget their other responsibilities, especially civic duties. By using my own experiences from both high school and college to create a new curriculum that is relevant through environmental/science-based issues, I am providing them with the knowledge and confidence of science which they can use to perform civic duties with greater ease and automaticity. Their conversations and rationales backing their decisions can be science based. They can research, interpret, and evaluate data without feeling overwhelmed. They can continue to be motivated to advance their knowledge and understanding of science related topics and issues.

This research based curriculum development is the reason I love teaching. By finding new ways to engage and motivate my students and give them the tools they need to be successful now and later, I can challenge myself to always continue to improve. In chapter two, you will be able to see the research and literature reviewed to support my curriculum development. This includes a review of the current and new Minnesota State Science Standards, Education for Sustainability, and student motivation and understanding of secondary science. In chapter three, I have provided an overview of the curriculum unit with a short summary of each lesson. This unit will focus on physical and chemical properties of the three states of matter using soil, water, and air. Finally, in chapter four, I conclude with a reflection and conclusion of my work, including my plan to implement the curriculum, limitations and future research, and benefits to teaching.

CHAPTER TWO

Literature Review

Introduction

Student motivation about learning a subject is critical for achieving positive educational outcomes, and studies have shown that these motivations tend to decline throughout adolescence (Wang, Chow, Degol, Eccles, 2016; Wigfield et al., 2006). Students have shown a decline in intrinsic motivation from ages nine to seventeen for science subjects, specifically, chemistry and physics due to a perceived lack of connection to the content over the last several years (Gottfried, Marcoulides, Gottfried, & Oliver, 2009). The difficult task for teachers is determining what makes content relevant for multiple students of different backgrounds and ages, but also adhering to the standards implemented within the school district. To add challenge to the effort, teaching standards change. Some districts use national standards while others use state standards, but they are able to choose which they use. This can create times of transition between state and national or even between updated versions of each.

The goal of teaching is to prepare students for life post-secondary. Using socio-scientific issues can create a bridge in making content relevant for increased understanding and motivation in students. Environmental science in particular, can integrate the three dimensions of relevance; individual, societal, and vocational, to achieve this goal (Eilks, Sjöström, & Hofstein, 2014; Stuckey, Hoffstein, Mamlok-Naama & Eilks, 2013).

The literature presented will be focused around three defining themes: secondary Minnesota state science standards, education for sustainable development, and student motivation and understanding of secondary science. These three themes will be the foundation for a newly developed curriculum for a 9th grade Physical Science classroom. The curriculum sample provided will be focused around the following question: *How does teaching Chemistry through an Environmental Science lens affect the level of student understanding and motivation in learning high school science?*

The Minnesota State Science Standards have been unchanged for about ten years and new standards are currently under review for implementation (Minnesota Department of Education, 2019). The new standards are moving toward a similar framework to the Next Generation Science Standards (NGSS) which promotes an interactive and applicative approach by using three dimensions within each standard: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts (Next Generation Science Standards). The standards are in their final, third draft according to the timeline provided by the Minnesota Department of Education (2019). Comparing the new and old standards will provide a guide for the creation of a new Physical Science curriculum.

The formation of a new Physical Science curriculum will be focused around the Education for Sustainable Development (ESD) approach. This approach to teaching, applies science, especially Physical Science, to sustainable practices to help students become responsible citizens who participate in a democratic society in order to shape a sustainable future (Garner, Siol, & Eilks, 2015). There are several layers to ESD which are interrelated, including ecological, economic and social perspectives (Jegstad & Sinnes, 2015). This also means that there is not an absolute, agreed upon definition of ESD or precise method of how to teach it. By using a combination of researched methods, a culminating semester plan will be produced as well as sample lessons to work with a traditional-style school setting.

The layers of the ESD approach allow students to create internal motivation and understanding through socio-scientific issues-based education (Garner, Siol, & Eilks, 2015). Sjöström, Rauch, and Eilks recognized that students' motivational beliefs about learning physical science are critical for performance, increasing enrollment, and increasing interest to pursue a college major or career in science, technology, engineering, and mathematics (as cited in Denissen et al., 2007; Maltese et al., 2014; Osborne et al., 2003). Also, past research has shown student motivation tends to decline throughout adolescence (Wigfield et al., 2006). Relevance of content is important in determining the intrinsic and extrinsic motivation in learning science for secondary students (Stuckey, Hofstein, Momlok-Naaman & Eilks, 2013).

Secondary Minnesota State Science Standards

The Minnesota State Science Standards have been unchanged for about ten years. (Minnesota Department of Education, 2019). New standards are in the third draft and are under review for full implementation by the 2023-2024 school year and are moving toward a similar framework to the Next Generation Science Standards (NGSS) which promotes an interactive and applicative approach (Minnesota Department of Education, 2019). This approach is pleasing to applying environmental science to a chemistry curriculum as many of the standards require students to reflect on human impact on the Earth.

Current Minnesota State Standards. The current Minnesota State Standards are categorized by grade level and then strand. The strand denotes the category of science, of which there are three: Physical Science, Earth and Space Science, and Life Science. The substrand is a topic within the strand, similar to a unit in a curriculum. The standard describes the specific content students should learn about the substrand. This denotes what students should understand by the time the standard has been taught within the classroom. The code is the shorthand for the standard. It gives readers and teachers a quick way to determine and find the standard in the document. Lastly, the benchmark is listed as a way to measure student understanding and gives examples of ways to teach students the information presented within the standard (see *Figure 1*).

Grade	Strand	Substrand	Standard "Understand that...	Code	Benchmark
9-12	2. Physical Science	4. Human Interactions with Physical Systems	1. There are benefits, costs and risks to different means of generating and using energy.	9.2.4.1.1	Compare local and global environmental and economic advantages and disadvantages of generating electricity using various sources or energy. *For example*: Fossil fuels, nuclear fission, wind, sun or tidal energy.
9-12	2. Physical Science	4. Human Interactions with Physical Systems	1. There are benefits, costs and risks to different means of generating and using energy.	9.2.4.1.2	Describe the trade-offs involved when technological developments impact the way we use energy, natural resources, or synthetic materials. *For example*: Fluorescent light bulbs use less energy than incandescent.

Figure 1. Minnesota State Science Standard sample (Minnesota Department of Education, 2009).

New Minnesota State Standards. The new standards have a similar layout to the old, with a few changes. There is a new column named, "content area," and the code is now included with the benchmark. The benchmarks are written to reflect the integration of three dimensions with the wording of each benchmark including a practice, a core idea and a cross-cutting concept. Benchmarks include statements of emphasis and/or examples that will help, but do not limit curriculum and instruction (Minnesota Department of Education, 2019).

The three dimensions mentioned include: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The first dimension of Science and Engineering Practices, focuses on practice used by scientists and engineers. The second, Crosscutting Concepts, lists key concepts which create connections from various disciplines of science and engineering. The last dimension, Disciplinary Core Ideas, includes concepts from the physical sciences, life sciences and earth and space sciences. Engineering, technology, and applications of science are included to provide an understanding of the built world (Minnesota Department of Education, 2019).

Finally, the new science standards place benchmarks within categories to allow for application and specification of the standard to direct content (see *Figure 2*). For example, 9-12 Earth & Space Science gives at least one benchmark for each anchor standard. These benchmarks categories include: Earth's Place in the Universe, Earth's Systems and Processes global, Weather and Climate, and Human Impacts and Sustainability in Earth's Systems (Minnesota Department of Education, 2019). The new standards are far fewer in number than previously and have an intense emphasis on how Earth was formed, its behaviors in relation to gravity, and human impact with potential solutions (Minnesota Department of Education, 2019).

These standards are in their third draft and were last posted to the Department of Education website on May 20, 2019. According to the posted timeline, this should be the last draft as a final draft was to be submitted to the commissioner for approval by May 10, 2019 (Minnesota Department of Education, 2019).

Grade	Strand	Substrand	Standard
9-12 Earth and Space Science	1 Exploring phenomena or engineering problems	1.2 Planning and carrying out investigations	2.1.1 Students will be able to represent observations and data in order to recognize patterns, and possible relationships between variables

Content Area	Benchmark
ESS: Human Impacts and Sustainability in Earth's Systems	9E.1.2.1.2 Plan and conduct an investigation of the properties of soils to model the effects of human activity on soil resources. (P:3, CC: 2, ESS3, ETS2) *Emphasis is on identifying variables variables to test, developing a workable experimental design, and identifying limitations of data. Examples of variables may include soil type and composition (particularly those found in Minnesota), erosion rate, water infiltration rates, nutrient profiles, soil conservation practices, or specific crop requirements.*

Figure 2. 2019 Minnesota State Science Standards sample (Minnesota Department of Education, 2019).

With the implementation of the new Minnesota State Science Standards, the need for new curricula for the sciences is important. New curricula should meet the goals of the standards, which are to promote an interactive and applicative approach (Minnesota Department of Education, 2019). The use of Education for Sustainable Development (ESD) fits these goals as well as the goals of NGSS. This would prepare students for curriculum if they attend a school with Minnesota standards or NGSS standards.

Education for Sustainability

Education for Sustainable Development (ESD) is an approach to teaching that applies science, especially Physical Science, to sustainable practices to help students become responsible citizens who participate in a democratic society in order to shape a sustainable future (Garner, Siol, & Eilks, 2015). It seems that as time has passed, the idea of ESD has morphed from terms such as Sustainable/Green Chemistry to *Bildung* to Education for Sustainable Development. Each has their own subtle differences which have emerged based upon students' thought process and needs, as well as the urgency of the planet's state.

Sustainable/Green Chemistry. Garner, Siol, and Eilks (2015) used the following definition for Sustainable or Green Chemistry, "[it] is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in design, manufacture and application of chemical products," (as cited in Anastas and Warner, 1998, p. 11). Using the principles that Anastas and Warner developed, teachers are more easily able to design a curriculum based around sustainability. However, there are some concerns with using Green Chemistry as a base for curriculum development. Sjöström, Eilks, and Zuin (2016) argued that Green Chemistry does not extend to the socio-science realm to form educated citizens who make value-based decisions and are able to engage in democratic decision-making on sustainability issues.

Bildung. "Bildung," also known as "Allgemeinbildung" (Burmeister, Rauch, & Eilks, 2012), is a German term that is most closely translated into the concept of developing critical consciousness, character formation, self-discovery, insight, and having the ability to engage with questions of truth, value, and meaning (Vásquez-Levy, 2002). The concept was developed by Wilhelm von Humbolt (1767-1835) to describe holistic growth and self-realization (Hu, 2015). An argument could be made that *Bildung* and ESD are similar enough to be considered sister concepts with their main differences in name, place, and time of origin. A considerable amount of research uses the terms interchangeably and within the same concept framework. Within *Bildung*, Sjöström suggested three subdivisions of applied chemistry, socio-cultural context, and critical-philosophic approach, to clarify development of science curriculum. These three subdivisions are depicted in a pyramid model (see *Figure 3*) with "applied chemistry" at the base and "critical-philosophic approach" at the top (2011).

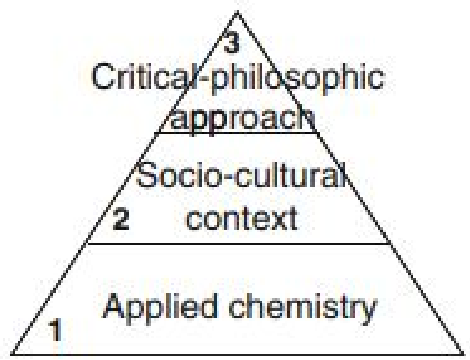

Figure 3. Three subdivisions of *Bildung* (Sjöström, 2011).

"Applied chemistry" is the relation of chemistry to everyday scenarios or situations, such as chemical phenomena, consumer products, healthcare, and environment (Sjöström, 2011). There is no clear link among these applications, as they are specific to the content taught at the time. The middle layer of the pyramid, "socio-cultural context," refers to the historical, sociological, cultural, and political perspectives of chemistry (Sjöström, 2011). Sjöström's goal for the top of the pyramid, "critical-philosophic approach," is to implement philosophical reflection and socio-political action concerning chemistry (2011).

ESD. Education for Sustainable Development is similar to *Bildung* in that it hopes to teach science to promote sustainable practices and help students become responsible citizens who participate in a democratic society in order to shape a sustainable future (Garner, Siol, & Eilks, 2015). Jegstad and Sinnes cited the following definition of ESD from Summers, Childs, and Corney (2005):

> [e]ducation for sustainable development enables people to develop the knowledge, values and skills to participate in decisions about the way we do things individually and collectively, both globally and locally, that will improve the quality of life now and without damage to the planet for the future. (p. 629)

Promotion of ESD was implemented by the United Nations Education, Scientific, and Cultural Organization (UNESCO) by proclaiming the World Decade of Education for Sustainable Development (DESD) for 2005 to 2014 (Garner, Siol, & Eilks, 2015). ESD tends to encompass a more multi-dimensional approach to teaching chemistry by including the understanding of ecology, economy, and society as a whole (Burmeister, Rauch, and Eilks, 2012). Burmeister, Rauch, and Eilks (2012) suggested the following strategies for a successful curriculum: the adoption of green chemistry principles in lab work, the addition of sustainability strategies as content, the inclusion of socio-scientific issues and controversies in teaching, and use of chemistry education as part of ESD-driven school development. Jegstad and Sinnes (2015) used the previous strategies to develop a visual model (see *Figure 4*) for five different ESD categories to achieve a holistic perspective of ESD.

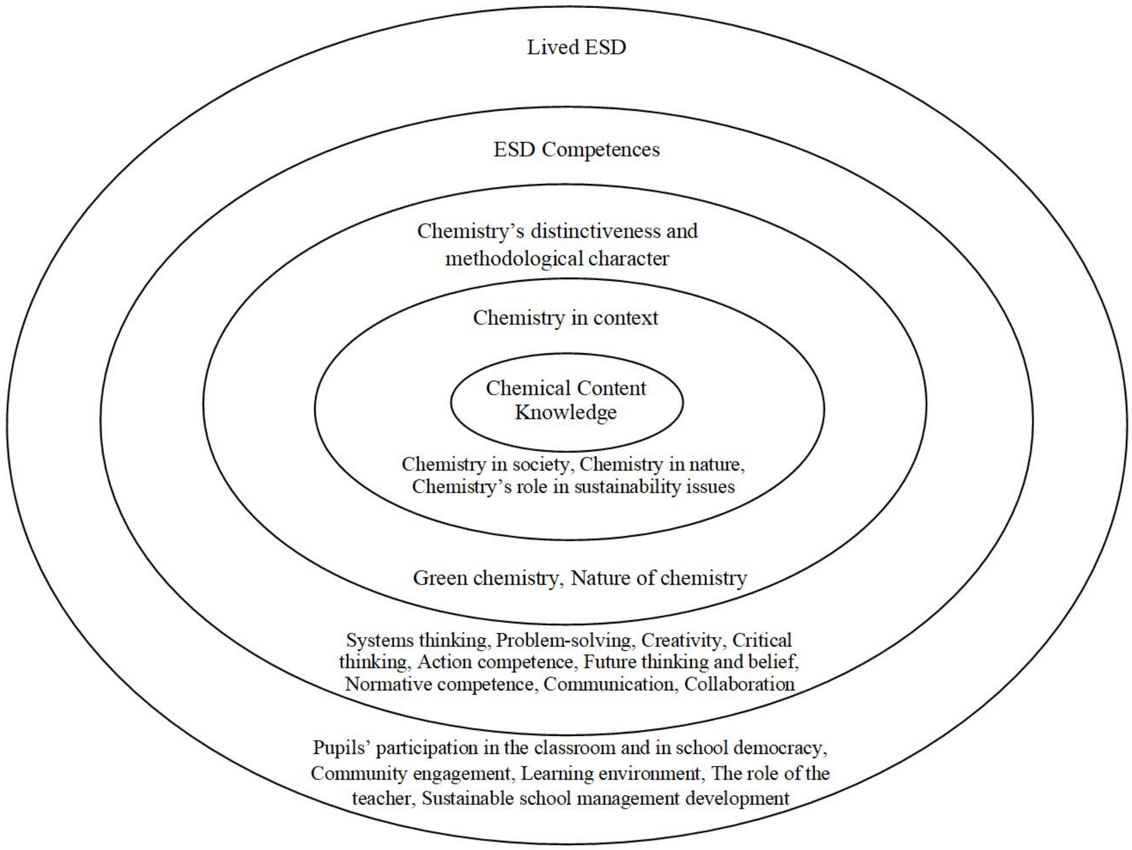

Figure 4. The elliptic model of ESD in chemistry education: a model for planning and analyzing chemistry ESD (Jegstad and Sinnes, 2015).

Concerns for ESD implementation have arisen since its push, especially in foreign countries. For example, Jegstad and Sinnes recognized that in Norway, formal secondary schools have been accused of not prioritizing ESD (as cited in Brænden, 2008; Koller, 2009; Laumann, 2007; Raabs, 2010; Schreiner, 2006), potentially due to time constraints, lack of teaching resources, and issues with the subject discipline (as cited in Barrett, 2007; Palmer, 1998; Sandell, Öhman, and Östman, 2003). Another challenge found with implementation of ESD is maintaining a balance between subject-specific and general ESD perspectives (Jegstad and Sinnes, 2015). Curriculum that is too general may cause

ESD to overpower chemistry content, whereas curriculum that is too chemistry-oriented risks reverting back to fact-based learning (Jegstad & Sinnes, 2015). Curriculum should be chemistry-based and applied to environmental socio-science based issues rather than the reverse.

Using a combination of the above methods will help develop a unique curriculum for a secondary physical science course that will use environmental topics to reinforce content and promote interest in science topics. This interest will hopefully be carried into adulthood to allow for sustainable decision making and an increase in science-related careers.

Student Motivation and Understanding of Secondary Science

Sjöström, Rauch, and Eilks affirmed that students' motivational beliefs about learning physical science are critical for performance, increasing enrollment, and increasing interest to pursue a college major or career in science, technology, engineering, and mathematics (as cited in Denissen et al., 2007; Maltese et al., 2014; Osborne et al., 2003). Also, past research has shown student motivation tends to decline throughout adolescence (Wigfield et al., 2006). Based on feedback one study compiled, students begin to lower their perceived competence in science, leading to declines in interest and desire to pursue science in the future (Wang, Chow, Degol, & Eccles, 2016). This is thought to be due to changes in maturity of cognition and environment of learning. Young students who were once overly optimistic begin to use social cues and comparisons from teachers, peers, and parents to gain a more realistic judgment of their abilities (Wang, Chow, Degol, & Eccles, 2016). Student motivation and understanding of secondary science are key to determining the efficacy of an ESD method of teaching.

Motivation of secondary students. On average, students show a decline in intrinsic motivation from ages nine to seventeen for science subjects, specifically, chemistry and physics due to a perceived lack of connection to the content (Gottfried, Marcoulides, Gottfried, & Oliver, 2009). Wang, Chow, Degol, and Eccles (2016) verified that task values strongly predict performance as well as persistence in science. For example, students' perceived importance, interest, and usefulness of a science topic correlated with achievement and therefore, a greater amount of time spent on academic activities (as cited in Neathery, 1997; Singh et al., 2002).

Relevance of content is important in determining the intrinsic and extrinsic dimensions of motivation in learning science (Stuckey, Hofstein, Momlok-Naaman & Eilks, 2013). Physical Science can be made more relevant for students by including different dimensions of relevance in science education: individual, societal, and vocational (Stuckey, Hoffstein, Mamlok-Naama & Eilks, 2013). Stuckey, Hoffstein, Mamlok-Naama and Eilks' (2013) three dimensions of "relevance" in science education (see *Figure 5*) can be summarized as:

1. Individual dimension: matching student curiosity and interests, providing them with necessary and useful skills for coping with everyday lives and future, and contributing to the development of intellectual skills.

2. Societal dimension: preparing students for a self-driven and responsible life in society through the understanding and interaction of science and society, and developing skills for participation and contribution in society.
3. Vocational dimension: offering information to students about future professions and careers, preparing for academic or vocational training, and opening formal career chances.

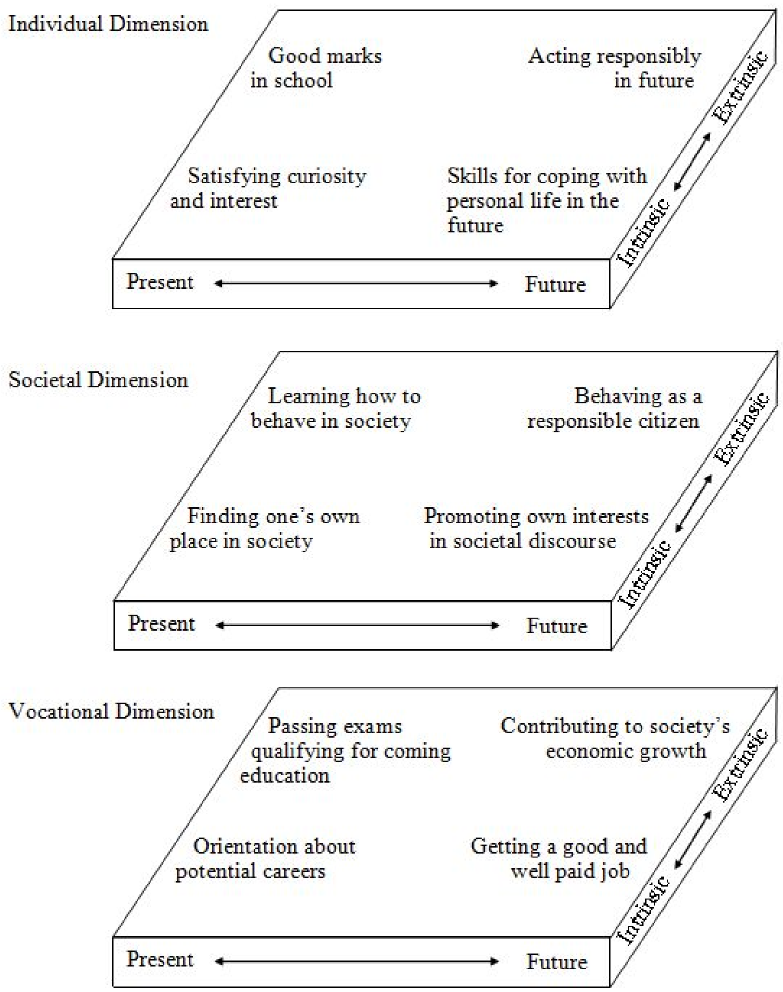

Figure 5. Three dimensions of student relevance within science education (Stuckey, Hoffstein, Mamlok-Naama & Eilks, 2013).

Through the curricula and teaching methods Eilks, Sjöström, and Hofstein (2014) evaluated as most promising for promoting relevant science education, it was determined all three dimensions were used. They also suggested that secondary science education is best served by SSI curricula when trying to incorporate all three dimensions (as cited in Sadler, 2011).

Socio-scientific issues-based science education. Personal observations have eluded to a strong connection between student motivation and socio-scientific issues such as climate change, vaccines, and genetically modified organisms (GMOs). Sadler, Romine, and Topçu defined socio-scientific issues (SSI) as "complex societal issues with conceptual, procedural, and/or technological associations with science" (2016, p. 1622). Sadler, Romaine, and Topçu confirmed that in recent years, science education researchers have recognized the significance of SSI as a means of engaging students in science (as cited in Topçu, Sadler, & Yilmaz-Tuzun, 2010; Zeidler, 2003). The relationship of ESD-related topics, especially those that are publicly and/or politically debated, can drive an increase in not only relevance to students, but also in making learning chemistry more motivating, meaningful, and skill-based (Garner, Siol, & Eilks, 2015). Burmeister, Rauch, and Eilks (2012) brought up the potentially controversial nature of using SSI in that there may be limited potential of understanding a socio-scientific issue based on student social and economic standing. In other words, some issues can be considered less relevant based on student experience with that issue.

Determining which socio-scientific issues to use within a classroom to increase student motivation and understanding depends upon the students within the room.

Relevance will change with each new group of students. Hopefully, it will not vary too much between class periods as this would make the workload of the teacher immense and potentially unmanageable. Teachers may use Stuckey, Hoffstein, Mamlok-Naama and Eilks' (2013) three dimensions of "relevance" in science education (see *Figure 5*), but they will have to know their students in order to determine specific topics. These topics may change year after year, therefore it is up to the teacher to put in the effort of learning the culture and interests of their students. By using socio-scientific issues (SSI) to increase student motivation in the classroom, student understanding should also increase.

Understanding of secondary science. Determining student understanding of content can be difficult. Depth of understanding must be a primary goal to determine understanding, rather than memorization of words, skill of performing, or creation of a product (Wiggins & McTighe, 2011). Measuring understanding can be done is several ways and Wiggins and McTighe (2011) discussed six facets that can be used in assessments. These facets include: explain, interpret, apply and adjust, have perspective, show empathy, and have self-knowledge. The first three facets are verbs often found in the Minnesota State Science Standards (Minnesota Department of Education, 2019) and Next Generation Science Standards (Next Generation Science Standards, 2013). Although the last three are not often found in the standards, if at all, they are an important part of the ability to transfer content to a situation (Wiggins & McTighe, 2011).

> [p]upils not only need knowledge of scientific content, but also an understanding of how reliable and valid data are collected and interpreted. They need to recognize the tentative character of scientific knowledge and to understand how

human interest may shape the process and products of science. (Jegstad & Sinnes, 2015; Gräber, 2000; Hodson, 2008; Kolstø, 2000, p. 659)

When applying an ESD approach to curriculum, perspective, empathy, and self-knowledge become important in completing the last two rings of *Figure 4,* "the elliptic model of ESD in chemistry education: a model for planning and analyzing chemistry ESD" (Jegstad and Sinnes, 2015). Perspective understanding involves students making tacit assumptions and implications explicit (Wiggins & McTighe, 2011). This type of understanding increases a students ability to think critically, ask more questions, and expose assumptions (Wiggins & McTighe, 2011). This is an invaluable skill in post-secondary readiness pathways including, education and career. Empathy is the ability to understand another person, people, or culture, which can lead students to rethink situations and also change viewpoints based on further understanding (Wiggins & McTighe, 2011). Perspective and empathy relate to the fourth ring in Jegstad and Sinnes' (2015) elliptic model of ESD *(Figure 4)* where students apply systems thinking, problem-solving, creativity, critical thinking, action competence, future thinking and belief, normative competence, communication, and collaboration. These encompass how students choose to live their lives currently and in the future. They can decide which aspects of their lives are going to incorporate environmentally conscious choices and how they will express those choices to their peers, family, and community.

Self-knowledge is the ability to know one's ignorance and how patterns of thought and action inform understanding (Wiggins & McTighe, 2011). Self-knowledge is key to student understanding in that it demands they question themselves and the way they see the world (Wiggins & McTighe, 2011). Self-knowledge relates to the final ring of Jegstad and Sinnes' (2015) elliptical model of ESD *(Figure 4)* where students embody lived ESD, which encompasses pupils' participation in the classroom and in school democracy, and community engagement. This ring takes one step further compared to the previous in that it determines how they participate in societal responsibilities such as voting. Students will need to put themselves in another's shoes to "see" the world from the other's perspective. This will help shape their world views and observe the bigger picture of the world rather than what they experience on a daily basis.

Some may feel that these three facets are "unteachable" in the sense of covering content from resources such as textbooks or standards. Wiggins and McTighe (2011) discussed this in relation to, "[i]t is not teaching that causes learning" (p. 228). Just because content is covered through lecture or reading, does not mean students will retain or learn the information if has no application to their lives. Rather, using a textbook as a resource or support provides for better teaching to promote understanding (Wiggins & McTighe, 2011). By using socio-scientific issues, the classroom can become a place of practice and discussion to explore the three facets listed. Understanding does not only come through transfer of content, but also through experience and inference (Wiggins & McTighe, 2011).

> "To have taught well is not to have used a great set of techniques or given the learner some words to give back, but to have caused understanding through words, activities, tools, guided reflection, the learner's efforts, and feedback" (Wiggins & McTighe, 2011, p. 228).

Wiggins and McTighe (2011) also promoted the importance of collecting evidence from students to determine understanding. This evidence can be in the form of assessments. However; assessments can vary in format, but must evoke transferability: finding out if students can use and apply what they've learned (Wiggins & McTighe, 2011). Wiggins and McTighe (2011) made it clear there is no perfect assessment and that each assessment needs to be directly related to the learning target. Therefore, multiple forms of assessments, including observation, should be used to collect evidence of student understanding.

Creating the right assessment or experience that best determines student understanding brings big ideas to life and makes the concept real and relevant to previous experiences and knowledge (Wiggins & McTighe, 2011). Therefore, not only does the teaching of content needs to be relevant to the student to promote understanding and motivation (Eilks, Sjöström, & Hofstein, 2014), but the assessment also needs to be relevant to students in order to determine understanding (Wiggins & McTighe, 2011). Wiggins and McTighe (2011) called for an increase in formative assessments to determine understanding throughout teaching rather than at the end of a unit. They also discussed the importance of authentic performance. Wiggins and McTighe (2011) determined if an assessment is authentic if it:

- is realistically contextualized.
- requires judgement and innovation.
- asks the student to "do" the subject.

- replicates key challenging situations in which adults are truly “tested” in the workplace, in civic life, and in personal life.
- assesses the student’s ability to efficiently and effectively us a repertoire of knowledge and skills to negotiate a complex and multistage task.
- allows appropriate opportunities to rehearse, practice, consult resources, and get feedback on and refine performances and products.

Authentic assessments should be derived around authentic problems (Wiggins & McTighe, 2011). Using environmental issues not only addresses an authentic problem, but incorporates a socio-scientific issue which in turn, will increase student motivation within the classroom.

Understanding can be developed through the use of a nontraditional classroom through discussion, activities, and experiences rather than only transfer of content. This type of non-formal learning can present a unique environment for students.

Non-formal learning. The environment that students learn in makes a difference in their understanding of content. Formal and informal learning are the two most common styles; however, new evidence has pointed to a new learning style to complement an ESD curriculum, non-formal (Garner, Siol, & Eilks, 2015). The main difference between formal and informal learning is whether the learning has a specific structure and is connected to a syllabus or curriculum. Non-formal tends to lie somewhere between formal and informal (Garner, Siol, & Eilks, 2015). ESD can be implemented in a number of ways in both formal and non-formal learning environments, however, Garner, Siol, and Eilks confirmed that ESD works well when formal and out-of-school learning are combined (as cited in United Nations Economic Commission for Africa [UNECA], 2012). Garner, Siol, and Eilks (2015) suggested several methods of non-formal education can be incorporated into formal education, such as field trips, learning centers, or outdoor excursions to reinforce ESD content. Other researchers have used computer modules and textbooks to help bring those experiences into the classroom. One study stated that students identified chemistry as useful and applicable to their daily lives and became more aware of the relationships between chemistry and society when given a non-formal lesson of using a module to apply chemistry concepts to a real world issue (Mandler, Mamlok-Naaman, Blonder, Yayon, & Hofstein, 2012).

The Chemistry in the Community (ChemCom) textbook was designed by the American Chemical Society (ACS) to develop chemistry-literate and science-literate citizens by focusing on chemistry for life and citizenship (American Chemical Society, 2012). Each unit within the Chemistry in the Community textbook is centered around a chemistry-related, societal issue or problem which promotes student problem solving and life-skills (American Chemical Society, 2012). This is a great non-formal resource as there is a reduction in the amount of textual content and an emphasis on lab tasks and modules. One study showed that students using the *ChemCom* curriculum did better on chemistry post-exams than peers taking a formal learning course (Mandler, Momlok-Naaman, Blonder, Yayon, & Hofstein, 2012).

The use of an Education for Sustainable Development (ESD) curriculum through a non-formal classroom setting meets the goals of the new Minnesota State Science Standards. By combining socio-scientific issues (SSI) with Education for Sustainable

Development (ESD), students will hopefully be able to not only understand secondary science better, but be motivated to participate in and learn science. The incorporation of socio-science issue-based content can make material more relevant to students. This can help improve student motivation and understanding of secondary science currently and in the future. In order to determine if these statements are accurate, a new curriculum must be developed and implemented.

Summary

The new Minnesota State Science Standards give an applicative approach for student content learning (Minnesota Department of Education, 2019). Although they are still under review, they are in their second draft phase and seem to be receiving positive feedback from teachers and administrators across the state (Minnesota Department of Education, 2019). The new standards pair well with an Education for Sustainable Development (ESD) approach to teaching secondary level physical science. An ESD approach in the classroom promotes student learning in a way that teaches science to promote sustainable practices and help students become responsible citizens who participate in a democratic society in order to shape a sustainable future (Garner, Siol, & Eilks, 2015). By using an ESD approach, students are more motivated and better able to understand content, especially when using socio-scientific issues (SSI) as applicative material. Students are still considered to meet state or national standards through applicative understanding even if the material is not verbally covered through lecture (Wiggins & McTighe, 2011). Socio-scientific issues are issues that relate to societal conflicts and students' everyday life. By using SSI, students are better able to relate to content with increases in their motivation to learn (Garner, Siol, & Eilks, 2015).

By utilizing an ESD approach with the new standards, a new curriculum can be created for ninth grade physical science chemistry. The following chapter will encompass the following: an overview of the new curriculum inspired by ESD and SSI, the intended audience for implementation of the curriculum, and an explanation of theory to the curriculum. Chapter three discusses how this will be accomplished through curriculum design as well as the demographics of the intended audience. A short discussion of the timeline used to complete the project as well as how the curriculum will be evaluated within the school and science department is also included.

CHAPTER THREE

Project Description

Introduction

Student motivation about learning a subject is critical for achieving positive educational outcomes, and studies have shown that these motivations tend to decline throughout adolescence (Wang, Chow, Degol, Eccles, 2016; Wigfield et al., 2006). Students have shown a decline in intrinsic motivation from ages nine to seventeen for science subjects, specifically, chemistry and physics due to a perceived lack of connection to the content over the last several years (Gottfried, Marcoulides, Gottfried, & Oliver, 2009). The difficult task for teachers is determining what makes content relevant for multiple students of different backgrounds and ages, but also adhering to the standards implemented within the school district. To add challenge to the effort, teaching standards change. Some districts use national standards while others use state standards, but they are able to choose which they use. This can create times of transition between state and national or even between updated versions of each.

The goal of teaching is to prepare students for life post-secondary. Using socio-scientific issues can create a bridge in making content relevant for increased understanding and motivation in students. Environmental science, in particular, can integrate the three dimensions of relevance; individual, societal, and vocational, to achieve this goal (Eilks, Sjöström, & Hofstein, 2014; Stuckey, Hoffstein, Mamlok-Naama & Eilks, 2013).

The following chapter will provide an overview of a chemistry curriculum unit created through the use of socio-scientific issues (SSI) and education for sustainable development (ESD) methods to answer the question: *How does teaching Chemistry through an Environmental Science lens affect the level of student understanding and motivation in learning high school science?* Chapter one focused on the rationale of creating the project. Chapter two provided a literature review to delve into the content further and included the topics of Minnesota state science standards, ESD, and student understanding and motivation. The material in these two chapters will provide a guide to the curriculum project overview.

The curriculum was created to not only increase student motivation and understanding of chemistry through the use of socio-scientific issues but also to give students the ability to make decisions throughout their life based on a sustainable viewpoint. The relationship of ESD-related topics, especially those that are publicly and/or politically debated, can drive an increase in not only relevance to students, but also make learning chemistry more motivating, meaningful, and skill-based (Garner, Siol, & Eilks, 2015). Chapter three looks at the rationale for the development of a chemistry curriculum, the framework used to develop the curriculum, the setting and audience intended, a description of the overall project with an overview of a sample of the new curriculum, the timeline of the development, and how the new curriculum will be evaluated during and after implementation.

Rationale

Research has shown student motivation to learn physical sciences tends to decline throughout adolescence (Wigfield et al., 2006). By using an education for sustainable development (ESD) approach, students are more motivated and better able to understand content, especially when using socio-scientific issues (SSI) as applicative material. Socio-scientific issues are topics that relate to societal conflicts and students' everyday life (Garner, Siol, & Eilks, 2015). The curriculum will use ESD and SSI based content.

By utilizing an ESD approach with new standards and SSI topics, a new curriculum can be created for ninth grade physical science chemistry to not only increase motivation to learn through relevance, but also increase students' ability to understand the content presented.

Curriculum Framework

The lessons that make up the following curriculum sample were created using the 6th edition of *Chemistry in the Community (ChemCom)* textbook which was created by the American Chemical Society (2012). This textbook guides students through activities and readings that explore the chemical world by using topics related to sustainability. Most of the topics and the order in which they will be taught are derived from the textbook. Examples and some lab activities were also used as inspiration for the lessons.

Jegstad and Sinnes (2015) developed a model for five different ESD categories to achieve a holistic perspective of ESD was also utilized for curriculum development. The five different ESD categories and a summarized description are as follows:

1. Chemical Content Knowledge: Education *about* sustainable development and emphasizes chemistry issues that are relevant for sustainable development.
2. Chemistry in Context: Chemistry taught in a relevant context in order to promote full understanding of current sustainability issues.
3. Chemistry's Distinctiveness and Methodological Character: How to work sustainability into chemistry and understanding the characteristics of scientific knowledge in that it is tentative and never absolute, subjective, involves human inference, and socially and culturally embedded.
4. ESD Competencies: Emphasizes ethical competence, communicative competence, and other competences encompassing socio-scientific decision-making skills.
5. Lived ESD: Influences all educational experiences, both within the chemistry classroom and the school culture.

These categories helped develop the curriculum sample presented. Based upon analysis of the current curriculum in place, categories one and two are present. The hope for the new curriculum is to achieve all five categories by applying socio-scientific issues related to Minnesota (most students' home state) and performing investigations where students will be using real, physical samples from Minnesota.

Curriculum Design

This curriculum was developed to give secondary physical science teachers the option to teach chemistry through student-relevant, socio-science issues-based topics.

Topics presented should be relevant to students living in, at a minimum, the United States or similar setting, but use science standards developed for the state of Minnesota. These standards are very similar to the Next Generation Science Standards (NGSS) and should be able to be transferred with ease. The goal of this curriculum is to engage students, enhance motivation to learn science, and to increase understanding of secondary science content.

The curriculum was also designed using Wiggins and McTighe's (2011) Understanding by Design (UbD) method which focuses on creating activities and assessments that truly determine student understanding. Focus was also placed on connecting these assessments and activities with the verbs used within the standards. UbD templates were used to plan individual lessons as well as a unit overview (Wiggins & McTighe, 2011).

This curriculum is meant to be taught in any classroom, but focuses on allowing teachers who do not have access to outside resources such as funding, museums, field trips, or the outdoors, to teach content that engages at a level of having access to those resources. This curriculum is considered non-formal, which means it will be using resources outside of and in addition to, the traditional lecture tools such as a presentation or notes-based lecture. The curriculum is meant for students to eventually use what they have learned in order to become responsible citizens who participate in a democratic society in order to shape a sustainable future.

Curriculum Overview - Chemical and Physical Properties of Matter

The curriculum unit provided includes content topics of chemical and physical properties of matter through the examples of soil, water, and air. These topics are represented in several of the Minnesota State Science Standards for Earth and Space Science. Each lesson is meant to be 80 minutes and includes an article to show a real-life application of the content, an investigation to introduce the properties of each state of matter, and a slide lecture to explain and link concepts. The unit concludes with an inquiry lab where students will need to apply what they've learned about soil, water, and air properties.

Lesson One - Soil

This lesson focuses on an introduction to chemical and physical properties of matter as well as the chemical and physical properties of soil. Students are given an article that brings to light the toll agriculture has on the planet. After reading the article, students are to investigate the properties of soil through the testing of local soils. The following day of class, students are to take notes on properties they investigated. Finally, they will write a claim, evidence, reasoning paragraph based on the initial article and investigation.

Lesson Two - Water

This lesson investigates the properties of water through separation, filtration, and adsorption. Students will receive an article about the Boundary Waters Canoe Area Wilderness and the potential mining of metals. After the article, students are to investigate properties of water by cleaning a sample that has been "fouled." The following class period will include a lecture of properties of water including structure, hydrogen bonding, and polarity. Students will conclude the water lesson through a jigsaw activity. They will watch and emulate and present modeling of the properties discussed in the presentation to the class.

Lesson Three - Air

This lesson looks at the properties of gases and how different variables, such as temperature, pressure, and volume interact to create unique environments. The article for this lesson focuses on the illnesses of Minnesota residents due to atmospheric pollution. Students will then participate in a stations activity to determine gas relationships. The next class period will include a lecture where students create a paper foldable to keep in their notes for organization of gas relationships. The lesson will close with an overview of the summative lab to be performed the following two class periods.

Lesson Four - Summative Inquiry Lab

This lesson includes the summative assessment for the unit which is an inquiry based lab. The lab has students use what they have learned about the properties of the three states of matter to determine soil and soil water permeability.

Setting and Audience

The curriculum presented is designed for secondary Physical Science students. The concepts presented will incorporate previously learned material as well as relevant content to support learning of new Chemistry topics. The use of socio-scientific issues, labs/in-class activities, and computer modules creates a non-formal classroom experience. This curriculum can be taught at any Minnesota high school as it aligns to the

Minnesota state science standards. Modifications can be made to the curriculum based on what constitutes as “relevant” to the students within the classroom.

The curriculum that is presented within this project will be used for 9th grade Physical Science students at a four-year, public charter high school in a downtown, open campus environment. Students experience three, 80-minute, academic class periods on an A/B day schedule. Most class sizes represent 75% female to 25% male distribution with about 65% White, 17% Black, 11% Hispanic, 5% Asian, and 2% American Indian (Saint Paul Conservatory for Performing Artists, 2019).

Evaluation

Evaluation of the curriculum will be a continuous process throughout implementation through the use of Professional Learning Communities (PLC) groups established within the school. PLC groups include members of each teacher’s department as well as teachers not in the department but teaching the same grade level of students. PLC groups focus around 4 major questions (DuFour, Eaker, & DuFour, 2005):

1. What do we expect our students to learn?
2. How will we know they are learning?
3. How will we respond when they don't learn?
4. How will we respond if they already know it?

Data in the form of quiz and test results and student work examples will be evaluated within the group to answer each of the listed questions. Based on discussions around the data and examples, decisions can be made to determine if modifications are necessary.

Summary

Chapter three included the rationale and curriculum framework for this project. A description of the setting of curriculum implementation as well as the curriculum audience where provided. Summaries of each lesson gave an overview of how the unit will look during implementation. A timeline of project development was described as well as a proposal for evaluation post-implementation.

Chapter four includes a personal reflection of the work completed. It will also include thought processes and impacts of research on the design of the project. Finally, the fourth chapter will provide a look into implications, limitations, and possible changes before a final conclusion.

CHAPTER FOUR

Reflections and Conclusions

Introduction

Throughout the development and research of my capstone project, I was brought back many times to the original reason I began this journey. I kept trying to place myself in my students' shoes. This, in turn, brought me back to my days as a student which are described in chapter one. My journey through high school and college really defined the content provided to create the most complete and relevant content to my future students. My experience as a new teacher helped create documents that were complete, clear, and focused to give any following teacher the best start possible. This was the overarching drive behind my question of: How does teaching Chemistry through an Environmental Science lens affect the level of student understanding and motivation in learning high school science?

Chapter two was difficult to say the least. Not because there was a lack of literature to be reviewed, but because there were so many different ways to go about it. Trying to find what would work for my students and school was important and helped me narrow down the literature provided.

Chapter three discusses the framework and design process. It also describes the audience, both students and teachers, that would be incorporating this unit into their teaching. Using the understanding by design (UbD) framework and Minnesota State Science Standards really helped focus the content provided. Instead of creating material for students to memorize, I wanted to create a curriculum that really involved students and used their natural ability to question to drive the lessons.

Chapter four will focus on the future of the curriculum through discussions of possible implications, limitations, future research and designs, and communications through benefits to the teaching profession. It will also revisit some important literature I have used throughout and contain my own reflections about the process of developing the project.

Learnings

While creating this capstone project, I have learned quite a few things about the research and writing process. Narrowing down topics and subtopics is extremely important when determining what to put in the literature review. Each component should be purposeful. This was difficult for me as there was a lot of research on the topic, however, much of it was out of the country and therefore fit into foreign curriculums. Throughout the writing process, the literature review and curriculum were the easiest to write. I have had the most practice here with my undergraduate being in both science and education. The difficult parts were writing in chapter one and four in the first person. With that science degree, it has been ingrained in me to never write in first person. Sometimes I felt that I struggled with keeping a professional tone while writing in first person.

I have also learned to a better degree what it takes for me to accomplish my goals and meet deadlines. I now know that I need small amounts of time to work each day. I do not do well with long time frames of continual work. I have learned that I need to get out of the house to work and that I do best with the background noise of others conversing or working themselves. Coffee shops became my best friends.

This has also taught me that not everyone can work that way. By completing the capstone project with others in the class, it became apparent that some people wait until the last minute while other completed the week's worth of assignments on the first day. Having to wait for others, or making others wait for me, gave me a great appreciation for the structure of the capstone courses.

Revisiting Literature

There were several prominent authors within my literature review that I would not have been able to complete this project without. They are Jesper Sjöström, Ingo Eilks, and Grant Wiggins and Jay McTighe. Although there are plenty more cited, these authors surround the basis of sustainable learning, relevant content, and curriculum design respectively.

Sjöström and Eilks have worked both independently of each other as well as together on implementing sustainable education within secondary schools. After evaluating sustainable education through Green Chemistry, which seemed to only look at the reduction of chemical hazards through chemistry, Sjöström, Eilks, and Zuin (2016) argued that Green Chemistry did not extend to the socio-science realm to form educated citizens who make value-based decisions and are able to engage in democratic decision-making on sustainability issues. Through the marrying of socio-scientific issues as well as sustainable education, Education for Sustainable Development (ESD) was born.

Burmeister, Rauch, and Eilks (2012) suggested the following strategies for a successful curriculum: the adoption of green chemistry principles in lab work, the addition of sustainability strategies as content, the inclusion of socio-scientific issues and controversies in teaching, and use of chemistry education as part of ESD-driven school development. When including socio-scientific issues into teaching, Sjöström, Rauch, and Eilks affirmed that students' motivational beliefs about learning physical science are critical for performance, increasing enrollment, and increasing interest to pursue a college major or career in science, technology, engineering, and mathematics (as cited in Denissen et al., 2007; Maltese et al., 2014; Osborne et al., 2003). Eilks also discussed the importance of keeping socio-scientific issues relevant to students. Relevance of content is important in determining the intrinsic and extrinsic dimensions of motivation in learning science (Stuckey, Hofstein, Momlok-Naaman & Eilks, 2013).

While Sjöström and Eilks were not the only contributors to ESD, they were in the forefront for curriculum development. Burmeister, Rauch, and Eilks' strategies can be applied to curriculum development using Wiggins and McTighe's Understanding by Design (UbD) approach.

Creating the right assessment or experience that best determines student understanding brings big ideas to life and makes the concept real and relevant to previous experiences and knowledge (Wiggins & McTighe, 2011). Therefore, not only does the teaching of content needs to be relevant to the student to promote understanding and motivation (Eilks, Sjöström, & Hofstein, 2014), but the assessment also needs to be relevant to students in order to determine understanding (Wiggins & McTighe, 2011).

Authentic assessments should be derived around authentic problems (Wiggins & McTighe, 2011). Using environmental issues not only addresses an authentic problem, but incorporates a socio-scientific issue which in turn, will increase student motivation within the classroom.

Implications and Limitations

The implications of this curriculum requires students to not only take the class, but also maintain a desire to pass the course. Without the internal motivation to pass the course, student interests seem irrelevant. It needs to be stated that this irrelevance is specific to the course and not the individual. Responsibility and interest is not one sided in that the teacher needs to be willing to put forth the effort to determine relevancy and interest within the students.

There are a couple limitations that teachers need to take into consideration before implementing these lessons. One of them includes knowing what is relevant to their students. Teachers need to be able to modify the materials used so that they are representing local environments. It would do no good for a teacher in California to replicate the exact lessons as their students would have little to no connection to the investigations using samples from Minnesota. If the topics and investigations are not relevant or current and students can not connect with the subject, the point of the connection is lost and students may lose motivation.

Another limitation with the curriculum is a chemistry teacher's familiarity with environmental sciences. Environmental science endorsements are set under a Life Science licensure. Chemistry is a separate license in most states, including Minnesota.

Often, teachers like to stay within their comfort zone when it comes to teaching. It may be difficult for a physical science teacher with a chemistry or even physics license to add life science into their repertoire.

Although there are limitations with this curriculum, teachers are resourceful and passionate beings. With the structure given, I feel confident that most would be able to apply it to their environment and be comfortable learning a bit more about a science that would increase motivation among their students.

Future Research

The future of sustainable education is wide open to continue to pursue different research techniques and applications within the classroom. With the new standards, both Minnesota State and Next Generation, sustainability seems to be the common topic. Creating curricula pertaining to sustainability should not end with science either. Other content areas such as social studies, math, English, and art have the ability to use it within their lesson plans, especially with the STEAM (Science, Technology, Engineering, Art, and Math) movement in education. Also, much of the research I found pertained to curricula creation, but there was little to do with the results of implementation. Sustainable education is just at the beginning stages of life and has the potential to blossom into something huge, which could ultimately determine our country and our planet's future.

Results

I am excited to start implementation of this curriculum as soon as this coming school year. Depending upon the outcome of student feedback in the form of conversation as well as scores, I hope to continue to apply the format to the remaining units of the course. Discussion among the science department will also have a great impact on whether or not the structure continues. Not only does the curriculum need to be beneficial for the students as they are currently in the course, but it also needs to progress them into future science courses. This discussion will take place within Professional Learning Community (PLC) time that is built into our course schedule.

Benefits to Teaching

One of the topics I hear most commonly discussed among teachers about students is engagement. Without it, students seem to let information go in one ear and out the other. Keeping students engaged takes practice and more than anything, work. Teachers are already engaged within their content. It is why they teach it. To pass that passion and interest for a topic on to students is difficult. It takes more than a teacher being passionate about their subject.

Through my research and experience, learning about students and what interests them is they key. Keeping material relevant so they can see the advantage of staying awake and learning the material is one of the most important things a teacher can do in the classroom. Students ask, “why do we have to learn this?” Many teachers may not have the answer. By linking content to what is important to students, will give you the answer.

By applying the structure I have provided within my curriculum sample, teachers will be able to give students a reason to learn science. An initial socio-scientific issue, such as water pollution in their home state, is used as a jumping point. From there, investigating claims of how that water gets polluted through an activity or mini-lab, to finally giving the specifics of how the properties of water works. This organization allows students to maintain their interest in the topic as they uncover a little more each day.

Final Thoughts

Chapter four was a representation of conclusions and reflections of my capstone project. It covered my learnings as a teacher and student throughout the capstone creation process, revisited prominent authors from literature reviewed, looked at limitations and future research pertaining to my research question, and finally gave perspective of possible results and benefits to teaching. I'm thankful for this process and am grateful to have a supportive administration willing to let me implement this curriculum with my students. I feel like a truly understand what it means to be a continual learner and appreciate the lifelong efforts of teaching. I am proud of myself for the work completed and the work to be completed in the future.

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