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Energy, matter, and change: A high school chemistry unit development

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Abstract

The project I have chosen to focus on for the creative component of the Science Masters of Arts program is the creation of a high school chemistry instructional unit. The focus of this unit is on Energy, Matter, and Change, which is addressed in the Iowa Core/Next Generation Science Standards (NGSS) (Lead States, 2013a). This unit will be adapted using Unit 2, Energy Particles in Motion and Unit 3, Energy and States of Matter of the Modeling Instruction curriculum developed by the American Modeling Teachers Association (Modeling Instruction for High School Chemistry, 2017). The Energy Particles in Motion unit focuses on matter and its constant state of motion as well as gas laws. The Energy and States of matter unit looks at energy conservation and energy transfer. Together, parts of these two individual units will cohesively fit together and be used to develop an NGSS Chemistry aligned unit (Hestenes, 2010).

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Chapter 1

Introduction and Framework

The project I have chosen to focus on for the creative component of the Science Masters of Arts program is the creation of a high school chemistry instructional unit. The focus of this unit is on Energy, Matter, and Change, which is addressed in the Iowa Core/Next Generation Science Standards (NGSS) (Lead States, 2013a). This unit will be adapted using Unit 2, Energy Particles in Motion and Unit 3, Energy and States of Matter of the *Modeling Instruction* curriculum developed by the American Modeling Teachers Association (*Modeling Instruction* for High School Chemistry, 2017). The Energy Particles in Motion unit focuses on matter and its constant state of motion as well as gas laws. The Energy and States of matter unit looks at energy conservation and energy transfer. Together, parts of these two individual units will cohesively fit together and be used to develop an NGSS Chemistry aligned unit (Hestenes, 2010).

I teach in a rural Iowa school district which requires 3 years of science for high school graduation. This requirement is a district as well as a state requirement (Educational Commission, 2007). Of those three years, students in my district are required to take 2 trimesters of physical science, 1 trimester of earth science, and 2 trimesters of biology. This means not every student is required to take chemistry. Why focus on developing an instructional unit in a class that is not required in the district I teach? In 2009, 68% of high school graduates took biology and chemistry while 30% took biology, chemistry and physics (National Center for Education Statistics [NCES], 2016). In addition, in 2014, 44% of high school graduates went on to a 4 year institution (NCES, 2016). The College Board suggests any student planning to attend a 4 year institution should complete 3 years of the following classes: biology, chemistry or physics, and earth/space science (College Board, 2017). All of these statistics show a large number of students will likely take chemistry at some point in their high school career.

With the adoption of NGSS in 2015 in the state of Iowa, it became a priority for me to make adjustments to my lessons, specifically in chemistry, in order to meet the new standards. From my experience, many students find chemistry to be intimidating and struggle to understand big ideas due to the complexity and microscopic level of many concepts (Park, 2017). These concepts are often abstract and difficult to explain without the use of models or analogies. Misconceptions about chemistry concepts are often developed at a young age due to the simplistic examples provided. Students may be given chemical change examples such as baking a cake or cooking an egg and a misconception is developed that chemical changes are irreversible. In addition, the complexity of chemistry (or any other science) lies in the fact that science learning is tri fold, meaning students are asked to evaluate concepts microscopically, macroscopically, and symbolically. Finally, learning science becomes more complex when students are asked to solve mathematical problems (Gabel, 1999).

I saw a need to develop an instructional unit to meet the NGSS and to help students see that chemistry isn't as intimidating as they once thought. Because chemistry is required for high school students to attend most 4 year universities, it is necessary that they have the best opportunity to be successful. The development of this unit will make me a better educator by pushing me to dig deeper into the NGSS in order to incorporate all three dimensions. These three dimensions of the NGSS include cross cutting concepts (skills students need to think like scientists no matter what area of science is being studies), disciplinary core ideas (concepts being studied), and science and engineering practices (students learning by doing science) (Lead States, 2013c). In addition, it will help students be successful in high school and beyond because they will understand concepts on a deeper level and be able to connect them to the real-world.

Connecting concepts to real world experiences is key in helping students make sense of the challenges and concepts they encounter in a science classroom (Chase, Pakhira, Stains, 2013). Additionally, in order for students to be successful, they must learn how to monitor their learning (Ausubel, 1963). I will incorporate *Modeling Instruction* in my chemistry course to engage students in content that provides them with opportunities to make connections with the real-world and their past experiences.

In order to develop a chemistry unit, it is important to identify the required standards issued by the State Department of Education (Iowa Department of Education, 2006b). The state science standards have gone through many changes over the last 17 years. In 2008, the governor of Iowa signed a law which required all public and nonpublic Iowa schools to fully implement the Iowa Core. The Iowa Core was developed to be a set of guidelines for all teachers in the areas of science, math, and literacy to help prepare students for success after graduation by providing them with a rigorous and relevant learning environment. Additionally, the Iowa Core provided educators with the necessary tools to ensure essential subject matter and skills were being taught and learned. By 2010, a final draft of the standards were released.(Iowa Core, About Iowa Core section, 2006). The Iowa Core addressed math, English language arts, social studies, and science. The Iowa Core Science Standards were modeled after the National Science Education Standards, however, as jobs in the STEM fields grew, a need for a change to the standards developed (National Center for Education Statistics, 2016).

A study done by the Commission on Mathematics and Science Education (2009) showed jobs requiring an understanding of math and science continued to grow while U.S. students were performing below par in math and science. The concern was that if the system of education remained the same, millions of young Americans would be left unprepared to succeed (Commission on Mathematics and Science Education, 2009). In 2010, work began on developing new standards, now known as the Next Generation Science Standards (NGSS), to help address the gaps in science education to better prepare students for the math and science global economy they would face after graduation. Design teams were formed from 18 individuals who were nationally and internationally known for their works in various science fields. The teams split into four disciplinary areas: physical science, life science, earth/space science, and engineering. A Framework for K-12 Science Education, which is an evidence-based foundation for standards developed from current scientific research, was released in 2011. The framework included research on how students learn science and discusses what K-12 students should know by the end of each grade (Lead States, 2013b). After the Framework was developed, in 2013 several people who came from a variety of science fields published a final draft of the standards. The final draft of the standards was adopted by several states, including Iowa in 2015 (Iowa Department of Education, 2016).

The current version of the Iowa Core has adopted the NGSS. The NGSS has an added focus of engineering and technology, yet is written to interconnect all dimensions (Science and Engineering Practices, Disciplinary Core Ideas, and Cross Cutting Concepts), which will be discussed in detail later in this paper. The Iowa Core did not focus on connecting all science practices to one another, making them feel separate and unrelated. Many science teachers have already begun implementing several facets of the NGSS, and at the end of 2019, teachers in the state of Iowa will be expected to fully adopt the NGSS (Iowa Department of Education, 2016). Many teachers have already begun the implementation process by having students develop and formulate models, apply mathematics, construct arguments based on evidence, and communicate results of investigations. One of the ways I have engaged students in these practices is through the use of *Modeling Instruction*.

I received my undergraduate degree in Science Education through Morningside College in Sioux City. During that experience, I took a methods course with other pre-service science teachers and engaged in *Modeling Instruction* units. I took the role of the "student" to learn how *Modeling Instruction* would be facilitated in a classroom setting. I was immediately hooked because I felt I was able to develop and learn science concepts on a much deeper level, so I knew my future students would as well. When I student taught, my cooperating teacher used *Modeling Instruction* in her Physics classroom. At that point, I knew I wanted to find a district that supported *Modeling Instruction*. When I began my first year of teaching in 2012, I incorporated *Modeling Instruction* in teaching Physics right away. It was not until I completed my first year of teaching that I began to dig into the Chemistry Modeling curriculum. In 2015, I took a course through UNI to gain more experience with *Modeling Instruction*. Each year I use it, the more comfortable I become and the better I get at asking guiding questions to my students.

Modeling Instruction is a research-based curriculum reform started in 1989 and supported by the National Science Foundation (NSF) from 1989-2005 (Hestenes, 2010). *Modeling Instruction* puts an emphasis on phenomena as the central part of concept development and application of learning and doing science. The goal of a Modeling classroom is to provide students with experience of the natural world. With *Modeling Instruction*, a traditional lecture style classroom is replaced with a more coherent and student-centered environment. Computers are often an essential scientific tool used to produce graphical models for students to analyze, identify patterns, and develop concepts. (Jackson, Dukerich, & Hestenes 2008). The goal of *Modeling Instruction* is to "organize course content around *scientific models* as coherent units of structured knowledge; to engage students collaboratively in *making and using models (*which is a central part of the NGSS*)* to describe, explain, predict, design, and control physical phenomena" (Jackson, Dukerich, & Hestenes 2008, p. 10).

Most of the *Modeling Instruction* physics curriculum I used in my classroom addressed the Iowa Core physics standards. I had great success with effectively teaching physics students the standards using this type of instruction as evident by the increase in pre and post test scores given at the beginning and middle of the course. By getting rid of the traditional lecture style and putting students at the center of their learning, they became more involved with the learning process. They also learned the concepts on a much deeper level. The Modeling curriculum design I had so much success with was developed at Arizona State University by David Hestenes. In the mid 1980's the United States began being labeled as a Nation at Risk and a need for change in science education became apparent (Hestenes, 2010). Hestenes and many colleagues spent years researching and developing the foundations for *Modeling Instruction*. By 1993, this form of instructions was taught through a series of professional development workshops nationwide. The original content focus of the workshops was physics, but has since been developed to include chemistry, biology, and physical science (Hestenes, 2010).

For this project, *Modeling Instruction* and a 5E learning cycle will be used to address the NGSS in a chemistry unit. *Modeling Instruction* is an adapted learning cycle, so incorporating a 5E learning cycle in *Modeling Instruction* can be easily incorporated. Learning cycles are typically divided into a 4-5 phase process. The first phase of Engagement piques students curiosity, introduces a topic of study, and helps identify what students are thinking. The second phase known as the Exploration provides students with an opportunity to investigate physical phenomena, make observations, collect data, and try to make sense of the data collected . In the third phase of Explanation, students begin to develop mental images and use formal language to show their understanding of a concept. This phase allows students to begin to develop conceptual understanding by requiring critical thinking. The next phase of Elaboration allows students to apply their understanding of concepts to more in depth problems or real-world situations. In the last phase of Evaluation, students demonstrate their understanding which could be done in a variety of different ways.

It is important to develop some way for teachers and students to monitor student learning and understanding throughout the entire learning cycle process and not just at the end. Incorporating formative assessments is one way to do this. Formative assessment is defined as an assessment strategy used throughout the course of an instructional period for the purpose of improving teaching and learning (Reeves, 2005). Students are given homework to help solidify concepts, but quizzes can be used as a formative assessment strategy by teachers to monitor student progress and understanding. Another type of formative assessment that can be used by teachers are Paige Keeley formative assessment probes. These probes were written to address the National Science Education Standards, which correlate with the NGSS (Eberle & Keeley, 2008). The probes are a combination of a multiple choice and short answer. Students select the answer they best agree with and are asked to defend their answer in the form of a short answer response (Keeley, 2015). They are developed to identify student misconceptions about the related concepts and to get an idea of what students are thinking. Teachers can use these probes in addition to homework and quizzes to monitor student understanding before, during, and after a unit.

Homework quizzes are another type of formative assessment that can be used to monitor student learning throughout a unit. A homework quiz is developed from homework assignments. Students are given homework to help practice and solidify concepts and from the homework, a quiz is designed and given the next day. These quizzes are a formative assessment strategy used by teachers to monitor student progress and understanding. If a teacher sees the class as a whole score low on a homework quiz, then he or she should return to the concept being assessed and re-address any misconceptions. Homework quizzes also provide an opportunity for teachers to address misconceptions that individual students may have.

Modeling Instruction, learning cycles, and formative assessments will be used in this project to address the Next Generation Science Standards. I enjoy having the opportunity to interact and help shape students into productive citizens. My goal as an educator is to not only teach students content, but to help them become lifelong learners. Most of the students I see in chemistry will attend a 4-year university. Because of this, it is necessary that the students have the best opportunity to be successful. By developing a high school chemistry instructional unit, I will be able to reach a large percentage of students who need my course. Students will benefit from the conceptual understanding through the real-world problems they will encounter in my classroom.

Chapter 2

Literature Review

At this stage in my teaching career, I struggle to challenge my students in the age of "Google". I hear many educators debate whether or not we as teachers should require our students to memorize or learn information they can find on Google. An example of this would be the struggle between whether or not students should be required to memorize the elements on the periodic table. Many educators believe if a question can be "Googled", then there is no need to teach students about it. Though many disagreements regarding this topic exist, most educators would agree that we want our students learn relevant information that helps them solve problems in the future.

The following literature review will discuss research related to the following areas:

1. Connections and mapping to the Iowa Core and Next Generation Science Standards (NGSS).
2. Significant findings of science education literature relevant to a high school chemistry instructional unit focusing on Energy Particles in Motion and Energy and States of Matter.
3. An overview of research-based curricula, instructional strategies and techniques consistent with the framework including the use of the learning cycle and *Modeling Instruction*.

The Iowa Core Science Standards

The Iowa Core Science standards were originally developed to address National Science Education Standards (The Iowa Core, 2006). The following includes highlights of the Iowa Core Science Standards:

- "The emphasis must be on student inquiry. Deep grasp of scientific concepts and processes isn't possible with a classroom diet of lectures, readings and "cookbook" labs. Students must be actively investigating, designing the experiments, questioning and exploring, and defending conclusions.
- The curriculum follows the guidelines of the respected National Science Education Standards, including its focus on four content-specific categories: Science as inquiry, physical science, earth and space science, and life science.
- The curriculum is designed for all students, not just those who have traditionally succeeded in science classes." (The Iowa Core, 2006, p. 5).

Jobs related to STEM fields grew nationally, but students remained unprepared for the needs of the growing global economy. In 2016, only 36% of high school students who took the ACT met the college readiness benchmark levels in science nationally and only 41% of students met them in math (ACT, 2016a). In the same study, only 20% of students nationally met the STEM benchmark standard but is lower than the Iowa percentage of 23% (ACT, 2016b).

The Iowa Core and 21st Century Skills

Unfortunately, it is difficult to predict what the career and job outlook will be like for students in the future. This means that students need to know how to think critically, engage in mental activity, use information to plan ahead, seek meaning and explanations to problems, be self-reflective, and use reasoning to question the world around them (Iowa Department of Education, 2009). The Iowa Core 21st Century skills states, "We believe schools must move beyond a focus on basic competency in core subjects to promoting understanding of academic content at much higher levels by weaving 21st century interdisciplinary themes into core subjects" (Iowa Department of Education, 2006, p. 1). The 21st framework addresses this through the following topics:

1. Civic literacy
2. Employability skills
3. Financial literally
4. Health literacy
5. Technology literacy

Students in a learning environment that promotes 21st Century employability skills will "have the academic and social skills as well as the personal characteristics that empower them to be productive, caring, and competent citizens." (Iowa Department of Education, 2006a, p. 6). In order to develop these employability skills, students should be asked to work in teams, communicate effectively, think innovatively, and solve problems creatively. Though all of these skills are still vitally important in today's ever changing society, changes to the standards was still needed to better prepare students for STEM related jobs. New science standards were developed to help address these gaps.

Next Generation Science Standards (NGSS)

NGSS was created through a collaborative effort by 26 states (Lead States, 2013b). The draft went through multiple reviews and in the end, was adopted by many states, in many forms, including Iowa. Each standard within the NGSS is written as a Performance Expectation (PE) and can be broken down into three dimensions developed from the National Research Council's (NRC) vision for what it means to be proficient in science (2012). The NRC's framework discusses a set of expectations for science students. The goal of the K-12 framework was to:

> …ensure that by the end of 12th grade, *all* students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology (National Research Council, 2012, p. 2).

The NGSS integrate science and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs) in science identified as the three dimensions. These standards were developed to prepare all K-12 students for success in college and/or 21st Century careers (NGSS, 2013).

The three dimensions explained in detail go as follows:

(1) Disciplinary Core Ideas (DCIs): DCIs focus K-12 science curriculum, including instruction and assessment, on the most important aspects of science. In order to be considered core, the ideas found need to meet the each of following criteria (2013):

- "Have **broad importance** across multiple sciences or engineering disciplines or be a **key organizing concept** of a single discipline;
- Provide a **key tool** for understanding or investigating more complex ideas and solving problems;
- Relate to the **interests and life experiences of students** or be connected to **societal or personal concerns** that require scientific or technological knowledge;
- Be **teachable** and **learnable** over multiple grades at increasing levels of depth and sophistication."(Lead States, 2013e, para 1).

DCIs include four areas of science: physical science, life science, earth and space sciences, and engineering, technology, and applications of science.

(2) Scientific and Engineering Practices (SEPs): The SEPs describe traits effective scientists possess as they investigate and build models and theories about the natural world around them. They also focus on the designing and building process engineers use. The NRC's goal was to emphasize the importance of cognitive, social, and physical practices necessary to being successful at inquiry in science (Lead States, 2013a). Compared to the Iowa Core, NGSS takes inquiry a step further by incorporating engineering practices in order for students to see the relevance of science, technology, engineering and mathematics (the four STEM fields) to everyday life.

(3) Crosscutting Concepts (CCs): The final dimension of the Next Generation Science Standards are the Crosscutting Concepts. The goal of these are to illustrate the links between all areas of science to one another. CC's include: Patterns, similarity, and diversity; Cause and effect; Scale, proportion and quantity; Systems and system models; Energy and matter; Structure and function; Stability and change. When these CCs are explicitly emphasized, students should be able to develop a scientifically based view of the world around them.

Science phenomena are described as observable events that occur in the universe that we can use our science knowledge to explain or predict. The goal of NGSS is for students to use evidence to develop new ideas that can explain and/or predict phenomena. Students learn to explain phenomenon by developing and applying the three dimensions of the NGSS (DCIs, CCCs, and SEPs). The focus in a classroom is to move from the mindset of "learning about a topic" to "figuring out how or why something happens." When students shift to this mindset, they begin to appreciate the social relevance of science to their real worlds (NGSS, 2013).

Through teaching students the NGSS, they become better equipped with the Iowa Core's 21st century skills, which will lead them to success in their lives after graduation.

Phenomena

Phenomena are events that occur in the universe that can be explained using science knowledge to explain or predict (Lead States, 2016e). Quality phenomena is meant to drive instruction. The most effective phenomena are culturally or personally relevant to students. Phenomena are used in the NGSS to encourage students to use science and engineering to make sense of the world around them. The intent is for students to develop an understanding of phenomena through their engagement with the three-dimensional learning of the NGSS (DCIs, CCCs, and SEPs). When a classroom is centered around phenomena, teachers are better able monitor students proficiency in engaging in the three dimensions. Phenomena do not need to be flashy or unexpected and they need to be simple enough that students are able to inquire about them without needing large amount of prior knowledge on a concept. In addition, the focus is not only on the phenomena itself, but on the questions that students generate because of the phenomena. It is important to remember that not all questions need to be answered. Some students will likely ask questions that are not grade appropriate or are not answered through the intended DCI. In this case, teachers should help guide students into re-shaping their questions (Lead States, 2016e). The DCIs, CCCs, SEPs, and phenomena play a vital role in the planning that must go into the development of an NGSS unit. By having students actively engaged in an instructional unit aligned with the NGSS, they will:

- Develop an in-depth understanding of content
- Communicate
- Collaborate

- Inquire
- Problem-solve
- Learn flexibility (Lead States, 2016e)

These skills parallel with the Iowa Core 21st century skills and will benefit them throughout their educational and professional lives.

Learning Cycles

The NGSS identifies patterns as a cross cutting concept (CCC) that all students should be able to identify and utilize in every science discipline after taking science courses at the high school level. According to research done by Piaget, in order for students to make sense of a concept they are learning in any subject, they need to be able to be actively engaged in reasoning (Piaget, 1964). This happens in two ways; concretely and formally. Concrete reasoning occurs when students are able to think back on direct experiences, concrete examples, and familiar actions. When reasoning occurs abstractly or without referring back to experiences, this is considered formal reasoning (Karplus, 1977). Science concepts require formal reasoning due to the frequency of abstractness. Students learn and apply science concepts when they have had a relatable experience, but limitations arise when concepts are beyond their life experiences.

It is up to the teachers to identify the reasoning abilities of each student. Since it is unlikely that all students will be formal reasoners, teachers must help develop new reasoning patterns. In order to help develop new reasoning, students must use their present reasoning patterns to meet a demand and then see the shortcoming of using this technique. When students see their reasoning skills are inadequate, they hopefully develop a different technique. Teachers implement a learning cycle to guide students into this new way of thinking.

The learning cycle was originally developed from the work of Jean Piaget by Robert Karplus and J. Myron Atkin in 1962 (Karplus, 1977). Learning cycles are built on the foundation of inquiry. The inquiry process builds upon students' curiosities and questions by experiencing a phenomenon. Students develop models, find patterns, and learn concepts by experiencing learning through inquiry. A learning cycle applies the teaching approach of inquiry and organizes it into a series of phases. There are several variations to "E" learning cycles (3E, 4E, 5E, etc), but each consists of three main phases; exploration, concept development, and concept application (Duran & Duran, 2004). This unit development will utilize a 5E Learning Cycle because it is the most commonly used (Bybee et al., 2006).

Engage: The first phase of a 5E Learning Cycle consists of piquing student interest. With the implementation of the NGSS, this could be in the presentation of a phenomenon. This phase is important because it allows teachers to tap into student's prior knowledge on a subject. It also allows students to ponder their thoughts and ideas on a topic as well as share their ideas with classmates (Duran & Duran, 2004).

Explore: In the exploration phase, students work through an activity in an attempt to gather information that will help them answer questions they had from the engagement phase. The activity in this phase may consist of a hands-on lab or it could be a short reading. In either case, teachers ask guiding questions which help students to develop a set of testable questions (Duran & Duran, 2004).

Explain: The explanation phase is what I coin the "meat and potatoes" of the concept development. Here, formal language, scientific terms, and conceptual ideas are discussed. The goal of this phase is for students to connect their prior knowledge with new concepts to develop a conceptual understanding of a topic. Teachers should ask their students to explain concepts to one another in their own words. When ideas are shared out loud and debated in small groups, it creates an environment for ideas to be refined and revised (Duran & Duran, 2004).

Elaborate: Elaboration, which is oftentimes referred to as the application phase, takes the concept development a step further by asking students to apply new knowledge to a new situation. This phase allows students to "chunk" information so that it may be stored and accessed again at a later time. Through elaboration (application) students make connections between new and former experiences and through that process, their conceptual understanding and processes are further developed (Duran & Duran, 2004).

Evaluate: The final stage of the 5E learning cycle is the evaluation phase. A final evaluation is given at the end of the learning cycle and is an assessment of student learning (Iowa Department of Education, 2006c, para.1). It should be noted that this is not the only time students should be assessed. Assessment should take place throughout the entire learning cycle starting with the engagement phase. Small, informal forms of assessment that provide feedback to students and help them to monitor their learning throughout a learning cycle are known as formative assessments can and should be combined with a more generalized summative assessment at the end of the development (Iowa Department of Education, 2006c, para 1). Teachers commonly evaluate students through a test, project, or lab practicum, but it is also important for students to share their learning with each other. When students do this, not only to they improve on their communication skills, but it allows them to assess their own progress (Duran & Duran, 2004).

Learning Cycles are useful for lessons that take one period or can be used over the course of several days to help plan a unit. In the end, the science and engineering practices used in this stage allow students to behave like scientists by making observations, developing questions, gathering information, and analyzing and interpreting data.

Modeling Instruction

Modeling Instruction incorporates modified learning cycles by beginning with a demonstration and class discussion to engage students in the lesson. Students are then asked to gather together in small groups to collaborate in planning and conducting an experiment or investigation in order to answer or clarify the overlying question (exploration phase of the learning cycle). Students apply and evaluate their discoveries by formulating a model for the phenomena in question. They further develop their models by comparing to other peers in the classroom. After the initial state of *Modeling Instruction* is complete, students apply their model to a new situation to help deepen their understanding of a concept(s) (Jackson, Dukerich, Hestenes, 2007).

Data show that teachers who implemented *Modeling Instruction* into their physics classrooms saw students' content knowledge double compared to students who were not taught in modeling classroom. (Jackson, Dukerich, Hestenes, 2007). Not only was an effective research-based method being used, but *Modeling Instruction* aligns well with the Science and Engineering Practices (SEP) found in the NGSS. Specifically, with regard to models and *Modeling*, the Phoenix Union School district developed SEP statements:

- I construct mental and conceptual models to represent and understand phenomena.
- I use models and patterns to predict behaviors of systems, or test a design.

- I refine my models in light of new empirical evidence (Phoenix Union High School District, 2015).

These statements related to models and *Modeling* correlate with the SEPs listed below. *A Science Framework for K-12 Education* lists eights practices of science and engineering (SEPs) that are essential for all students:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (Lead States, 2013d, pg. 1)

In addition to *Modeling Instruction*, teaching through inquiry is another teaching strategy used by many educators to help meet these goals of NGSS. When teachers use the inquiry approach, they are demanding students use these eight practices of science and engineering. This not only helps students learn the material better, but will help students perform better on future state assessments. Each performance expectation taught combines a relevant practice of science or engineering with a Disciplinary Core Idea (DCI) and Crosscutting Concept (CC). Future assessments will be designed to assess students' understanding of science and engineering within the DCIs and CCs. Edwin H. Hall, a professor of Physics at Harvard University, agreed science was important because of the experience with natural phenomena. He also held strong opinions about the theories on how to teach science (Smith & Hall, 1902). He most favored the inquiry approach where students were not asked to discover anything on their own, just seek answers to questions that they did not already know the answers to. He felt this method was a good balance for students. Inquiry kept students "just enough in the dark as to the probable outcome of his/her experiment and just enough in the attitude of discovery to leave his/her prejudiced in observations" (Smith & Hall, 1902, p. 278). Though Hall's work occurred around the early 1900's, his beliefs about the structure of a science classroom are very analogous to how an NGSS classroom is supposed to look with a specific phenomenon at the center. George DeBoer (1991) discussed Hall's ideas about phenomenon in his book *A History of Idea in Science Education: Implications for Practice.* According to DeBoer, Hall felt phenomena should be at the heart of discovery. In a lab or activity, students should be asked to make observations about a phenomenon and then record their inferences (DeBoer, 1991). Hall argued that laboratory focus was an important aspect of inquiry learning because it peaked student interest, helped improve their ability to make observations, and provided detailed amounts of information (Smill & Hall 1902).

One concern Hall had was that teachers did not have a lot of laboratory experience, so they did not feel comfortable implementing discovery learning and phenomena in their classrooms. He did not believe lab work was the only way for students to learn science because learning solely through experience took too much time. Hall believed lectures were still an important part of the classroom and also supported teacher demonstrations (DeBoer, 1991). DeBoer interpreted that Hall strongly believed if students were able to see the application of science in their everyday lives, they would learn it better (DeBoer, 1991).

In addition to addressing the three dimensions in the NGSS as well as the 21st century standards listed in the Iowa Core, teachers should take a variety of strategies into consideration when planning a 5E learning cycle science instructional unit. Most teachers are knowledgeable in their content and try numerous teaching strategies, yet some are more effective than others. A teacher's personal qualities play a contributing factor to their success in the classroom. The most successful teachers have accurate perceptions about students and their behavior (Bybee, 2014). In order for teachers to obtain accurate perceptions about the students in their classrooms, they must find ways to monitor their learning.

Formative Assessments

Assessments are given in schools to serve a variety of purposes. Formative assessments are one type of assessment used by teachers to check *for* learning. In order for an assessment to be considered formative, data must be collected on student responses and instruction must be changed or altered to meet the needs to the students taking the assessments (Keeley, 2010). Formative assessments are used before the instructional process as a way for teachers to ascertain students' preconceptions and throughout instruction to monitor learning. To prevent students from passing a test and reverting back to their former misconceptions, formative assessments are used to give teachers an idea of what their students think and know prior to and throughout the instructional process (Keeley, 2010). These assessments allow teachers to make adjustments to their lessons based off the learning progress of the students. It is also important that students are actively involved in the assessment process so they learn throughout the assessments while also providing feedback to teachers (Keeley, 2008). If students realize they are struggling to understand a particular topic, it is more likely they will pay more attention to the topic (Pintrich, 2002). Within the development of a 5E learning cycle, there are a variety of formative assessments teachers can give students to help the students examine their prior conceptions. If student preconceptions are revealed to be incorrect through a formative assessment, a door is opened which allows students to construct new ideas (Keeley, 2008). Formative assessments, which are integrated in the Science Assessment Instruction and Learning Cycle (SAIL Cycle) supports the 5E learning cycle by providing teachers with suggestions on the type of formative assessments called Formative Assessment Classroom Techniques (FACTs) they should give students based on where teachers are in the learning cycle (Keeley, 2008). For example, if teachers are beginning a unit and are in the engagement phase of a learning cycle, an appropriate FACT would provide an opportunity to find out students' interest on a topic. In the elaboration phase, a FACT may be given that asks students to link newly developed ideas to an old concept.

Formative assessments help in four ways. First they create something that motivates students to learn through the success and failures students experience in their formative assessments. Second they show students the most important concepts to learn by providing instant feedback. Thirdly, students are given strategies on how to learn. They see that learning does not occur passively because they are given immediate feedback and asked to adjust their past ways of thinking. In the end, the more active they are in their learning, the more successful they will be. Lastly, students learn how to judge their learning based on the feedback they receive on the formative assessment (Bell, 2001). Preconceptions and misconceptions are used to guide instruction. For a teacher, this may mean using a *Modeling* activity to help students experience science and develop understanding of a concept in a way that replaces an old idea.

Page Keeley formative assessment probes. Page Keeley probes are one type of formative assessment used in science classrooms. These probes were developed and specifically aligned to the NGSS and are a way for teachers to discover the preconceived ideas students have about various topics when they enter the classroom (Eberle & Keeley, 2008). When students are asked to complete a Page Keeley probe they are asked to:

1. Select an answer choice. The possible answers given are developed through research about commonly held ideas students have over concepts or phenomena.
2. Complete an explanation that supports their answer choice (Keeley, 2015).

The explanations students leave often provide the most insight for a teacher by showing the level at which they understand and use scientific concepts (Keeley, 2015). The probes help identify student misconceptions and what students are thinking. These probes can be given prior to instruction and used to guide a unit or they can be given after some level of instruction has taken place as a way to monitor student progress (Keeley, 2015).

Homework quizzes as a formative assessment. One frustration many teachers have regarding assigning homework is the fact there is no way to ensure each student completes the homework by his or herself. Teachers assign homework to provide students with a practice opportunity to better learn a concept or skill. If students don't complete their homework or copy their homework from a classmate, they are not getting the necessary practice they may need to solidify concepts or learn a skill. Gender and time requirements influence students' likelihood to come to class with homework complete. Seventy-eight percent of rural high school students believe their homework takes them a reasonable amount of time (Reddick & Peach, 1993), and the more time students spend on homework, the more useful they feel it is (Deveci & Onder, 2015). In terms of gender, middle school females are more careful and take homework more seriously than male students (Deveci & Onder, 2015). It is up to teachers to help students see that the homework they assign is meaningful and purposeful. When students realize homework can help them academically and intellectually, they will be more likely to complete it (Wilson & Rhodes, 2010).

One way to encourage students to stay on top of their homework is through frequent homework quizzes. Since there is no way for teachers to know whether or not students are completing homework on their own, a formative assessment in the form of a homework quiz can be given. Formative assessment is defined as an assessment strategy used throughout the course of an instructional period for the purpose of improving teaching and learning (Reeves, 2005). Homework quizzes are short and are given the day after homework has been assigned. The quiz questions are based off of concepts found in the homework. Homework quizzes help students monitor their understanding of a concept, but they also assist teachers in gauging student learning by serving as a formative assessment. Though formative assessments are not typically graded, points can be assigned to create a motivator for students.

Research shows that students who are given regular quizzes related to class content are more likely to review their notes prior to class and are more likely to be engaged throughout a course. Quizzes also encourage participation and reinforces the importance of staying ahead of classwork (Haigh, 2007). One of the reasons the quiz process works is due to the fact that it facilitates student engagement with content, motivates students due to the impact on course grades, and encourages discussion between learners and teachers (Haigh, 2007).

Again, the quizzes are considered to be formative assessments, so the goal is to use the quizzes to lead instruction in one way or another. Unfortunately, quizzes can be a source of anxiety for certain students. If quizzes reduce student grades, they may not be considered a useful strategy. The best quiz strategy should encourage student learning, foster class participation, and reward the students attempting to stay ahead of their classwork (Haigh, 2007). Khanna (2015) found that students given ungraded pop quizzes outperformed students who were given graded quizzes and students not given quizzes. Though students in the graded pop quiz group were actively retrieving information, which should have helped them on their final exam performance, post class surveys indicated the graded quizzes made them anxious, which had a negative effect on their performance (Khanna, 2015). Grades are not the only factor that makes students anxious. Time limits on quizzes also foster anxiety in students. Based on this, teachers may want to consider designing a course in which quiz scores are not counted toward the final course grade (Anthis & Adam, 2012).

One way to allow students to receive grades on their quizzes yet experience less anxiety is to change the grading format. In a study done by Hadsell (2009), students in a finance course were given optional weekly quizzes. If the students completed the quizzes and had a higher average quiz score than their exam score, quizzes counted as 10% of their grade. If they did not score better on quizzes than their exam, quizzes were not counted. Results showed that students who chose to consistently complete the quizzes saw an increase in exam scores. Additionally, quizzes appeared to encourage students to stay up to date on their studies and fostered self-discipline.

In summary, due to the large number of students who take chemistry and the need to develop science, technology, engineering, and math (STEM) courses to prepare students for jobs related to this area, a unit development was needed. This unit will use *Modeling Instruction* and 5E learning cycles to address Iowa Core and NGSS standards. Formative assessments such as homework, quizzes, and Paige Keeley probes will be used throughout the unit in order to help the teacher and students monitor student progress. Other than Paige Keeley probes, research was done in the topic of energy and matter that addresses the misconceptions students will likely have in relation to energy and matter.

Student Misconceptions in Energy and Matter

By the time students are in high school, they should be able to make the connection that atoms and molecules are linked to the conservation of energy. Students generally have an easier time keeping track of where energy comes from and goes when dealing with physical systems such at fire heating water, but struggle with understanding and representing energy storage and flow for molecular configurations (Kind, 2004).

It is common for students to think of energy as a substance that behaves like matter - a substance that flows and in conserved. This is technically, not a correct view, but can be an acceptable analogy to helps students try and understand energy better. Many scientific explanations include reference to energy, making it an important concept for students to learn (Driver, Squires, Rushworth, Wood-Robinson, 1994).

When students begin to talk about energy, it is likely they will use the term “energy” without being able to define it. Generally, this is discouraged, but is an acceptable practice because it begins to get students thinking about energy flow. There are three energy-related ideas that are more important for students to understand than knowing how to define it. The first is energy transformation. Students should learn that in order for a physical event to occur, a transfer of energy from one form to another is necessary. The second idea is the conservation of energy. It’s imperative that students understand that a reduction of energy in one place results in a gain of energy by the exact same amount somewhere else. The final energy related idea important to students is that whenever an energy transfer occurs, some of the energy is released in the form of heat and spread around us, making it unavailable to us to use (Summers, 1983).

Heat energy is difficult for students because it is used interchangeably with the term "temperature". Dissipated heat energy from a hotter object to a cooler object results in a reduction in temperature for the warmer object, which leads students to incorrectly infer that energy is reduced. In the end, requiring students to memorize definitions for heat, temperature, system, and transformation will not likely able them to show understanding. Qualitative approximations are more important for understanding energy and its transformations and conservations and should have a higher priority over memorizing terms (Slisko, Dykstra, 1997).

In summary, these misconceptions will be addressed throughout this unit following a 5E learning cycle. The different stages of the learning cycle will be intertwined with resources from *Modeling Instruction* as well as formative assessments. The formative assessments being used will primarily be Page Keeley probes as well as homework quizzes. The strategies are being implemented in order to follow the 3 dimensional learning (CCs, SEPs, and DCIs) outlined in the NGSS.

Chapter 3

Project Description

As previously mentioned, the goal of this project is to develop a student-centered instructional unit over energy, matter, and change for a high school chemistry class. The unit will be adapted from two *Modeling Instruction* units, Unit 2, Energy Particles in Motion and Unit 3, Energy and States of Matter. The unit will address Disciplinary Core Ideas (DCIs), HS-PS3 Energy, found in the newly developed Next Generation Science Standards (NGSS). Performance Expectations (PEs) that will be specifically addressed include:

- **HS-PS3-1**: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- **HS-PS3-2:** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
- **HS-PS3-4:** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

The unit will follow a 5E learning cycle format and will utilize formative assessments such as Paige Keeley probes and homework quizzes to monitor student learning throughout the unit. In addition, these formative assessments will help guide decisions regarding content during the unit. Students often have a difficult time with the concept of energy no matter what grade level they are in (American Association for the Advancement of Science, 1994). This instructional unit will divide the major concepts of energy being covered into four cohesive sections in an attempt to make it less intimidating for the instructor and the students. A 5E learning cycle will be used in each section in order to connect major ideas. *Modeling Instruction*, Page Keeley probes, Colorado PhET simulations, labs, and quizzes will be incorporated into unit instruction. This unit is estimated to take approximately 15, one-hour class periods, with each section taking 4-5 days. Because energy terms are commonly used and referred to in the study of chemistry, this unit will take place at the beginning of a chemistry course. In the chemistry course that I teach, this unit will be taught after unit 1, which is where we discuss proper data collection, analysis, and calculation techniques used throughout the course.

In *Section 1,* students will deepen their understanding of particle behavior. They will be asked to readdress the behavior of particles in the three states of matter and apply their understanding specifically to gases in order to develop an explanation and application of gas laws. Students will begin to explore the effects of an increase of energy on particle behavior. Students begin this section by completing an activity that uses Colorado PhET (Physics Education Technology) simulations (Perkins, et al., 2006). With over 16 different simulations designed for chemistry alone, students use animated simulations to learn through exploration (Wieman, Adams, Perkins, 2008). These simulations focus on students engaging in virtual investigations and making connections to real-life phenomena as well as the underlying science behind why these phenomena occur (Perkins, et al., 2006). In addition to PhET simulations, students will also do an inquiry lab (KMT Stations), which is set up as four different stations. Setting the lab up in stations requires fewer materials because the students rotate around to each “lab set up” rather than having to have enough materials for the lab in each group. A gallery walk is a way to present PowerPoint presentations to a large number of students quickly.

Students prepare a presentation with a partner and then must become experts in the topic they are presenting on. Each person has an opportunity to present to a small number of students, which helps to develop communication skills as addressed in the Iowa Core 21st Century Skills.

Section 2 addresses common misconceptions associated with energy, heat and temperature. A demonstration was used to engage students in the topics. A demo was picked due to the length of time it would take. The unit takes up a large chunk of time, so the engagement piece was not meant to be extensive. Students are asked to explore concepts related to heat and temperature in an inquiry based investigation. The goal is to get students to address their own misconceptions about temperature and heat. Students will develop explanations of energy, temperature, and heat by watching a video that addressed concepts explored in the exploration learning cycle phase. They begin to identify systems and system interactions in a worksheet over temperature and heat. Finally, in order to require students to use crosscutting concepts and the concept of conservation of energy, students will conduct a scientific experiment which will allow them to be able to predict outcomes of systems when objects of varying temperatures are combined.

Section 3 focuses on representing energy and systems using the law of conservation of energy and energy bar graphs. Energy bar graphs will help solidify the law of conservation of energy by quantitatively showing energy lost by one object is gained by another. The bar graphs, which require students to model their understanding, were adapted from *Modeling Instruction.*

In the final section, *Section 4*, students will learn about the variables that affect energy changes in a system. Students are engaged in thinking about these variables with another short demonstration. Types of substances, amount of substance, and initial and final temperatures will be explored in order to see how these variables will affect energy transfer using an online virtual lab, which will save on time and materials. The specific heat equation will be used to quantitatively represent energy transfer in an out of systems. A PowerPoint presentation was developed to clear up any misconceptions formed through participation in the virtual lab and also provides students with a time to ask questions related to specific heat problems. In the elaboration phase, students have the opportunity to bring in their own drink of choice to test the specific heat of that drink. This allows students to apply what they are learning in class to something real and relevant in their lives.

A variety of instruction resources and strategies were used in each component of the learning cycle. In the *engagement phase*, investigations were the main strategy chosen to introduce topics. This strategy was chosen in order to pique student interest. Since students are investigating on their own without a lot of outside guidance, it allows them to reflect and ponder their preconceived ideas, which is an important part aspect of the engagement phase (Duran & Duran, 2004).

In the *exploration phase*, students begin to gather information, which will help them answer questions they developed about a concept in the engagement phase. This is also where students begin to form models that help them explain phenomena. PhET simulations, investigations, and virtual labs were placed in this phase of the learning cycle because they are guided inquiry resources, which allow students to develop ideas on their own with the guidance of the instructor. The Page Keeley probes were implemented so teachers would be able to monitor the initial models and ideas that students begin to develop in this phase. Homework quizzes are given in addition to the Page Keeley probes as formative assessments. These quizzes allow the teacher and students to monitor learning. If misconceptions are developed, they are identified and addressed throughout the unit rather than at the end.

The *explanation/elaboration* phase is where concepts and ideas from the exploration phase are solidified. Consequently, this is the longest phase of the learning cycle. Since formal language in introduced throughout this phase, students explicitly learn and discuss this information in the form of videos, readings, handouts, and discussions. These strategies allow students to refine and revise their ideas. Students are asked to research certain concepts on their own through a PowerPoint presentation and share their findings with their peers via a PowerPoint gallery walk (discussed more in the teacher notes). Worksheets are given to students to help them further develop new skills and homework quizzes are given as a formative assessment so the instructor is able to gauge level of understanding.

The assessments given throughout the unit and in the *evaluation phase* of the learning cycle were chosen to assess a specific set of NGSS performance expectations. Drawings/explanations were chosen as the form of assessment in order to connect the initial phenomenon with concepts and skills learned throughout the learning cycle. Investigations and graphical models were also chosen because they help to meet the science and engineering practices (SEPs) of the NGSS. The style of assessments, specifically the lab assessments/investigations, elicits student conversation and helps to develop better communication skills.

There are two summative assessments given throughout this unit. One at the end of Section 2 (Mixing Water Investigation) and one at the end of the unit (Can Crusher Investigation). Each assessment will be in the form of a lab assessment and a rubric will be used for each in order to evaluate students understanding. These assessments were chosen in order to meet the Performance Expectations established by the NGSS. The performance expectations in this unit ask students to plan and conduct investigations and build models, which is what these assessments do. A detailed explanation of the NGSS performance expectations being addressed in this unit can be found in Appendix A. After the Performance Expectations were identified, the unit was designed around a storyline (Appendix B). A storyline is used to connect phenomena to each section of the unit. The storyline was developed after extensive time was spent in a professional development program offered by the University of Northern Iowa known as Integrating Crosscutting Concepts in Iowa Science Curriculum (ICCISC). In this program, several science professionals developed units using the storyline approach. When a unit is designed around a storyline, a sequence of investigations is used to help students figure out parts of the story that will allow them to understand the phenomena better. The series of investigations contained in a unit helps students put the "story" together (Reiser, 2014). The storyline format used was adapted from a unit developed over Waves by other science educators involved with the program. Below is an outline of the Energy, Matter, and Change Unit that was designed using a storyline for this project.

Unit Outline (Full set of materials can be found in Appendix C)

Section 1 (How do gas particles in the tank behave?)

1. Exploration:
   1.1. *States of Matter University of Colorado PhET Interactive Simulation:*
2. Explanation:
   2.1. *Diffusion of liquid and gas:*
   2.2. Kinetic Molecular Theory (KMT) Stations
   2.3. KMT Station Summary
   2.4. Quiz - KMT
   2.5. (Optional) Student Powerpoint and gallery walk
3. Elaboration:
   3.1. Real-Life Examples
4. Evaluate
   4.1. Drawing/Explanation of phenomenon (Tank Implosion)

Section 2 - What effect do changes in temperature and energy have on the particles in the tank?

1. Engage: Dye in Water
2. Exploration:
    2.1. Page Keeley: “Ice-Cold Lemonade” Volume 2
    2.2. Investigation H2: Telling Hot
3. Explanation:
    3.1. Eureka video: “Heat vs Temperature”
    3.2. (Optional) Notes
    3.3. Worksheet Heat vs Temperature (adapted from Modeling Curriculum)
    3.4. Quiz - Heat vs Temperature
    3.5. Energy and systems reading/notes
    3.6. Page Keeley: “Mixing Water” Volume 2
4. Elaboration/Evaluation:
    4.1. Mixing Water Investigation (PS3-4)
    4.2. (Optional) “Ice-Cold Lemonade” and “Mixing Water”
    4.3. (Optional) Photo/drawing from phenomenon

Section 3 - How does the environment of a system affect the system’s behavior?

1. Engage: A Cup of Hot Coffee
2. Explore: Losing Heat
3. Explanation:
    3.1. Energy Reading:
    3.2. Energy bar chart video
    3.3. Energy Stations and student handout
    3.4. Energy diagram assignment
    3.5. Energy diagram quiz
4. Elaboration/Evaluation:
    4.1. Computational Model:
5. Evaluation: Energy Model - Tanker Implosion

Section 4 - What effect does mass, heat, temperature, and material have on the behavior of items in a system?

1. Engage:
    1.1. Ice Cube Confusion:
2. Exploration:
    2.1. Q, m, T Diagram
    2.2. Online virtual lab
3. Explanation:
    3.1. Discussion/Notes Specific Heat
    3.2. Specific Heat mini poster
    3.3. Quiz: Specific heat

3.4. $Q=cm\Delta T$ notes
3.5. $Q=cm\Delta T$ assignment (qualitative and quantitative)
3.6. Quiz: $Q=cm\Delta T$

4. Elaboration: Specific heat capacity of water vs popular drink

Summative Assessment

- Can Crusher Investigation (PS3-1, PS3-2)

A detailed explanation of each level of the 5E learning cycles above can be found in the Instructional Notes, Appendix C. The instructional notes contain hyperlinks to each handout, activity, formative assessment, quiz, summative assessment, and homework, which makes it easier to navigate.

Chapter 4

Reflection

This project has made the biggest impact on my ability to implement the NGSS into my classroom. I had done a lot of work with NGSS prior to completing this project by participating in a variety of professional development programs. The UNI Integrating Crosscutting Concepts in Iowa Science Classrooms (ICCISC) was a professional development program that I spent the most time with and put in the most effort (Del Carlo & Escalada, 2017). In this program (which took place over the course of three years), in collaboration with other teachers I learned a lot of strategies for implementing the NGSS, but it was not until I took the time to develop an entire NGSS aligned Chemistry unit on my own, that I felt I had a good grasp on the standards. I spent a lot of time researching and identifying the SEPs, CCCs, and DCIs so I would have evidence for why I chose to use certain activities or assessments, which is exactly what I ask my students to do; develop evidence-based arguments.

The students in chemistry will certainly benefit from being a part of an NGSS aligned unit, but the benefit does not end with one course. Now that I have taken the steps necessary to build an NGSS aligned unit, I have become better at reading an understanding the NGSS. I have also begun to be more creative in my assessment strategies; such as having students do a lab or project to show their understanding of the standards. These skills will allow me to create more NGSS aligned units, which will benefit all of the courses I teach. These units will also help the professional science education community at my school because I will be able to help guide other teachers in creating NGSS units for their classrooms. Together, we will be able to fully implement NGSS by 2020.

The science education community of fellow science teachers throughout the state of Iowa I have had the opportunity to work with throughout my journey as a UNI MA Science Education student will also benefit from this unit development. Together, we have developed units, lessons, activities and assessment strategies that meet the NGSS. We have also learned how valuable sharing resources can be. This professional community will benefit from this project by gaining another NGSS aligned resource that can be used in the Chemistry classroom.

The idea for this unit development came about after I reflected upon how I taught energy and matter concepts in the past. Upon review of assessment (both formative and summative) scores from the 2016/2017 school year, I knew I needed to make a change to the way I was teaching these topics. When the first summative assessment was implemented after incorporating more energy concepts to the curriculum, 8 out of 19 students scored at a 70% or less. I had already implemented homework quizzes into my classroom. This idea came about after speaking with a colleague about frustrations I felt regarding the amount of time and effort students were putting into the homework they were given. I was giving homework and thought students would be intrinsically motivated enough to complete it with the objective of gaining a deeper understanding of topics. I felt as though students were copying each other’s homework and because of this, I was unable to tell whether or not each student actually understood the concepts in the homework. A colleague suggested I give quizzes over the homework so I would be able to see how well students understood the content. After implementing the quizzes, I felt students began to take more ownership in their homework. The results of the quiz scores have required me to make adjustments to my lesson plans during the unit rather than at the end. If students do well on a quiz, then we don’t need to spend more time on the concept. If the scores are low, then more time needs to be spent on said concept. I knew I wanted to improve the Energy, Matter, and

Change unit I was teaching in Chemistry, I thought this was a good opportunity to see what the research said about quizzes as well as alternative assessments such as Page Keeley probes, which I had also used before. The insights I gained from my past experiences as an educator propelled my desire to develop a unit around those experiences.

I have already started to gain new insights because I recently began to implement this unit into my own classroom and have already made notes for changes and adjustments. After asking students to engage in activities and assignments, I have had to add more clarification to questions based on how the students respond to the line of questioning. I have also made adjustments to the time frame for the learning cycles. Certain parts of the learning cycles have taken longer than expected while others have taken less time than expected. Through my undergraduate experience at Morningside College in Sioux City Iowa, I learned the value of striving to be a lifelong learner. This is what encouraged me to seek out my Master of Arts in Science Education through the University of Northern Iowa (UNI). Throughout my time at Morningside and UNI, I have learned to be more reflective. Part of being that reflectiveness in education is striving to always improve lessons, activities, assessments, etc. based on past performance of students. One of the adjustments I have had to make thorough implementation is to the timeline. Since I have never use some of the activities and labs prior to starting the unit, I was unaware of how much (or little) time each task would take. This is something that will vary greatly among teachers implementing the unit since school schedules differ. However, every teacher has a limited number of days in a semester or trimester, which means certain parts of the 5E learning cycle will need to be tweaked in order to cover all of the standards required by the NGSS.

Including this Chemistry unit into a full year's worth of NGSS aligned chemistry units could further develop this project. The *Modeling* curriculum has been discussed at length in this paper and has provided physics teachers with a year's worth of materials. Unfortunately, the *Modeling* curriculum does not completely align with the NGSS, so developing a chemistry curriculum that could be shared and networked with the science education community in the state of Iowa would be helpful for those teachers looking for ways to implement NGSS by 2020.

Developing a year's worth of NGSS Chemistry aligned units will take an extensive amount of research and a significant amount of time. When I started this project, I had no idea how much time and research it would take to develop a unit that met NGSS requirements. I have heard many science educators ask why there aren't NGSS unit available to use in the classroom, and the reality is, these units aren't developed overnight. Throughout this project, I have learned how much of a time commitment these units are in order to develop a quality product.

Though this project has taken a substantial amount of time, I have had the opportunity to network with several people from the scientific community, which has helped me grow professionally. I have been able to network and take courses with a number of professors at the University of Northern Iowa (UNI). Many of these professors provided me with resources I use in my classroom as well as a contact to connect students and peers with others who are interested in science, education, or UNI. For example, one of the courses I took through UNI introduced me to software that allows examples of compounds in the particle model form to be built. In addition, I connected with professors and science education peers through a workshop I attended at Upper Iowa University. The workshop utilized Environmental Issues Instruction and focused on food, farming, and climate change. Some of the educational strategies I learned in this workshop were incorporated into the Matter, Energy, and Change unit, while other strategies will be used in other NGSS units I develop. Through all of these experiences, I have worked in teams with others, which has improved my communication skills within my professional community.

My professional growth does not stop with the completion of this project. My value to lifelong learning goes beyond growing educationally. The communication, networking, and educational skills I have gained throughout this project have given me the confidence I need to grow professionally in the future. Moving forward, one of the main goals I have is to apply to be a part of the state of Iowa's Teacher Leadership and Compensation System (TLC). TLC is a state funded system that rewards highly effective teachers with leadership opportunities and an increase in pay. Students' learning improves when teacher instruction improves. Teachers in the leadership roles funded by TLC take on the extra responsibility of helping colleagues analyze data and improve instructional strategies. Since I have done both of these tasks through the development of this project, I am excited to strive to take on a new role to help improve instruction and learning in my district. Finally, I hope to have the opportunity to open my classroom to pre-service teachers so I can share the resources and knowledge I have gained about NGSS, *Modeling Instruction* s, formative assessments, and learning cycles.

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Appendix A
Instructional Goals

Next Generation Science Standard Performance Expectations:
HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Section 1 Instructional Goals
Topic: Particle Behavior
Learning Objectives (As outlined by the evidence statements in the NGSS):

1. Students develop models in which they identify and describe the relevant components, including clearly depicting both a macroscopic and a molecular/atomic-level representation of the system;
2. Depicting the forms in which energy is manifested at two different scales: Molecular/atomic, such as motions (kinetic energy) of particles (e.g., nuclei and electrons), the relative positions of particles in fields (potential energy), and energy in fields.
3. Students describe the relationships between components in their models, including:
    a. Changes in the relative position of objects in gravitational, magnetic or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy).
    b. Thermal energy includes both the kinetic and potential energy of particle vibrations in solids or molecules and the kinetic energy of freely moving particles (e.g., inert gas atoms, molecules) in liquids and gases.
    c. The total energy of the system and surroundings is conserved at a macroscopic and molecular/atomic level.
    d. As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields
4. Students use their models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects on both the macroscopic and microscopic scales.

Section 2 Instructional Goals
Topic: Energy - What Is It? Heat vs Temperature

Learning Objectives

1. Representation: Students identify and describe the components to be computationally modeled, including:
    a. The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero);
    b. The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and
2. Students describe the purpose of the investigation, which includes the following idea, that the transfer of heat energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
3. Students develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including:
    a. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object to show that the heat energy lost by the hot object is equal to the thermal energy gained by the cold object and that the distribution of thermal energy is more uniform after the interaction of the hot and cold components; and
4. In the investigation plan, students describe:
    a. How a nearly closed system will be constructed, including the boundaries and initial conditions of the system
    b. The data that will be collected, including masses of components and initial and final temperatures; and
    c. The experimental procedure, including how the data will be collected, the number of trials, the experimental setup, and equipment required.

5. Students collect and record data that can be used to calculate the change in thermal energy of each of the two components of the system.

6. Students evaluate their investigation, including;
    a. The accuracy and precision of the data collected, as well as the limitations of the investigation; and
    b. The ability of the data to provide the evidence required.

7. If necessary, students refine the plan to produce more accurate, precise, and useful data that address the experimental question.
8. Students identify possible causes of the apparent loss of energy from a closed system

(which should be zero in an ideal system) and adjust the design of the experiment accordingly.

Section 3 Instructional Goals

Topic: Representing Energy "Modeling Energy Transfer and Conservation of Energy"

Learning Objectives:

1. Students use the algebraic descriptions of the initial and final energy state of the system, along with the energy flows to create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy.
2. Students use the computational model to calculate changes in the energy of one component of the system when changes in the energy of the other components and the energy flows are known.
3. Students use the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows.
4. Students develop models in which they identify and describe* the relevant components, including:
    a. All the components of the system and the surroundings, as well as energy flows between the system and the surroundings;
5. Students use their models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects on both the macroscopic and microscopic scales.
    a. ****This is a huge connecting learning objective to Section 1.

Section 4 Instructional Goals

Topic: Variables Affecting Energy Changes

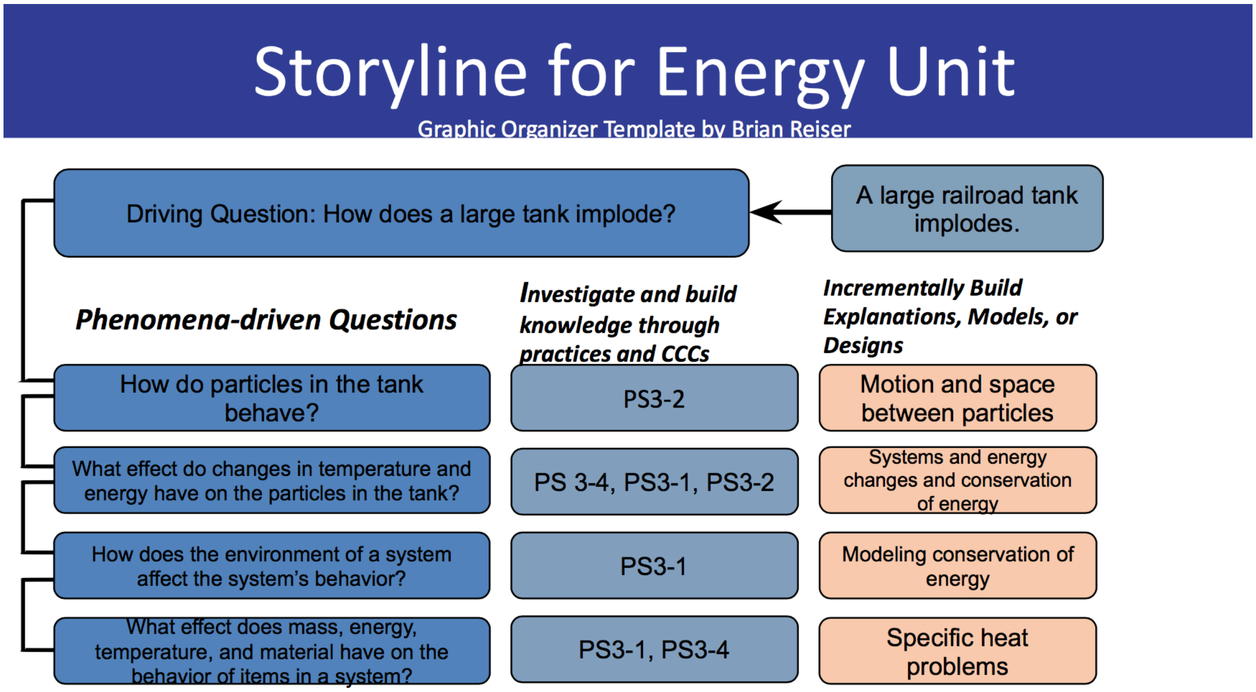
Learning Objectives:

1. Representation: Students identify and describe* the components to be computationally modeled, including
    a. The initial energies of the system's components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of in units of Joules for each component), including a quantification in an algebraic description to calculate the total initial energy of the system;
    b. The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system
    c. Students identify and describe* the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system.

2. Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including:
    a. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object to show that the energy lost by the hot object is equal to the thermal energy gained by the cold object and that the distribution of thermal energy is more uniform after the interaction of the hot and cold components; and
    b. The specific heat capacity of the components in the system (obtained from scientific literature).
3. In the investigation plan, students describe*:
    a. How a nearly closed system will be constructed, including the boundaries and initial conditions of the system
    b. The data that will be collected, including masses of components and initial and final temperatures; and
    c. The experimental procedure, including how the data will be collected, the number of trials, the experimental setup, and equipment required.
4. Students collect and record data that can be used to calculate the change in thermal energy of each of the two components of the system.
5. If necessary, students refine the plan to produce more accurate, precise, and useful data that address the experimental question.
6. Students identify possible causes of the apparent loss of energy from a closed system (which should be zero in an ideal system) and adjust the design of the experiment accordingly.

Appendix B

Storyline for Energy Unit



Appendix C
Instructional Notes

A Google folder containing the complete set of instructional materials listed below is found at: https://drive.google.com/open?id=12Bm4gOOzGlPuHh3N9j9uJoh6Bb0qjinG_6oc7KaEVqk

Instructional Notes (Approximately 15 days)

Overarching Phenomenon: "Tank Implosion" (15 minutes)
https://www.youtube.com/watch?v=Zz95_VvTxZM

- This video will be looped so it replays several times. Students are given 5 minutes to observe the video and come up with questions they have about the phenomena. They should also draw/explain what they think is happening and why they think it happened.

Section 1

2. Exploration: (45 minutes)
    2.1. *Heat, Energy, and States of Matter University of Colorado PhET Interactive Simulation:*

        In this activity, students will have a chance to review characteristics of the three different states of matter (excluding plasma). They should be able to identify similarities and differences between the three states and begin an explanation of what causes matter to change from one state to the next. A venn diagram should be used as a formative assessment at the end of the activity in order to see how well students have developed these ideas.

3. Explanation: (1 hour)
    3.1. *Diffusion of liquid and gas:*

        Oftentimes, students learn to represent the behavior of particles in different states of matter by drawing circles in small boxes. This can create a misconception that these particle behaviors only take place in small, constricted areas. The diffusion of gas and liquid demos allow students to think about how particles in the gas and liquid state are constantly changing and moving.

        For diffusion of a gas, have the students form a circle around a scented object (candles work well for this). Keep the lid on the candle and have the students stand a good distance away from the scented object. Take the lid off the candle and tell the students to move closer and closer to the candle until they can smell the object. Once they smell it, they should stop moving closer. Once everyone has stopped moving, ask the students to make observations. They should see that their peers are varying distances away from the candle. Ask them why they think this is. They should be able to come up with the fact that the scent behaves like gas particles and moves randomly, which is why each person didn't smell the candle the same distance away. They will likely mention the fact that each person's biological "sniffer" behaves differently as well. Have them go back to their desks and create (draw) a storyboard (about 5-7 slides) the represents how they think the scent traveled from the candle to their noses. Remind them to include the gases in the room as well as the scent and to create a key for each. Tell them to go to https://authoring.concord.org/activities/1067/single_page/1dd7d11e-7b12-4e77-bc69-00e4d19f177f and look at the perfume interactive. They should explore the interactive and write down how their storyboard is similar and different to this interactive. Ask them, "how can you change the rate of diffusion of gases". By exploring the interactive, they should be able to answer this question.

The diffusion of a liquid demo is very similar to the gas diffusion. "*In this demonstration, obtain two large beakers or flasks. Fill one with cool to cold water and the other with very warm water (not boiling). Allow the water to become still on a demo table before beginning the demonstration. Add 1-2 drops of a dark food dye to the water in each flask and observe the diffusion of the dye in the water. Using two different colors, such as red and blue, makes it easier to keep track of which beaker is hot and cold during discussion.*

Students are asked to describe what they saw macroscopically, and then explain their observations in terms of the particle model we have developed so far (small, separate particles in motion that move randomly by collision). The discussion should draw students to explain the observed behavior in terms of the effect that adding energy to the system of particles has on temperature and the speed of the particles.

*This demonstration is followed up with the assignment to prepare two storyboard sequences[1], one each for the hot water and cold water diffusion observations. To contrast the difference in rate, each storyboard sequence should contain the same number of frames at the same time intervals. These can be prepared individually as a homework assignment or, if preferred and class time allows, prepared in groups on whiteboards." (*Unit 2 Teacher Notes V3.5 *Modeling Instruction*)

3.2. Kinetic Molecular Theory (KMT) Stations (30 minutes)

At this point, students should begin to understand the main ideas behind Kinetic Molecular Theory (KMT), even though specific terminology has not yet been used. The KMT stations (from the American Association of Chemistry Teachers) will help to solidify KMT while also introducing proper vocabulary to the students. Remember, it is more important for students to understand and apply KMT rather than simply memorizing it. This activity is divided into three separate stations where students explore the relationship between temperature, pressure, and volume.

3.3. KMT Station Summary (30 minutes)

The KMT Station Summary is attached to the KMT Station Student handout, but should be assigned to students as homework to complete on their own. Here, students are given the rules of Kinetic Molecular theory and asked to apply KMT to the stations they completed in class.

3.4. Quiz - KMT (15 minutes)

This quiz, which was adapted from concepts in the stations, should be given the day following the KMT stations. Students are asked to respond to questions related to pressure, volume, and temperature in order to apply the rules of KMT. The quiz serves as a formative assessment for the teacher as well as the students. The quiz should be graded in class to offer immediate feedback.

3.5. (Optional) Student Powerpoint and gallery walk (45 minutes)

Based on the science requirements in each district, some teachers may want to discuss the Gas Laws with students. Here, students are divided up into groups of two and asked to create a powerpoint or create a model on a whiteboard based on an assigned gas law. A gallery walk is held so each student has an opportunity to learn the gas laws and their relationship to KMT.

In the powerpoint, students are assigned a specific gas law (i.e. Boyle's Law). In the powerpoint, students should include:

Variable changed
Variable affected by the change and how
Variable held constant
Real-life example of the law
How/why the gas law follows KMT

After the students have time to put together their Powerpoint slide(s) on their assigned gas law, the students separate into two groups. One of the partners stays behind to present about his/her gas law and the other student goes around and listens to presentations from gas laws assigned to his/her peers. When the partner listening to the other presentations is finisher, he/she will return to his/her partner and the two will switch positions. The partner who listened to presentations stays behind and presents and the partner who presented travels around the room listening to presentations and taking notes. In the end, each students should learn about each gas law.

5. Elaboration:

5.1. Real-Life Examples (20 minutes to share)

Students are asked to provide real-life examples of physical phenomena in which gas laws/KMT are applied. They should come back to class the following day with examples of gas laws they have experienced.

5.1.1. Example: A student had popcorn for a late night snack. As a kernel of popcorn is heated, the pressure inside the kernel increases even though the volume of the kernel remains constant. When the pressure builds enough, the kernel "explodes" providing a delicious treat! This is an example of Gay Lussac's Law.

6. Evaluate

6.1. Drawing (20 minutes to draw)

Students return to their original drawing from the phenomenon "Tank Implosion" and make adjustments/explanations of what happened based on what they have learned so far. It may be useful to provide and/or discuss main ideas or words covered in this unit to help guide students. Example

Section 2

1. Engage: Focus Question: *What effect do changes in temperature and energy have on the particles in the tank? (20 minutes)*

1.1. Dye in Water (20 mins)

Students will investigate the behavior of food coloring in water. This short activity uses beakers which contain two different temperatures of water. One beaker should contain hot water (almost boiling) and one beaker should have chilled water. Students should be directed to add one drop of food coloring to each beaker and record observations. The food coloring will disperse quickly in the hot water and slowly in the cold water. This will help students begin to see how temperature affects the behavior of particles.

2. Exploration: (1 hour)

2.1. Page Keeley: "Ice-Cold Lemonade" Volume 2

Students will be asked to complete the Page Keely formative assessment probe "Ice-Cold Lemonade". This formative assessment will allow teachers to see any preconceptions students hold about the behavior of heat. Many students will report that the "cold" from the ice cubes will move to the lemonade, causing the lemonade to cool down. Because this is a common response, "Telling Hot" will help to address this issue.

2.2. Investigation H2: Telling Hot

This activity is from the American Association of Physics Teachers. The goal of the "Telling Hot" activity is to show students that touch is not an accurate way of measuring the "hotness" of an object. In the first part of the activity, each student will touch various beakers of water and record on a whiteboard whether or not they think the water it hot or cold. Students should share out their results on a whiteboard, and as a class, students should begin to develop the idea that touch is not a good indicator. Once this idea has been developed, part II of the activity asks students to rank various objects in order from hottest to coldest using touch. After the objects have been ranked, they should take the actual temperature of the objects. Again, the results could be shared out on a whiteboard. Based on the conclusion questions students are asked to answer, a discussion without the whiteboarding session is also an option. After the discussion, students should see that taking the temperature of objects with a thermometer rather than judging the temperature on touch is a more reliable method.

3. Explanation:
   3.1. Eureka video: "Heat vs Temperature" (20 minutes)

   At this point, students should accept that touch is not an accurate way of determining "hotness" or relative temperature or objects, but they will likely not understand the different between heat and temperature. Have them watch this Eureka video and write down key point as they watch it. As a group, come back and discuss key ideas. From the video, students should see that temperature and amount of substance contribute to the amount of heat an object has. They should also understand that even objects that feel cold still have heat.

   3.2. (Optional) Notes (20 minutes)

   At this point, it may be a good idea to review the concept of heat and temperature with your students. Attached, you will find a brief powerpoint presentation that may be helpful in facilitating a discussion.

   3.3. Worksheet Heat vs Temperature (adapted from Modeling Curriculum)

   After the activities for this unit, students should complete this worksheet to apply the concepts of heat and temperature. Whether or not students work in group of individually is up to the discretion of the teacher. A quiz should be given the following day in order to gauge student understanding.

   3.4. Quiz - Heat vs Temperature (15 minutes)

   This short quiz should be given at the beginning of the period. Have the students grade their own quiz so they are aware of gaps in their learning.

   3.5. Page Keeley: "Mixing Water" Volume 2 (10 minutes)

   This formative assessment will allow teachers to see the preconceptions students have about the result of two substances with varying temperatures being combined. The goal is to drive home the idea of system interactions.

4. Elaboration/Evaluation:
   4.1. Mixing Water Lab (HS-PS3-4) (40 minutes)

   This lab is a spin off of the "Mixing Water" formative assessment probe. It also assesses NGSS standard HS-PS3-4. A rubric is provided to the students and the teacher in order to assess student understanding of system interactions. In addition, students are assessed on their ability to plan and carry out an investigation.

   4.2. (Optional) "Ice-Cold Lemonade" and "Mixing Water" (15 minutes)

   You may ask your students to respond to the Page Keely formative assessments again as a way to re-assess their understanding of energy transfer.

   4.3. (Optional) Photo/drawing from phenomenon (25 minutes)

Since we are still trying to connect all of these ideas of energy transfer to the phenomenon shown at the start of the unit, it may be a good idea to re-show the phenomenon here while encouraging students to include images related to heat and temperature and energy transfer.

4.3.1. SAMPLE

Section 3

1. Engage: Focus Question: *How does the environment of a system affect the system's behavior?* (10 minutes)
2. Explore: Losing Heat (20 minutes)
   2.1. Students are presented with a variety of "coffee cups". The "System" is the water.The cups should be made out of different material. Students should predict which coffee cup will keep the water the warmest. The initial temperature of water should be taken and after 5 mins, the temperature of water in each container should be taken again. Students should begin to see that different environments (i.e. materials) cause heat to transfer differently. Suggested materials are beakers, polystyrene cups, aluminum cans, coffee mugs, thermos paper cups, etc.
3. Explanation:
   3.1. Energy Reading (20 minutes):

   Students will be provided a reading about energy and vocabulary associated with energy. Teachers may want to have a discussion after students read the handout to clear up any questions students may have about the terminology being used.

   3.2. Energy bar chart video (15 minutes)

   This is a short video (approximately 6 mins) that discusses how to represent energy flow using energy bar charts. Students should watch the video and take notes over how to complete energy bar charts so they are prepared for the energy station activity. Teachers may want to complete another example to clear up any confusion.

   3.3. Energy Stations and student handout: (45 minutes)

   Students observe a variety of heat transfer scenarios. Students are asked to draw energy diagrams for each station. Stations should include examples students have seen throughout the prior sections. (Ice cold lemonade, Mixing Water, Boiling Water, Freezing Water). After the the students have had a chance to complete each station with an energy diagram, a whiteboarding session should be held in order to discuss the results. This will also allow students to ask questions and clear up any confusion. Example

   3.4. Energy Diagram Assignment

   Since this is the first time students have likely seen or completed energy diagrams, it's a good idea to provide them with an assignment over energy diagrams to allow for more practice.

3.5. Energy diagram quiz (20 minutes)

A quiz is given the day after the assignment and graded in class. This will show teachers what the students understand and what they are still struggling with about energy diagrams.

3.5.1. Sample

4. Elaboration/Evaluation:

4.1. Energy Model - Tanker Implosion

Students are asked to complete a diagram using labels to explain the tank implosion from the phenomenon observed. They are also asked to complete an energy diagram for the situation. Finally, the students are asked to explain why the background story to this phenomenon is likely inaccurate.

Section 4

1. Engage: (20 minutes)

1.1. Ice Cube Confusion Class Demonstration:

3 different sizes of ice cubes will be placed in 3 different beakers. These beakers will be placed on 3 different hot plates, which will be set at different temperatures. Students will be asked to predict which ice cube will melt faster with an explanation as to why they made the decision they made. It is up to the teacher as to whether or not to tell the students what the relative temperatures of each hot place are set at. The goal of this is to get students thinking about the variables that affect energy transfer.

2. Exploration: (15 minutes)

2.1. Q, m, T Diagram

Students will be presented with a Q, m, T diagram and asked to fill in qualitative predictions. (Found in the modeling curriculum). This diagram gets students thinking about the specific heat equation without giving such an algorithmic set of instructions.

2.1.1. Example

2.2. Online virtual lab to introduce specific heat (45 minutes)

Students often understand the Q, m, T diagram very well, but the diagram lacks the discussion of specific heat. This virtual lab introduces the idea of specific heat. Students should begin to understand that energy transfer is also affected by the type of substances involved.

3. Explanation:

3.1. Discussion/Notes Specific Heat Capacity (25 minutes)

After completing the virtual lab, students may still struggle to understand the difference between specific heat and heat. This short powerpoint presentation allows for a discussion to be had as well as a short formative reflection response from the students.

3.2. Specific Heat mini poster

In order to compare the specific heats of different substances, students are asked to create a qualitative mini poster (8 ½ x 11 inches) that shows the difference in meaning between the specific heat of one substance compared to another. An example of a mini poster can be found here. Students can use any example of a heat source they can think of and incorporate creative ideas into a mini poster that shows their understanding. A title as well as images and color should be included.

3.3. Quiz: Specific heat (15 minutes)

This quiz should be given at the beginning of the class period. It asks students to think about the specific heat of substances qualitatively and quantitatively. The quiz should be graded in class so the students have immediate feedback.

3.4. $Q=cm\Delta T$ notes (30 minutes)

At this point, students should be able to think qualitatively and proportionally about variables affecting heat transfer. It is also good to show students how to solve qualitative algebra problems for specific heat. Since they have had a chance to think proportionally about the variables, they should develop a deeper understanding of the equation when it is provided to them. Students should constantly ask themselves "does my answer make sense based on what I learned proportionally about these variables?"

3.5. $Q=cm\Delta T$ assignment (qualitative and quantitative)

This assignment should give students more practice with specific heat problems. The instructur should choose an assignment from the book that requires students to solve quantitative specific heat problems. They should be asked to solve for each variable a least once. A chemistry textbook is a suggested resource for these types of problems.

3.6. Quiz: $Q=cm\Delta T$ (20 minutes)

A quiz over specific heat should be given at the beginning of the period. The quiz is graded in class to provide quick feedback to the students and to the teacher.

4. Elaboration: Specific heat capacity of water vs popular drink (1 hour)

4.1. This is a very informal activity. The instructor may ask the students to bring in a drink of their choosing or provide a variety of drinks. Students are asked to rank the variety of drinks in order of lowest specific heat capacity to highest. Students should be put in group of 3 or 4 and given about 4 different liquids. The students are asked to come up with their own way of testing and gathering data for this activity. It would be a good idea to ask the students to present to the instructor their plan for collecting data. Though there are multiple ways to perform this experiment, the simplest way is for students to use either time or temperature change as their independent variable. Students can pick a desired temperature and place all liquids on the same heat source while timing how long it takes each drink to reach the desired temperature. They can also pick a set time and take the temperature of the liquids after the desired time. This will allow them to rank the specific heat capacity of each drink in order of least to greatest. The students should present their findings on a whiteboard and share it with the class when finished.

Summative Assessment Can Crusher Investigation (PS3-1, PS3-2) (2 days)

Additional Resources

Key Terms List
Gas Law Visual Representation