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Relating Chemistry to Society to Promote the Understanding of the World for High Schoolers

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RELATING CHEMISTRY TO SOCIETY TO PROMOTE THE UNDERSTANDING OF THE WORLD FOR HIGH SCHOOLERS

by

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CHAPTER ONE

Introduction

Research Question

Science is the base of the world around us but its relevance is often questioned. As a chemistry teacher, I get asked all of the time by students wanting to know why they even have to take chemistry. It is a question that every chemistry teacher hears at some point in their career from a student. If asked right now about how chemistry affects society a variety of answers would be given from the general public. Chances are that a few people could come up with the answer that 'atoms make up everything' but a large amount of the population wouldn't know how to answer that question. Science by nature is an inquiry based subject. What we as scientists have learned about chemistry and the world around us today was done through discovery. High school students seek to understand the world around them. More specifically they seek to understand how science content fits into their current lives in the world. This leaves me with the question of *how does relating chemistry to society promote the understanding of the world to a high schooler?*

In this chapter it is my goal to discuss my personal background in chemistry classes and how it led me to wanting to explore my research question in this Capstone for my current and future students. I will also cover how the new Minnesota science standards correlate to the application of knowledge through real world experiences, specifically the three dimensions that make up every standard. Lastly I will talk about who benefits from this capstone project, as it is not only my students but my colleagues, peers and even myself.

Personal Background

I loved science in elementary and middle school, but as I transitioned to high school it was no longer an interest of mine. I have realized it is because most of my high school science class were set-up in similar structures. We would take notes from a slideshow or textbook, complete multiple worksheets, take a quiz half through the unit and end with a unit test. If we were lucky the unit included a demonstration done by the teacher or maybe even a hands-on lab. Out of the science classes I took I enjoyed chemistry the most because of the hands-on aspect to it. Chemistry had multiple labs, my favorite being the ones where something would explode! It also felt as if we didn't do as many quizzes and tests but instead research projects and presentations.

College

Once I reached college I signed up for a mandatory science class specifically chemistry. On the very first day the professor asked if we liked cookies specifically if they were homemade, of course everyone said yes. He responded with 'great, you all like chemistry'(M. Scholten, personal communication, Spring 2020). I don't think many students agreed with that statement but it was a great opening to the class. He went on to explain that baking and cooking is chemistry in practice. I was hooked immediately. After that, I was interested in what else I do daily, that was chemistry. I continued signing up for more chemistry classes and signed up to be a teachers' assistant for the Chemistry in Society class at Hamline. The textbook that was used in the class explained many other daily parts of life that involve chemistry. Even though it was an 8:00 am class I could see how engaged the students were when we discussed the chemistry background and related it to their lives and the world around them.

Real-Life Chemistry

I began to wonder why aren't high schoolers taught chemistry more like that. Any class I was put into for the teaching licensure program the students always asked why I picked to teach chemistry. Every time I gave the same statement telling them that I get the opportunity to explain how the world works to them. Some laughed but more often than not they asked for an example of how chemistry could ever be important to them. So I opened with the cookie line. Most of the time the students had already learned about chemical reactions and were asking if baking was a physical, chemical or both types of reaction. I started to wonder which other topics could I find applicable life examples for and how it could create more chemistry classroom discussions.

Teacher

When I got my first job I was determined to include more connections to society using chemistry. I started looking for resources at my high school and realized there wasn't much in the textbooks for real life lessons. There were singular pages for the 'connection to life' but no further questioning, lesson, or assessment. So I started looking online and realized that there are multiple resources for college level classes and lessons but hardly any curriculum at the high school level. I realized there is a need for lessons, units, and activities at the high school level that relates chemistry to society.

Wondering how to best go about creating these resources led me to the question of *how does relating chemistry to society promote the understanding of the world to a high schooler?* All Minnesota students have standards that they must meet in science for the class to count for graduation. This project includes a look at the standards and how some unconventional learning styles can create engagement and societal connections.

MN Science Standards

The Minnesota Department of Education (MDE) has revised the standards for science education with full implementation by the 2024-25 school year (MDE, 2022). These standards follow the Next Generation Science Standards (NGSS) model. The standards give flexibility to design classroom experiences that helps to prepare students for college, careers and citizenship (Next Generation, n.d.). The MDE standards emphasize three different dimensions. The first is science and engineering practices, this dimension focuses on the everyday practices that a scientist would use to investigate the world around them. The second dimension is crosscutting concepts. It focuses on the connections between the four domains of science and encourages students to connect a main concept to other parts of their world view. The third and final dimension is the disciplinary core idea that the state requires students to have an understanding of. (NGSS Lead States., 2022, July 14).These dimensions encourage interdisciplinary learning experiences and real-life connections to the world the students are living in. The school that I am at is starting to implement the new Minnesota science standards (Science., n.d.), to allow the curriculum to approach a more hands-on experience and connection based units. Letting students lead their learning through different approaches allows for stronger engagement and ownership of their learning. My capstone project will help me put the new science standards into practice at my district, while also creating chemistry connections to society.

Benefits of Capstone Project

Creating and implementing a capstone project that makes chemistry connections to society will help expand students' knowledge, understanding, and engagement of the

subject. Students will not only meet their requirements for graduation from the state but will also be able to develop practice in critical thinking, research and knowledge of how their world functions at a scientific level. My colleagues and peers will benefit from a new resource being available to them as schools look to implement the new Minnesota science standards and to create a different type of chemistry class. Myself as an educator benefits from the experience of researching and creating a curriculum that shows chemistry connections to society and how those connections can directly relate to a high schoolers life.

Summary

Chemistry is a class that is often overlooked in the importance of knowledge. I believed in high school that it didn't hold much real value to my life, I just enjoyed making things explode. Until I reached college I was informed that almost every little action I do has a scientific reasoning that is backed by chemistry. As a chemistry teacher now I think that it is vital that high school students get to understand chemistry as to how it relates to our society. It is important that there is another resource for all chemistry educators to have access to that meets state expectations. Along with this resource allowing students to take a lead in their learning and most importantly their understanding of their world.

In the next chapter, I further investigate the impact chemistry has on society. Including the history of the elements with their current uses, medical advances with connections to chemistry, and how chemistry impacts nature. I will investigate student engagement resources and how inquiry based learning is used in Science, Technology, Engineering, Arts and Math STEAM curriculum. Along with that I discuss the new

direction the Minnesota Science Standards are taking, with integrating the Next Generation Science Standards (NGSS) in three dimensions. Chapter three will detail the project description and outline curriculum that address these issues. The final chapter reviews the capstone process and project, along with a reflection of my learning.

CHAPTER TWO

Review of Literature

Chapter Overview

Creating connections of chemistry to society, can result in well-informed adults. There is also a set of standards that the Minnesota Department of Education believes every student should have knowledge on before becoming a graduate. Sustaining engagement in lessons can be done in a multitude of ways. The following literature review addresses relevant research pertaining to my research question: *How does relating chemistry to society promote the understanding of the world to a high schooler?*

The chapter opens with a discussion on how chemistry impacts society. It reviews a couple of the elements on the periodic table, the Food and Drug Administration (FDA), medicinal chemistry and how chemistry works in nature. With an increased understanding of how vital chemistry is to society, it can show how many different topics are available to relate to the life of a high schooler.

In the next section student engagement is explored. First I look at improving engagement in chemistry, through multiple ways. Including hands-on activities, personal health, technology integration and even tattoo ink. Then inquiry based learning is presented with research on what it is and how it allows students to take ownership in their learning. Also included in this section is research about success college and universities have had with a society focused science class.

Finally the Minnesota Chemistry Requirements are discussed. This includes the new standards that are in the rollout stage for schools. The Next Generation Science Standards (NGSS) and the three dimensions of science learning are also discussed in how

they correlate to the Minnesota Standards. The three dimensions include crosscutting concepts, science and engineering practices and disciplinary core ideas. Wrapping with showing the overlap between the Minnesota standards and the Next Generation Science Standards (NGSS).

Impact Chemistry has on Society

Chemistry is the study of matter and matter makes up everything in the world. (American Chemical Society, 2022). Therefore, this causes chemistry to be the study of the world. There Are different types of chemistry, such as physical chemistry, biological chemistry, environmental chemistry, medical chemistry, and more. (*The 20 types of chemistry (and its definition)*. Life Persona. (2022). There are multiple ways chemistry causes an impact on society. Some are large advances in drugs and organization, others are unseen to the human eye but are noticed when studied. These impacts include the history of discovering elements and the elements past and current purposes, how chemicals have been used in our food and how they still are. Along with medical advances with connections to chemistry and how chemistry impacts nature.

Periodic Table of Elements

According to Kean (2019), “the periodic table is a map” (p.13). The periodic table was created to organize the elements known and predict properties of elements to still be discovered. Though elements may share some characteristics they are one hundred percent individual. This can be seen on a molecular level and within the naked human eye because of an element’s history and uses. Antimony and Magnesium will be looked at out of 118 known elements to see their history and current uses in today’s society.

Antimony. Antimony symbol is At. Antimony's name comes from the Greek word meaning not-alone (Emsley, 2011). Before being determined as a toxic element it found a variety of uses. Nebuchadnezzar, a king in the sixth century, used antimony-lead paint in his place. Soon he went mad, sleeping outdoors in fields and eating grass like an ox (Kean, 2019, p. 21). It was used in mascara to give witchlike power, used as a laxative because it didn't dissolve so it could be reused but antimony found most success as a medicine (Kean., 2019). When mixed with other elements it was known as hangover cure and could help with parasitic infections (Emsley, 2011). Antimony is still an important metal in today's society, but with its toxicity known it stays clear from medical chemistry. Antimony is mixed with oxygen to create a flame-retarted that accounts for two-thirds of the flame-retardants used (Emsley., 2011).

Magnesium. Magnesium symbol is Mg. It is the 9th most abundant element in the Universe as it is formed in supernova stars (Emsley, 2011). Magnesium compounds soak up water like a sponge, so even on planets like Mars there is hope of finding bacteria among magnesium deposits (Kean, 2019). On Earth magnesium ions crown chlorophyll, which plants need in order to survive (Emsley, 2011; Kean, 2019). Magnesium is also needed in a human diet. Humans need about 200 milligrams a day, deficiency can cause high blood pressure, heart disease, diabetes, osteoporosis ("Magnesium deficiency", 2021, March). A visual use of magnesium is in magic birthday candles. There are small amounts of magnesium in the wick of the candle that causes the candle to relight itself over and over again as it reacts with the oxygen in the air (Emsley, 2011).

Chemistry in the World of Medicine

"Medical chemistry is the science that deals with the discovery or design of new therapeutic chemicals and their development into useful medicines" (Libretexts., 2022, July 4). Medicinal chemistry has been around for several thousand years, as humans have searched for cures in illnesses. It started with chewing herbs, berries, roots, and barks. According to LibreTexts Chemistry the earliest written records from the Chinese, Indian, South America, and Mediterranean cultures were able to describe the therapeutic effects of multiple plant concoctions. Medical chemistry has made many advances from just natural drugs. Without these advances few diseases would be treatable today (Libretexts, 2022, July 4).

Personal Diagnosis. Personal diagnosis could become a thing of the future. This would mean being able to understand any disease on a molecular level for each individual or group of individuals (Duburs, et al., 2012).When an organism goes from being from a healthy state to a disease state there are gradual shifts of equilibriums within the subject. A personal diagnosis would address the shift in equilibriums for each individual. Economic, ethical, and social implications show significant challenges to be overcome before personal diagnosis becomes a part of everyday life. Chemistry and molecular technologies are at the front of changing medicinal chemistry and nanotechnologies (Duburs, et al., 2012).

The coronavirus disease (COVID-19) that is from the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pushed science to the forefront of many lives, largely starting in December of 2019. According to the World Health Organization there were 640,395,651 confirmed cases of the COVID-19 disease as of November 2022. The

first vaccine was not given until December of 2020. (Rotton, T. 2022, December 2).The molecular structure of the virus was studied by many to help find a vaccination for the world. It was discovered that the SARS-CoV-2, the chemical name for COVID-19 was composed similarly to other coronaviruses (Erdem et al., 2022). The genome is made of a single-stranded RNA with 30 kb nucleotides encoding four main structural proteins. Having an understanding of the molecular aspects of these proteins and their interactions was crucial to the production of a drug and vaccine.

Though medicinal chemistry started with herbs, berries, roots, and bark it has grown into a field all its own. Creating drugs and vaccines for infections, diseases and pandemics. The field continues to push further as it works on creating individual diagnosis for each human.

Chemistry in Nature

According to Agosta (2001), "Throughout the living world countless chemicals tie creatures to one another, often giving rise to effects felt elsewhere in their biological community" (p. 191). Chemicals are a way that individual species can communicate with each other and can be used to help defend themselves as well. As species developed over time, they began to adapt their cellular machinery to produce chemicals for communication, warfare and other purposes (Agosta, 2001). One-celled organisms to complex organisms use chemicals for communication and warfare. Protos use a chemical signal as warfare to communicate with Lepts. Fight over the other's environment is where Protos and Lepts interact. The fight is not a fair fight as Protos have a special weapon. Protos carry a special chemical that when released causes panic and confusion in

Lepts (Agosta, 2001). Interspecies most often have warfare chemicals to use. Zebra's also use chemicals to fight against tsetse flies and their infectious bites (Agosta, 2001 p.189).

The Air We Breathe. The atmosphere on Earth is host to many types of greenhouse gasses. The unique bonding that the greenhouse gasses, such as Nitrogen Oxides, Ozone, Sulfur Dioxide and Hydrocarbons have contributed to the strength needed to break apart their molecules into safer compounds for Earth's atmosphere and sustainability (HOGG. 2014). Greenhouse gasses can be hard to control as they enter our atmosphere from natural pollution and anthropogenic pollution. Looking at the molecular structures of greenhouse gasses can give hints on how humans can help control them as natural pollutants. Chlorofluorocarbons are directly linked to breaking down ozone into oxygen (American Chemical Society National Historic Chemical Landmarks). The highly reactive chlorine atoms in chlorofluorocarbons convert the ozone molecules into oxygen, depleting the source of ozone that creates the ozone layer. By knowing how the reduction happens steps can be taken to reduce the ozone depletion.

Chemistry in nature includes not only organisms but also compounds and molecules that make up the atmosphere. Studying chemistry can show how interactions between species are due to chemical processes that happen within an organism's ability to communicate or protect themselves. Researching and understanding how chemistry acts within nature can help save resources that cannot be replaced once gone.

Student Engagement

There are three parts to this review and discussion. The first theme being discussed is improving engagement in chemistry. Increasing engagement can be done in a number of ways. This discussion will include the use of hands-on activities, technology,

and even tattoo ink. The second theme being discussed is inquiry based learning and how it aims to give students the opportunity to practice scientific methods in an engaging way. The third item being discussed in this section are courses that are designed for non-science majors. The course developed for colleges and universities allow chemistry to create strong connections to life and increase engagement in mainly non-science majors.

Inquiry-based learning

The word inquiry comes from the same root verb ‘to inquire’ or the adjective, ‘inquisitive,’ and means a process of questioning and looking for ways of finding information (Marshall, 2010). This is something that students do throughout their whole lives but it can often be stifled in the classroom. Inquiry-based learning practices are a type of instruction that aims to trigger a student’s curiosity of the subject. (Wolpert-Gawron, 2016). In chemistry designing experiments, communicating results, collaborative work, and critical thinking are all parts of effective inquiry-based learning. There are multiple styles of inquiry-based learning. They include confirmation, structured, guided, open, and authentic inquiry (Marshall, 2010). Each of the different styles add value to the learning situation.

Inquiry Styles. The following explanations come from Marshall (2010). Marshall (2010) explains inquiry as four types; Confirmation, Structured, Guided, and Open. Confirmation is having students follow step by step instructions. This can be useful in laboratory settings where safety procedures must be followed. Structured inquiry challenges the students to engage with the step by step instructions with opportunities to gather and interpret data. Guided inquiry has multiple opportunities for students to make

more decisions. This can be useful when students have gained experience and skills, they are able to use their own methods and design for carrying out procedures and data collection. Open inquiry is when students are able to select and/or design their own ways to solve a problem. Open inquiry still includes guidelines for students to follow, though far fewer than confirmation inquiry. Authentic inquiry is where the student becomes an independent investigator.

An applicable practice of guided inquiry-based learning done with a POGIL. Process-oriented guided inquiry learning (POGIL) was developed by the National Science Foundation. It combines both the guided inquiry approach and development of student process skills. This style of learning is presented as an activity that guides students through an explanation and allows them to construct, deepen, then refine their understanding of the classroom content.

With the multiple styles of inquiry-based learning courses are able to be designed in a way that allows the students to grow in their independence. Allowing for inquiry growth helps students understand that both craftsmanship and the spirit of exploration are essential to a scientific classroom (Cummins, et al., 2004).

Different Ways to Engage

There are multiple ways to increase engagement for students. It can be using real-world examples, hands-on activities and integrating arts in the Science, Technology, Engineering and Math(STEM) classes.

Real-world. Real-world examples are often used as entertaining side notes rather than being used as the focus point of concept-building (Bhattacharyya, 2010). Using real-world examples can look different in all classrooms. Some classrooms focus on

hands-on activities, others use technology, and discussion to integrate the real-world example. Arts have been added to science, technology, engineering and math to increase students' engagement of a subject's that often have a negative reputation.

Hands-on. Hands-on learning can increase students' confidence in the material that they are learning. By increasing that confidence it allows for students to want to dig more into what they are learning. (What are the benefits of hands-on learning?: Newschoo, 2022). In a study done by Anderson, et al., (2021) it was reported that people felt more interested and more relevant to them after having done a hands-on activity.. The study reported that 52% of people that their increased feeling was due to the everyday life content that was presented. Using both real-world examples and hands-on activities can increase engagement in chemistry.

Technology can also be used as a tool to increase engagement in the classroom. As technology advances so do people's means of acquiring, using, and sharing information. Technology should be embraced not hindered as a resource for the classroom. An outreach program was created by the Department of Chemical and Biomolecular Engineering at New York University Polytechnic School of Engineering. In this outreach program a blog was created to enhance students' learning in a high school chemistry classroom (Kim et al., 2014). In this program students had access to the blog not only during class time but also outside of school hours. Results showed that "students participating in the program exhibited improved engagement in science, class participation, and understanding of the topics" (Kim et al., 2014).

In Italy there was a Scientific Degree Plan that was designed towards high school students to promote enrollment in science degrees in college that applied tattoo ink to

chemistry. Research has stated that tattooing is of increasing popularity especially in young adults and high school students (Evert, 2016). The class discussed fundamentals of tattoo inks that allowed intersections to happen within the branches of chemistry (Donia et al., 2021). This class allowed students to connect a personal interest of theirs and see the effects chemistry had on it. Such as the pigments, Food and Drug Administration regulations, metal contents, chromatography separation and analysis of chemical tests.

STEAM. Adding arts to Science, Technology, Engineering and Math (STEM) subjects have become increasingly popular. Science, Technology, Engineering, Arts and Math (STEAM) is meant to enhance science lessons and allow students to have more creativity when discussing problems. (Conradty & Bogner, 2019). Integrating the arts into STEM can help students critical thinking skills about real-world problems. It allows students to express themselves in their learning. Inquiry-based learning encourages students to take a lead in the content. Adding an artistic component to lessons lets students go more in depth with their explanations in ways they may feel more comfortable in. Some authors have declared creativity as the 21st century's key skill and think it should be an essential goal to promote student engagement. (Conradty & Bogner, 2019). By using STEAM instead STEM science lessons can become more attractive, thus encouraging creating solutions. (Conradty and Bogner, 2019).

Chemistry for non-majors

High school students and college students often complain over how science connects to their lives. By finding new ways to increase engagement it can help the subject of chemistry's reputation of being out-of-date, or dangerous (Donia et al., 2021). A project that started at the University of Wisconsin-Madison aims to increase

engagement in science classes and help heal chemistry's reputation of being out of date. The project is called The SENCER project, which stands for Science Education for New Civic Engagements and Responsibilities (Middlecamp et al., 2006a). The class at the University of Wisconsin-Madison was formed because teachers were hearing multiple student complaints about the fact that chemistry courses were often culture free (Donia et al., 2021). The SENCER project works on designing new science courses that change the old way of thinking, to make the connection between science, people and society clearer (Middlecamp et al., 2006a). As the project has developed it continues to focus on creating engagement in complex topics rather than learning "Simple scientific topics in a simple way" (Middlecamp et al., 2006a). SENCER has over 50 course models as resources for colleges and universities across the country (*Resources and initiatives*, n.d.). By listening to their students and the students desire to learn how science interests in their world professors have been able to increase student engagement and student skills. In a survey done from a SENCER class the following results show how affect relating people and science can be (Middlecamp et al., 2006a). According to Middlecamp et al. (2006b) "One question asked how much the class adds to their skills in thinking about complex issues that involve both people and chemical principles. Here, 70% selected either the response "a lot" or "a great deal".

Increasing student engagement can be seen as a daunting goal for educators. There are multiple ways in which engagement can be created. In chemistry using real life examples helps students connect to the material on a personal level. This allows learning to carry personal responsibilities (Middlecamp et al., 2006b).

Chemistry Requirements

Minnesota science standards are going through a transition period. This section will discuss the new standards that have been approved and will be fully implemented in the 2024-25 school year. The section will also discuss the Next Generation Science Standards (NGSS) that have three dimensions of science learning. Those three dimensions include crosscutting concepts, science and engineering practices and disciplinary core ideas. The new Minnesota science standards show overlap with NGSS as well.

Minnesota Science Standards

The Minnesota Department of Education (MDE) states that scientifically literate classroom communitie make observations of the world around them. The MDE has adopted the 2019 Academic Science Standards in 2021 with full implementation to be in the 2024-2025 school year. A Framework for K-12 Science Education was the foundational document used to develop the 2019 Academic Standards in Science (Science., n.d.). This book was also used to develop the Next Generation Science Standards (NGSS) . The supporting resources and assessments developed for NGSS are also helpful for implementing the Minnesota 2019 Academic Science Standards (Science., n.d.).

Next Generation Science Standards

The Next Generation Science Standards (NGSS) are a set of K-12 national standards developed by the National Research Council (“*Next Generation Science Standards*,” 2022). The Next Generation Science Standards require the use of three-dimensional learning to create a larger focus on mastery level understanding. By

having the standards designed this way it allows for clarity in the natural progression of learning. The three dimensions include the following, science and engineering practices, crosscutting concepts, and disciplinary core ideas (“*Next Generation Science Standards*,” 2022).

Scientific and Engineering Practices. To practice science it is more than just memorizing facts it includes understanding and interacting with the world. NGSS uses word practice to convey that there is an emphasis on engaging in scientific investigation using both skills and knowledge specific to each practice. This dimension helps to explain and extend what inquiry means in science. The National Research Council (NRC) shows that inquiry shows a range of cognitive, social and physical practices in the science classroom (2012). This dimension allows for science's messy and fluid side to come out. Science is always changing, as society is changing so does science. (*Modern science:* 2022). Students use this dimension to practice seeing themselves as active members of the scientific community, and society as a whole, ebbing and flowing with the changes.

Crosscutting Concepts. With science being fluid and ever changing the concepts are not little boxes of knowledge to be learned and then forgotten. All of science shares many of the same basic concepts. Crosscutting concepts apply to all the domains of science. Repeated prescribed use of the crosscutting concepts have been shown to assist student understanding of new and difficult concepts (Yoon et al., 2018). It is important to emphasize the concepts as they provide the foundation for relating knowledge from various domains of science to create a coherent and scientific based view of the world. (“*Next Generation Science Standards*,” 2022).

Disciplinary Core Ideas. The third and final dimension of NGSS is disciplinary

core ideas. They are grouped into four domains; physical science; life science; earth and space science; and engineering, technology and applications of science (NRC, 2012). Disciplinary core ideas focus on the curriculum, instruction and assessment of the domains. When you incorporate the science and engineering practices and crosscutting concepts with the disciplinary core ideas, strong connections between the core ideas are emphasized. This is where the overlap to the Minnesota 2019 standards can really be seen. The core ideas use the science and engineering practices and crosscutting concepts to demonstrate the knowledge that students should have acquired during their chemistry course. Minnesota organized the standards with NGSS in mind so that students' knowledge of chemistry builds throughout the course.

So What does this Mean?

Knowing how chemistry interacts with society can help frame how material is presented to students. Starting with the history of atoms, is the history of the world. This creates a base for all other discoveries, including medicinal chemistry, biological chemistry, analytical chemistry, natural chemistry and many more types of chemistry. Creating interest and keeping students engaged can be a challenge in a subject that is historically unlikable, such as chemistry. Using all styles of inquiry-based learning creates a foundation for students to grow on. Allowing students to ask and form questions, design experiments, and become the overall investigator lets them wonder about the world around them. Then using engagement trips such as technology and hands-on experiments keeps students engaged in their learning. Leading up to having students that are experienced in the world of chemistry and can see how state standards interact with each other. The standards that are built off of the Next Generation Science

Standards allow for the gradual knowledge to form in students. Increasing student engagements can increase a student's applicable knowledge. Knowing what electron configurations are is wonderful for passing a standardized test. But using that knowledge to know what they represent and how they affect chemicals, such as greenhouse gasses, properties is applicable knowledge for students to become active and knowledgeable citizens on our Earth.

Summary

Chemistry is everywhere in the world. There are more than 20 types of chemistry but it all starts with the foundation of The Periodic Table of Elements. Elements have many diverse uses throughout the world including flame retardants and magic candles. Chemical advances in the world of medicine are leading to personal diagnosis for the future of medicine. Chemical knowledge is crucial to vaccines and treatments, most recently the COVID-19 virus. Chemicals in nature are what is crucial to species surviving in nature. Chemicals are used for communication, protection and warfare. Chemistry is done at a molecular level but put all together it is what makes up the world.

Student engagement can be increased through the use of guided-inquiry based learning. There are multiple styles of inquiry based learning that grow and build upon each other when used in the classroom. Inquiry based learning allows students to take the leadership role in their learning and gives them more freedom to trial and error learning. There are multiple ways that activities can increase student engagement as well. The use of hands-on activities, technology and discussions of topics students find interesting are all used to increase engagement. Arts are being added to STEM to create STEAM and this has seen an increase in students desire to continue in trial and error learning. Colleges

and Universities have programs designed with the combination of inquiry based learning, interesting topics, and STEAM to develop science classrooms that are engaging to not only for science majors but also for non science majors.

With Minnesota's new standards coming into full effect in the 2024-2025 school year it is important to have a solid understanding of how the Next Generation Science Standards (NGSS) shape Minnesota standards. NGSS has three dimensions that are crucial to scientific learning. Scientific and engineering practices are where inquiry based learning is practiced. It is both the skills and knowledge that is specific to the chemistry content. Crosscutting concepts integrate more than just chemistry knowledge. The basic concepts cover multiple science, technology, engineering, arts, and math (STEAM) domains. Disciplinary core ideas are the main content specific goal students should be investigating and learning throughout the course.

The next chapter outlines the curriculum project that was created to integrate societies real-world problems into an eleventh grade chemistry class and answer the question *how does relating chemistry to society promote the understanding of the world to a high schooler?*

CHAPTER THREE

Project Description

Introduction

Creating connections between chemistry and daily societal lives allows for students to see how chemistry affects them. In this chapter, I outline a curriculum that creates a connection between the air in the atmosphere, including the pollutants and how the pollutants are formed and their effects on the world. The curriculum then discusses chemical formulas and names and representing chemical equations. The goal of this curriculum is to increase students' understanding and engagement of chemistry by using a prevalent topic to today's society. Throughout this paper, I will address the question, *How does relating chemistry to society promote the understanding of the world to a high schooler?*

Project Framework

Inquiry-based learning is the framework for the Next Generation Science Standards that formed the Minnesota 2019 Science Standards. Inquiry-based learning focuses on students investigating phenomena as a way of learning both the content and science skills at the same time (Van Uum, et al., 2017). Using a phenomena, or a real-life example helps to increase students ability to understand how the content fits within their life. Inquiry-based allows students to take ownership in their learning. With the different styles of inquiry based learning students are able to have structured freedom with learning that keeps them safe and learning the content. Studies have shown that inquiry based learning increases students' engagement across contents while still allowing students opportunities to use critical thinking and interact with the content at a higher

cognitive level (Sinatra, et al., 2015). Using real-life examples in inquiry based learning allows for students to increase their understanding of chemistry and prepares them to become active and engaged members of society.

Audience

This curriculum is designed for 11th graders in a 9-12 high school in southwest rural Minnesota with a student body of about 650 students. The school has a staff of 44 teachers. The school's student racial demographics are approximately 92% White, 5% Hispanic, 1% Asian, 1% Black, and 1% of two or more races. The curriculum will be placed in an 11th grade investigating chemistry class for approximately two weeks with 55 minute class periods once a day. This class is designed for students who are looking at 2 year schools and trade schools, not students wanting to pursue science at a post-secondary level. Approximately 40% of the students in the class have an IEP or 504 plan. The course is the first half of a two-semester chemistry course that fulfills half of the chemistry credit required to graduate high school in Minnesota.

Project Description

This will be a thirteen day unit that will be completed over 55 minute sessions in the 2023-2024 school year during the first semester. The unit named *The Air We Breathe* will focus on the air in the atmosphere and the pollutants that are present. The pollutants' formations and their impact on life is studied. Within the unit students also learn how to write names and formulas for molecular compounds. Types of chemical reactions are studied and how to balance a chemical equation. Then there is a brief introduction to green chemistry at the end of the unit. During the unit students will have opportunities to conduct experiments, collect data, draw conclusions, communicate results, conduct

scientific research, use models and collaborate as a team. Students will have already covered the atom and all of its parts, the periodic table set-up, the elements, and their properties. The unit will start off with an activity showing a formation of air through household products. Students will then complete an escape room to show the learning of naming molecular compounds and molecular compound names. As students learn about different pollutants they will have an opportunity to research an EPA report about air quality. Then types of chemical reactions are identified through a chemical reaction lab. Students learn to balance chemical equations using m&m's and continue balancing equations with chemical equations present in the atmosphere. The unit ends with the study of ozone both in the troposphere and in the stratosphere and the formation of green chemistry. Finally students are given time to review the material learned and then given a unit test to meet school standards.

Inquiry Labs

A main goal of this curriculum is to increase student understanding by using real-world applications. Students will have the opportunity to complete multiple labs over the course of the unit. They will start off with more guidance and towards the end of the unit students have more freedom to make safe decisions based on the knowledge they gain in the unit. One of the first labs to be done in the unit has students mixing common household items to see how easy it can be to create a gas and the effect the gas has on a closed system. Another lab students will complete will have them doing multiple chemical reactions and identify what makes it a chemical reaction from the five signs they previously learned in the unit. Along with determining if it is a chemical reaction then they must determine what type of reaction is present from chemical formulas.

Scientific Research

Students will complete two research projects. In the first project students will be looking at a report the the U.S. Environmental Protection Agency (US EPA) releases every year. They will research emissions trends throughout the years. It will give students the opportunity to graph particulate matter emissions and then analyze the trends present. Within the research students will then share the information they gather with other students in the class. The second project will require less research from the students as they are going to be using knowledge they have learned during the unit as well. With a partner students will take on the role of a fake doctor with four different patients to advise. The patient scenarios all have to do with pollutants that they may have come in contact with over the years of their lives. Students will be tasked with giving advice to their patients on the cause(s) of their issues and the preventive measures that could have been taken. Students must cite their source and give detailed reasonings to the patients.

Assessment

The effectiveness of the unit will be assessed using formative and summative assignments. Grading for this audience is a 20/80 grading scale. 20% of their final grade is formative work while the other 80% is summative. Formative assessments include daily bell ringers, called catalysts, homework assignments, and mini labs and projects. Summative assessments include full labs with write up components, projects and the unit test. Student work and test scores will be compared with previous years' assessments to gain a better understanding of how relating the topic to society increases students' understanding.

Designing the Curriculum

This curriculum was designed following the Understanding By Design (UbD) method. Kiernan et at. (2000) stated understanding is to make sense of what you know, to be able to know why it's so, to use it in various situations and contexts. By following this design method there is focus on students' understanding of the content throughout the unit and inturn throughout the course of the class. Wiggins, & McTighe, J. (2005), states that "all methods and materials we use are shaped by a clear conception of the vision of desired results". By using the Template A I was able to start with the desired results and then design the methods and materials, also known as the lesson plans, to achieve those desired results.

Parts of the Template

The template is split into three different stages. Stage 1 is titled desired results in this section is where you will find the standard or standards that the curriculum will meet. Along with the essential questions that are being asked throughout the unit. Stage 1 is also where the objectives are stated for factual knowledge, procedural knowledge and conceptual knowledge that students will learn in the unit.

Stage 2 is the assessment evidence section. In this section performance tasks can be found, in this cas those would be the labs and activities to be completed in the unit. Other evidence/assessments are listed in stage 2. The stage also includes and extensions the unit may have and notes on differentiation that can be taken into consideration when completing the unit.

Stage 3 is the final stage and that is where the learning plan can be found. It has the learning activities and then lesson descriptions. Following this final stage is where the

detailed lesson plans are found. Each lesson plan has specific objectives for the day. The plan includes materials that will be used for the lesson and ends with an estimated time breakdown of the lessons activities.

Timeline

In order to have the curriculum implemented in the fall semester of the 2023-2024 school year. Planning took place during the spring and summer of 2023. Planning for each lesson requires a range of time depending on the level of interactive components and the material required. Most materials are found in the laboratory and chemical storage at the school. There will be a few items and materials that must be purchased during the school year to have for this unit as they are consumable materials and unable to be reused.

Summary

This chapter served as an outline of a curriculum that is designed in response to the question, how does relating chemistry to society promote the understanding of the world to a high schooler? Inquiry based learning is used as a method in instruction to promote student engagement. Real world applications and examples are also used to increase student engagement, and increase a designer to understand the chemistry content. The curriculum design was focused on a unit in an 11th grade investigating chemistry class that is required for high school graduation. The unit focuses on the air we breathe and the pollutants that are present in the air, with the integration of chemical equations, names and formulas. In the next chapter. I will review the capstone project and the results of designing and implementing the curriculum into a class to promote student’s understanding of content.

CHAPTER FOUR

Conclusion

Introduction

The main objective of this capstone project was to design a curriculum unit to address the question, *how does relating chemistry to society promote the understanding of the world to a high schooler?* The unit was designed to focus on the air and pollutants present in the atmosphere while integrating basic chemistry skills into the daily lessons. Air and the pollutants were the focus as society has been taking a larger interest in the air pollutant over the past years (Ward, et al., 2022).

In this chapter I will reflect on what I have learned throughout my capstone process, including what has been helpful to me and what I struggled with. I will revisit the literature I reviewed and how those findings impacted my project. I will discuss the limitations and implications of my project and finally look to the future and benefits of this curriculum unit.

What I Learned Throughout

As a researcher I learned that it takes time. Not only time to find sources but also time to read and comprehend those sources. I realized that it is important to read through the research even if it may not seem ideal as that is where some helpful information may be hiding. It was also important to read through the full source because there were sources that I thought would be great for my project and they ended up talking about a completely different topic.

During the research for chapter two I began to realize how much I missed reading about new chemistry developments, I ended-up subscribing to a few chemistry sites for

field updates. I do truly enjoy learning as a process. Researching and reading about different ways chemistry is impacting society has excited me for all the ways I could incorporate those findings into my teaching as well.

As a writer the biggest thing I learned while writing this capstone project was to be honest with myself when it came to expectations. Before writing this capstone I would sit down to write something and wouldn't be done until it was at what I deemed perfection. I learned early on in this process that taking brain breaks was vital to my productivity in the project. This was reinforced when talking with multiple students who were taking the class with me. The biggest takeaway I learned about myself from completing this research project is to enjoy the small victories and to never stop learning.

Revisiting the Literature

When looking back at the literature that was studied in chapter two there were 2 sections that I found very important when designing and creating my capstone project. The first section was the air we breathe, this is what my project curriculum unit focused on. It discusses that chlorofluorocarbons are directly linked to breaking down of ozone into oxygen (American Chemical Society National Historic Chemical Landmarks). This section of research is a part of the curriculum unit that was designed. There is a lab activity that shows how the chlorofluorocarbons break apart and react with ozone that is O_3 in its chemical formula and breaks apart into O_2 known as oxygen. The lab uses gum drop models to represent the ozone and oxygen chemical structures and then the students act as the chlorofluorocarbons that cause the chemical reaction. By using this literature from the American Chemical Society it created an opportunity for students to get a larger understanding of the chemical reactions that are taking place in the ozone layer depletion.

The second section that I found important for my capstone was titled chemistry for non-majors. This discusses the SENCER project, which stands for Science Education for New Civic Engagements and Responsibilities (Middlecamp et al., 2006a) This project focuses on increasing engagement for students in science classes. The project has over 50 course models as resources for colleges and universities (Resources and initiatives, n.d.). The idea of having that many resources for college students was amazing to me. When I was looking for a similar curriculum for a high school class I am teaching there were very few resources. I created this capstone project to be another resource for teachers that may be in the same boat that I am in. This literature was one of the biggest driving factors in my desire to create a curriculum unit for high school. The SENCER class survey showed that 70% of students who took the class believed it added to their skills in thinking about complex issues that involve both people and chemical principles (Middlecamp et al., 2006b). Having 70% of the students believe that, I knew this way of teaching chemistry needed to be added to the high school level and kept me pushing forward when I would hit ‘roadblocks’ when creating my capstone project.

There was one part of the literature review that I realized was very relevant after designing my capstone project. This specific sentence mentions that real-world examples are often used as an entertaining side note rather than being the focus point of concept-building (Bhattacharyya, 2010). As I was creating the curriculum unit I realized what the author was talking about. It is easy to put down content into a slideshow and then add those real life connections at the beginning or and end as a “driving question", but that was not the purpose of my project. The project is designed to show how the

concept is related to the content. In this case how the air we breathe relates to chemical structures, formulas and equations.

Implications and Limitations

This capstone project can be used in high school level chemistry classes. It is designed for students who are not going into a four year college, rather for students who are looking for 2 year college, or trade schools. Even though it does cover required chemistry skills for Minnesota graduates it does not go as in depth as 4 year colleges would expect for students who have taken high school chemistry. The curriculum unit was designed for a school that has an 80/20 grading scale, meaning that 80 percent of the students grade is their summative work such as test and quiz, and projects with a rubric and 20 percent of the grade is any other formal formative work.

This project does have limitations for how classrooms are set-up. Not every classroom may have the lab space or access to the materials that are required for certain activities. Those limitations could include the chemicals needed for labs or not have the funding to buy the consumables each year. Looking forward with this project in mind, the project could be expanded on levels of differentiation. The unit test is differentiated according to the schools expectations which it was designed for. It has the basic, proficient and mastery level questions that could also be integrated into some of the labs and post lab questions especially.

Expansion

In the future to expand on what this capstone project is starting to look at would be to conduct additional research to see how students feel about the engagement they have in the curriculum. Surveys could be added at the beginning and end of units just as

the SENCER (Science Education for New Civic Engagements and Responsibilities) project did for college level classes. These surveys would be designed to look at students' engagement in class and their understanding of how the topics relate to the world. Another direction I want to expand on in the future would be to create more units that are designed like this project. Ideally it would be great for a whole semester-long curriculum to be present that is designed to relate chemistry to society specifically for high schoolers. This would greatly benefit the teaching science community at the high school level.

Using the capstone project

I will be using my project for the class I am teaching right now and hopefully will still be teaching in the future. I would love to share this project with other teachers if given the opportunity and I want to monitor the results of students' engagement throughout the years as society continues to change to see if students are starting to take a greater interest in what is happening in the world around them. This capstone project will benefit the teaching profession as it increases engagement in students' desire to learn chemistry by relating it to the world around them.

Summary

This chapter allowed me to reflect on what I have learned throughout my capstone process. I realized it is important to be a lifelong learner as it brings new excitement when discoveries are made. I also learned that it is important to have grace with myself when creating new projects and allow myself breaks to not get overwhelmed. I looked back at the literature reviewed in chapter two and two main components that impacted my project, including the American Chemical Society’s knowledge on chlorofluorocarbons and the SENCER projects that are happening at college levels. There

are some limitations for the project depending on what type of classroom the curriculum will be used in and if the school has the resources for consumable materials. Using a survey would be a great way to expand on this project to study how students feel about the engagement they have in the curriculum and their personal understanding of how the curriculum relates to their lives. Another expansion I would like to see done is to have more units available as this type of chemistry teaching grows. Since there are not many resources like this for high school level classes I think it is important to spread this resource and to continue to grow in these types of resources for high school educators. Creating a whole semester-long curriculum will help teachers increase student's engagement in the world around them through chemistry.

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Appendix A

Template A

<table>
<tr><td colspan="2">Unit Title:
Subject:
Grade:</td><td>Teacher:
Duration:</td></tr>
<tr><td colspan="3">Summary of unit:</td></tr>
<tr><td colspan="3">Stage 1 – Desired Results</td></tr>
<tr><td colspan="2">Objectives/Standards:</td><td>Essential Questions:</td></tr>
<tr><td>Factual Knowledge
Students will know:</td><td>Procedural Knowledge
Students will be able to:</td><td>Conceptual Knowledge
Students will understand:</td></tr>
<tr><td colspan="3">Stage 2 – Assessment Evidence</td></tr>
<tr><td colspan="2">Performance Tasks:</td><td>Other Evidence/Assessments:</td></tr>
<tr><td colspan="2">Extensions:</td><td>Differentiation Considerations:</td></tr>
<tr><td colspan="3">Stage 3 – Learning Plan</td></tr>
<tr><td colspan="3">Learning Activities:</td></tr>
<tr><td colspan="3">Lesson Descriptions</td></tr>
</table>

Lesson

Lesson Objectives
I can… •
Lesson Materials
Lesson Plan
•