Exploring the Law of Conservation of Mass through Open Inquiry Experimentation

By Michelle Faggert, 2017 CTI Fellow
Martin Luther King, Jr. Middle School

This curriculum unit is recommended for:
8th Grade Integrated Science

Keywords: law of conservation of mass, scientific method, chemical reactions, open inquiry, guided inquiry, hands-on science

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This unit walks through the three levels of inquiry based scientific experimentation: structured inquiry, guided inquiry, and open inquiry. Focusing on the law of conservation of mass and chemical reactions, an activity is provided for each level of inquiry, as well as the background knowledge required for students and teachers. Beginning with structured inquiry and progressing to open inquiry, this unit allows students of all levels and with all needs to participate in open ended experimentation. Students will be able to improve their critical thinking and problem solving skills as they change their perspective of what it is to "do science."

I plan to teach this unit during the coming year to 140 students in 8th Grade Integrated Science.

Exploring the Law of Conservation of Mass through Open Inquiry Experimentation

Michelle Faggert

Introduction

In this unit, students will be able to demonstrate the law of conservation of mass through open inquiry experimentation. The objective of this exploration with the scientific method is to enhance students' understanding of the scientific process, as well as their problem solving capabilities. Furthermore, students will be able to experience firsthand a concept that is difficult to visualize and conceptualize. The unit will be differentiated to meet the needs of all students in an integrated science classroom, acknowledging that some students are not familiar with the scientific method, some have an emerging understanding of the process, and some are familiar and comfortable with the steps. To accomplish this, students will be walked through the three levels of inquiry based experimentation.

School/Student Demographics

Martin Luther King, Jr. Middle School, located in the Hidden Valley neighborhood of Charlotte, North Carolina, has a population of students that is currently 48% African American, 48% Hispanic, and 4% other ethnicities. We have approximately 1,050 students in grades 6-8. Our diverse population of students includes 17% percent of students that receive ESL services (English as a Second Language) and 8.5% of students that receive EC services (Exceptional Children). In addition, Martin Luther King Jr. Middle School, because of the number of high-poverty families it supports, qualifies as a Title I School under the Elementary and Secondary Education Act (ESEA). School-wide programs are in schools that have at least a 75% poverty level, based on the number of students designated as economically disadvantaged. Finally, Martin Luther King Jr. Middle School is part of the Charlotte Mecklenburg Schools Beacon Initiative, a turnaround program for urban schools. The Beacon Initiative is accompanied by quarterly assessments in each subject to assess and monitor student progress and growth.

I am currently teaching Integrated Science for 8^{th} grade students (ages 13-15) at MLK Middle School. Eighth grade science is a course that concludes with an End of Grade assessment, or an EOG, which is administered by the state of North Carolina. Classes occur in 90 minute blocks and students attend science on an A-Day, B-Day schedule. I have 141 students in 6 blocks, with class sizes ranging from 16 students to 32 students. Integrated science includes students of all levels and abilities, including English Language Learners and Exceptional Children, without distinction between classes. For this reason, students enter with different levels of prior knowledge, they learn at different paces, and they require different styles of teaching and learning. Last year the 8^{th} grade science department achieved 55% proficiency (a score of 3, 4, or 5) on the EOG, indicating that only about half of our students are college or career ready in science.

Rationale

Science, the exploration of the world through observation and experimentation, is a field that has inspired, revolutionized, and molded society since the beginning of time. Despite its expansive and varied application, I have found that some of my scholars do not view science as a relevant or even interesting topic. These students are less likely to become invested in their science education and therefore less likely to master the content. Based on a study by Dabney et al, university interest in STEM careers, a workforce that is inadequately sized, is influenced by middle school interest in science and math (1).

As a teacher of 8th grade science, a state tested subject, I have learned that student scores on the End of Grade assessment (EOG) are emphasized as a measure of student, teacher, and school achievement. In addition, standardized tests are administered several times a year due to Martin Luther King Jr Middle School's role in the Beacon Initiative. For this reason, a student's ability to take a standardized test seems to be valued above all other skills. I have witnessed students internalize this concept throughout their school career, claiming that they are "not smart" or "not good at science" because of a standardized test score. Furthermore, I feel immense pressure as a teacher to reiterate standards and test-taking strategies. I noticed that last year in particular, I was beginning to teach to the standard, rather than teaching science as an art and a way of exploring the world. This realization was confirmed by my students' disengagement and their tendency to ask for a simple solution, rather than attempting to work through a problem themselves. I found that students could easily regurgitate the correct answer, but could not explain the "why" behind the answer or convey the importance of that information.

With this unit, I hope to shift my instruction from teaching "what to think" to "how to think". Each week at the "Doing Science" seminars, we were able to visit a lab in different fields of science. We observed and interacted with biologists, physicists, anthropologists, chemists, and engineers. Although each lab was unique and the scientists were accomplishing a variety of feats, there were common themes that unified them all. In each lab, we observed a balance between research and hands-on science in the form of experimentation. In addition, each scientist that we met fostered a curiosity and love for learning that drove their research. Scientists demonstrated dedication, perseverance, flexibility, and the ability to learn from their mistakes, all qualities that would be highly valuable to my students. In addition, the teachers were able to take on the role of the student. In our first seminar, we were simply given materials and asked to investigate a pendulum with no further instruction. Overall, my experience in the labs and my participation in a summer research program reinvigorated my idea of what it is to "do science".

I chose to focus on the law of conservation of mass because this was one of the most difficult concepts for students to visualize and understand. This objective proved to be hard for some students to grasp, which was reflected in low student mastery of the content. Several times throughout the year, our professional learning community brainstormed alternative ways to teach this standard without much success. We found ourselves revisiting the basics, using methods such as word association, rather than allowing time for application. Allowing students to partake in a hands-on experiment will benefit all students in the classroom, especially kinesthetic and visual learners.

Unit Objectives

The primary objective of this unit is to have students partake in a lab experience that allows them to demonstrate the law of conservation of mass in both open and closed containers (see Appendix 1). They will be able to use a variety of materials and methods to explain how the idea of atoms and a balanced equation support the law of conservation of mass in both situations. By applying their prior knowledge of matter, atoms, and chemical reactions in a hands-on activity, students should be able to solidify their understanding of the concept, resulting in higher student mastery. According to a frequency study, students who participated in hands on activities in science at least once a week were more likely to show high levels of achievement in science than those who did not (2).

This lab will be presented to students as an open-inquiry lab, meaning that they will be provided with materials but will be asked to design the experiment. This will allow students to delve deeper into the scientific experimentation process. Rather than have the steps laid out for them, students will be required to think critically to come up with solutions to the problem at hand. Students will use prior knowledge, their observation skills, and trial and error to complete this experiment. Through this process, students will learn the advantages and the disadvantages that accompany “doing science”. I predict that students will be frustrated at first when they are given less instruction than they are used to. However, I believe that allowing scholars to work through the steps of the scientific method will enhance their ability to solve problems and apply their knowledge. Designing their own experiment will increase student engagement and provide students with a sense of ownership over the content. Students will begin to see themselves as scientists, with viable ambitions of choosing a science-based career.

Finally, students will develop skills that they can use outside of the science lab. I expect that students will make mistakes or end up with results they will not expect. Students will realize that in the field of science, mistakes and failures are a driving forces of change and innovation. Scientists persevere despite failures; they adjust their methodology or approach and attempt again. I experienced this sensation firsthand by participating in a summer research program through Charlotte Teachers Institute. I spent two weeks conducting research in Dr. Susan Trammel's physics lab, an area that I was previously unfamiliar with. Several times throughout the program, my colleagues and I made mistakes in the lab but rather than giving up, we had the opportunity to adjust our errors. The resilience and adaptability that come with failure are character traits that would greatly benefit our students, not only in school but in all aspects of life. The guidance counselors at MLK Middle School have identified that our students lack Social Emotional Learning (SEL), or social and emotional skills, and as a result our school has been working to address this disparity. The development of social and emotional skills can lead to improved attitudes, behavior, and academic achievement (3). One aspect of Social Emotional Learning is problem solving-working through an issue and persevering rather than becoming angry or giving up. This experiment will be an aid in developing these skills. Finally, the scientific method, the ability to identify a problem, ask a question, use observation skills, and create a solution, is a process that students can potentially use in their communities. Students will be empowered to observe discrepancies in their community and to advocate for a solution to that issue.

Content Research

Pacing

Unit 3, which encompasses 8.P.1.3 and 8.P.1.4 (Appendix 1), should take 5 class periods (90 minutes each). One day should be used to cover chemical and physical changes, one day to discuss chemical reactions, one day to discuss the law of conservation of mass and balancing equations, one day for the open inquiry lab, and one day to discuss the lab and assess student mastery.

Key Vocabulary
*2nd Tier Word*s:
Equation, concentration, rate, yield, conserve, balance

3rd Tier Words:
Physical change: When the appearance but not the composition of a substance changes.
Chemical change: When a new substance is created by the rearrangement of atoms.
Reactivity: How likely a substance is to react with another substance.
Catalyst: A component that lowers the energy required to perform a chemical reaction, therefore increasing the rate of the chemical reaction.
Precipitate: A solid produced from two liquids during a chemical reaction.
Reactant: The substance or substances present before a chemical reaction.
Product: The new substance or substances created after the chemical reaction has occurred.

Prior Knowledge

In Unit 1, students learned about the composition of atoms in an element, compound, and mixture. They have mastered the concepts that elements and compounds are both pure substances, but that elements are composed of one type of atom and that compounds are composed of two or more different types of atoms that are bonded together chemically. On the other hand mixtures are physical combinations of many different types of atoms. Students are aware that elements cannot be broken down, compounds can be broken down only with a chemical reaction, and that mixtures can be broken down physically. The structure of a substance, as described above, determines its chemical and physical properties. In the first two units, atoms were often depicted as gum drops. In various activities, students used gumdrops to depict elements, compounds, and mixtures. Elements were portrayed by gumdrops of one color, compounds were portrayed by two or more different gumdrops held together by a toothpick (a bond), and mixtures were a physical combination of many different types of gumdrops, some held together with toothpicks and some single.

In Unit 2, students became familiar with the structure of the Periodic Table of Elements. They are able to explain the ways in which the Periodic Table is organized, by atomic number, atomic mass, groups, periods, and chemical properties (reactivity, valence electrons, and metal vs nonmetal) (4). In addition, students can locate and name elements on the table based on element symbol and the number of protons. Furthermore, students have already been introduced to the formatting of a chemical formula. In a chemical formula as shown below in Figure 1, the element symbol represents the type of element present. The coefficient, the number in front of the element or compound symbol, determines how many molecules of the substance there are. The subscript, written to the lower right of the element symbol, shows how many of each kind of atom there are. If there is no subscript present, there is only one atom.

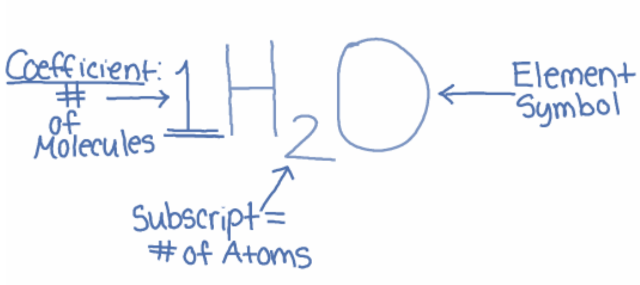

Figure 1: An example of a chemical formula. The parts of the chemical formula: coefficient, element symbol, and subscript are labeled.

Students should also have background knowledge about the scientific method. They should be familiar with the process and its significance. They should also know terms such as hypothesis, observation, independent variable, dependent variable, and conclusion.

Physical and Chemical Changes

Based on its atomic structure, a substance can be described by both its physical and chemical properties. Physical properties can be observed without changing the composition of the matter and include characteristics such as density, color, conductivity, malleability, luster, mass, volume, and length. Chemical properties, on the other hand, represent a substance's likelihood of undergoing change, or in other words its reactivity (5). There are two types of changes that occur to matter: physical and chemical changes. At an atomic level, a physical change does not change the chemical and physical properties of a substance, because no chemical bonds are created or destroyed. Physical changes include changes in size, shape, color, phase (evaporation, condensation, melting, freezing etc.), and dissolving. Physical changes are caused by actions such as breaking, cutting, and the removal or addition of heat.

Conversely, chemical changes involve breaking and then creating the chemical bonds that hold together atoms, resulting in the formation of a new substance (6). The new substance that is formed will have different physical and chemical properties than the original substance. The original substance is called the reactant, the new substance created is called the product. Chemical changes result from actions such as baking, burning, rusting, rotting, souring, and corrosion. When a chemical change occurs, evidence that might be observed includes an unexpected change in color, an unexpected temperature change, and the formation of a precipitate (a solid created from two liquids), bubbling, fizzing, and the unexpected formation of a gas. A situation in which a chemical change occurs is called a chemical reaction.

A chemical reaction can be portrayed as a chemical formula (seen below in Figure 2.) Figure 2 represents a chemical reaction between Hydrogen and Oxygen, resulting in the formation of water. The elements Hydrogen and Oxygen are displayed on the left side of the arrow as the reactants (the original substance). The arrow in the chemical formula means "yields" or produces and represents the chemical reaction taking place. The arrow points in the direction of the product, in this case water, which is the new substance that has formed from the breaking and formation of chemical bonds. Chemical reactions can occur at different rates. The rate of a chemical reaction depends on some of the following factors: surface area, temperature, concentration of reactant, and presence of a catalyst (7).

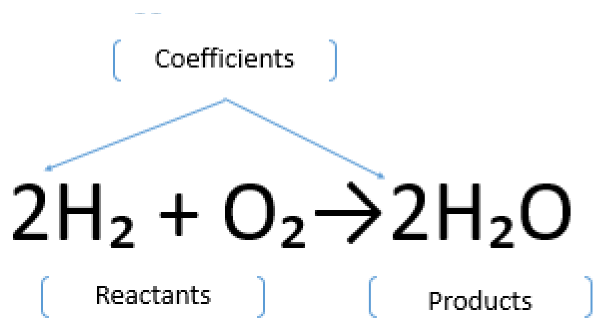

Figure 2: A chemical formula depicting a chemical reaction between Hydrogen and Oxygen to produce water. The reactants are found on the left side of the formula and the product, the new substance created during the reaction, is found on the right side of the formula.

Law of Conservation of Mass

Although many changes take place when materials react chemically, one thing that never changes is the amount of matter. The law of conservation of mass is the law stating that atoms are not created or destroyed during a chemical reaction (7). All atoms that are present before the chemical reaction occurs will also be present after the chemical reactions occurs. In other words, the mass of the reactant, the original substance, will be equal to the mass of the product, the substance that is created during the chemical reaction. This law was demonstrated through careful observation and measurement by French chemist Antoine Lavoisier in the 1780's. Lavoisier observed the reaction of heated mercury with air in a closed jar to determine that the overall mass of the system did not change during the reaction, despite the formation of a new substance.

Substances that appear to have gained or lost mass during the process of a reaction, for example plants growing through a series of reactions or a wood fire resulting in ashes, have chemically reacted with gases in the air. Although gases cannot always be seen, they are a form of matter and are therefore composed of atoms that have a measurable mass. For this reason, it is important to distinguish between an open system and a closed system. In an open system or an open container, gasses are able to escape and enter from the atmosphere. This will result in a product mass that is slightly less or more than that of the reactant. In a closed system or container, however, gasses are prevented from leaving or entering the system and the mass should be the same before and after the chemical reaction occurs.

Balancing Equations

The law of conservation of mass can be used to ensure that chemical formulas are balanced. Because atoms are rearranged, rather than created or destroyed, in a chemical reaction, there must be the same number and type of atom in the product and the reactant. Balanced formulas can also be used to calculate the mass of the products and the reactants.

In the image below (Figure 3), the reactant, seen on the left side of the arrow, is composed of two molecules of H_2 and one molecule of O_2. Previous to the chemical reaction, there is a total of 6 atoms, 4 Hydrogen atoms and 2 Oxygen atoms. The reactants are not bonded together and therefore they represent elements. The product, seen on right side of the formula, consists of two molecules of H_20, or water, which is a compound. In the product, there is a total of 6 atoms, 4 Hydrogen atoms and 2 Oxygen atoms. Neither the number nor type of atoms has changed as a result of the chemical reaction, the only thing that has changed is the arrangement of the atoms, and therefore the chemical and physical properties of the substance. The amount of matter, and therefore the mass, will remain the same before and after the chemical reaction. Figure 3 also demonstrates that if the same atoms are in the product and the reactant, than the mass of each side of the chemical formula will be the same. The mass of the reactant can be used to calculate the mass of the product, and the mass of the product can be used to calculate the mass of the reactant. The mass of each atom can be found on the Periodic Table of elements and is unique to each element.

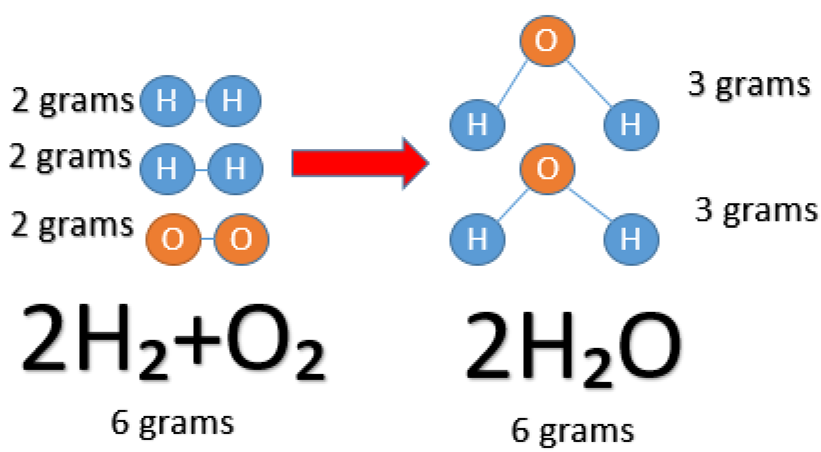

Figure 3: The image above represents the atoms and the chemical formula in a chemical reaction of Hydrogen and Oxygen to produce 2 molecules of water.

Instructional Implementation

Teaching Strategies

Levels of Inquiry

The levels of inquiry allow for a differentiated approach to hands on science and inquiry based learning. The three levels of inquiry that can be utilized in a classroom environment for a variety of objectives include structured, guided, and open (8). In the structured inquiry model, the teacher acts as the driving force of the experiment by providing the initial question, the materials, and an outline of the procedure. There are clear expectations for the students and it is easier to ensure that all students are on track and being held to a similar standard. On the other hand the creative process and higher level thinking may be restricted. The role of the students is to explain their findings by analyzing the data they recorded.

More responsibility is released from the teacher to the student in the next model. In a guided inquiry experiment the teacher provides the research question for the students but does not explain the procedure. Materials are provided and suggested but not predetermined. The student becomes responsible for choosing the materials and designing the experiment. The roles of the students and teacher are altered as well: the student becomes a problem solver rather than a direction follower and the teacher becomes the facilitator rather than the coach.

Finally, the open inquiry model shifts most of the responsibility onto the student: students formulate their own research question, design the procedure, and communicate their findings and results. The student finally becomes the researcher and reaches the highest level of thinking. Scholars are gradually released to this final level of inquiry with teacher guidance; it is not the beginning point for most students. By moving through each model of inquiry throughout a unit or throughout a school year, students should be able to confidently handle an open-ended experiment.

Cornell Notes

As seen in Figure 4, Cornell notes are structured so that the scholar's paper is split lengthwise into a right side and a left side. On the right, scholars take formal notes (9). The left side of the paper is designated for questions and keywords. In the footnotes, student summarize what they have learned. Cornell notes allow for a great amount of flexibility and also aid students in making connections between ideas, synthesizing information, and better applying acquired knowledge. In addition, utilizing the keywords allows students to recall the notes associated with that section (10).

• Key Words • Questions	• Formal Notes • Formal Notes • Formal Notes

Summary of Notes

Figure 4: Formatting for Cornell Notes.

Turn and Talk

This quick and informal teaching strategy allows students to engage in academic discussion (11). Answering questions in class does not often offer the opportunity for discussion; either students are not answering questions or the same students are being called on to provide the "right" answer. Turn and talk allows a differentiated method of student interaction where scholars get the chance to verbalize their thoughts and solidify their learning. In addition, they are also hearing the content again but from their peers and in other words.

Close Read

A close read is a deep, thoughtful analysis of a text that focuses on the text itself (12). In this case, the text is a chemical formula. The selection is often a short passage, as a successful close read requires many reads. Students do not need to have background knowledge about a text to perform this task. This process allows students to acquire a deeper level of background knowledge and to search for patterns within the text.

Gradual Release

The gradual release method, also considered a method of scaffolding, or "I do, We do, You do", moves the classroom instruction from teacher centered to student centered. At the beginning of the lesson, the role of the teacher is to deliver the content through direct instruction, think aloud, and modeling. . The goal of the student is to listen and ask for clarification. As the lesson progresses to "We do", the teacher and the class work together. The teacher asks prompting questions and works with struggling sub groups. The class answers questions alongside their classmates. Finally, the class should move to the "You do" portion of the lesson in which students independently answer questions relying solely on their notes while the teacher provides feedback (13).

Lessons

Lesson 1-Introducing Chemical and Physical Properties and Changes

Lesson Essential Question**:** You are conducting two lab experiments with a classmate that has been absent. In the first one, you mix salt and water. In the second, you burn a piece of paper. How would you help him/her determine whether or not a chemical or physical change occurred?

Potential Misconceptions: Phase changes (changes in state of matter) are chemical changes.

Activator: 8th Grade Camping Trip (Appendix 2). Teacher will read students a story about a camping trip the 8th grade teachers went on. The story can be changed to include any characters or events. As the teacher is reading the story, students will record changes from the story as being either chemical or physical. They will record these changes on a T-Chart. Students will turn and talk with their partner and compare what they have written in their chart. Students will work with their partner to determine how a chemical change differs from a physical change. Students will have an opportunity to share out what they believe to be the difference between a chemical change and a physical change.

Teaching Strategies: Students will take Cornell Notes on chemical and physical changes.

- During a physical change, the substance remains the same.
    - Examples: cutting, breaking, shattering, sanding
- Physical changes are easier to reverse
- During a chemical change, new substances are formed.
    - Examples: rusting, rotting milk, burning wood, bleaching clothes
- Chemical changes are more difficult to reverse.

Structured Inquiry Minilab (Appendix 2): Students will perform several demonstrations to complete their first mini lab. The initial lab follows the structured model so that students are introduced to and can become familiar with the scientific method surrounding chemical and physical changes. They will combine several ingredients and will record their observations (what they see, hear, feel, smell, etc.) in their science notebooks and decide whether the each experiment demonstrates a chemical change or a physical change. Before performing the experiment, students will be instructed to hypothesize about which changes will be chemical and which will be physical.

Lesson 2: Chemical Reactions

Lesson Essential Question: Your science teacher mixes two substances in a flask and tells the class that a chemical reaction has taken place. How will the students know? Choose one way to illustrate your answer (write a chemical formula, draw a chemical formula, draw a picture of the reaction.)

Potential Misconceptions: The production of a gas, temperature change, and a color change always indicate a chemical change.

Activator/Hook: Is it a Chemical Reaction?

Students will watch a series of videos/demonstrations. They must decide whether or not a chemical reaction has taken place. Students will share their answers with their table partner. Students will also be asked to justify their answers by sharing their observations. They will then have the chance to share out.

Possible Video Clips:

- https://www.youtube.com/watch?vs=hVK9Om4wzBM
- https://www.youtube.com/watch?v=rADVofp7XZc&feature=related
- https://www.youtube.com/watch?v=JOHdZsQXw7I
- https://www.youtube.com/watch?v=G4h3WgYBDz0
- https://www.youtube.com/watch?v=ROY4wWV4FTg

Teaching Strategies:

Students will take brief Cornell Notes on what a chemical reaction is and evidence that a chemical reaction has occurred. Teacher will create models of various compounds using gum drops. Teacher will demonstrate with the gumdrops by breaking them apart or creating new patterns that during a chemical reaction, the substance changes because the arrangement of the atoms changes.

- A chemical reaction occurs when the bonds that hold together a substance are broken and reformed to form a new substance. Atoms are rearranged in a chemical reaction.
- Heat, odor, color, change in temperature, formation of a gas, formation of a precipitate, and light are all evidence that a chemical reaction has taken place.
- The rate of a reaction can be altered by several factors.
  - Increase temperature, increase concentration, increase surface area, presence of a catalyst.

Rate of Reaction Guided Inquiry Lab (Appendix 3):
This second experiment will be a guided experiment. The students should be more familiar and comfortable with the scientific method in regards to chemical changes at this point. The teacher will provide the question and the materials but students will design the experiment. Students will be asked to answer the following question: How can you change the rate of a chemical reaction? To begin, the teacher will dissolve an Alka-Seltzer tablet in room temperature water. Students will observe and time how long it takes the chemical reaction to finish. They will then be able to examine the materials and design and conduct an experiment.

Lesson 3: The Law of Conservation of Matter

Lesson Essential Question: You are performing a chemical reaction. You start with 15 grams of reactant. How much will the product weigh if the reaction takes place in an open container? Justify. How much will the product weight if the reaction takes place in a closed container? Justify.

Potential Misconceptions: The product can weigh more than the reactant after a chemical reaction has occurred.

Activator/Hook: Sum of the Parts Mini Lab (Appendix 4)

Teaching strategies:

Cornell Notes on reactants and products:
- Reactants are what you start with before the chemical reaction
- Products are what you end with after a chemical reaction

Teachers will show students a chemical reaction as a chemical formula. They will label the products and the reactants. Teacher will show students several chemical equations and read several scenarios and ask students to determine which substances are part of the product and which substances are part of the reactants. This can be done as part of an I do, We do, You do (gradual release). Next, students will work with their table partner to close read a chemical formula portraying a chemical reaction and answer the following questions:
  - Which substances are part of the reactants?
  - Which substances are part of the products?
  - What elements make up the substances in the products?
  - What elements make up the substances in the reactants?

- What is the mass of the reactants?
    - What is the total mass of the products?
    - Are the elements in the reactants the same as the elements in the reactants?
    - How many atoms of each element are in the reactants?
    - How many atoms of each element are in the products?
    - Are the elements on the left equal to the elements on the right?

Students should come to the conclusion that the components and amount of the reactant are the same as the components and amount of the product. These chemical formulas are balanced. This should segue into the Law of Conservation of Matter. Students will take the following Cornell notes:

- Matter is neither created nor destroyed in a chemical reaction.
- Atoms are rearranged to form new substances
- What is on the left (in the reactant) must be on the right (in the product)
- The product weighs the same amount as the reactant

Teacher will provide students with the following scenario: You are at a family barbeque. There is a huge bonfire. Because you are a super scientist, you weigh the logs and coal that were used to make the fire. You determine that they weigh 234 pounds. After the bonfire you go back and weigh the ashes and discover that they ashes only weigh 175 pounds. You are confused because by the law of conservation the reactants should weigh as much as the products. What happened?

Students will be allowed to work through this scenario with a partner and then share out with the class. Teacher will then introduce the exceptions to the law of conservation of matter: Open vs. Closed containers (the fire pit scenario above is an example of an open container in which some of the mass of the product was lost to the atmosphere as a gas).

Practice with balancing equations: https://education.jlab.org/elementbalancing/

Lesson 4: Open Inquiry Lab

The fourth day of the unit should be used to prepare for and to execute the open inquiry lab. Now that students have become familiar with the scientific method through structured and guided inquiry, they should be prepared to engage in open-ended experimentation. Before the lab begins, students should be reminded of lab expectations: how to handle lab materials, how to clean up, how to act during a lab, and what is expected of them academically. They should also be conditioned with the mindset of an open-ended experiment: failure is expected, modification is required, and success should not be expected the first time. Students should be divided into intentional groups of four. These groups should include diverse learners with varied skill sets and levels of background knowledge. Each member of the group should then be assigned a role. Roles can also be intentionally assigned. As students participate in various ab throughout the year, these roles should be switched.

Roles:

Note Taker: This group member is responsible for recording procedures, data, and results before and throughout the experiment.

Materials: This group member is responsible for obtaining and returning materials in an appropriate condition.

Communicator: This person is the student that is allowed to ask questions to the teacher and other groups around the room.
Leader: The leader is responsible for keeping the experiment on track, for ensuring the data is being collected appropriately, and for checking on the other members of the group to make sure that they understand what is going on and that they are fulfilling their roles.

Asking a testable question: Teacher will introduce the idea of a testable question-one that can be experimented on in a laboratory investigation. Students will complete the Asking Testable Questions Worksheet (found in the Appendix 5) as a group.

Materials: Food coloring, hot water, cold water, water, yeast, hydrogen peroxide, Alka-Seltzer, beakers of various sizes, balloons, container with lids, containers without lids, vinegar, baking soda, Legos, ice, gumdrops, toothpicks.

Students will come up to examine the materials one group at a time and start brainstorming ideas.

Procedure: Students will use their lab sheets (Appendix 5) to develop a testable question. This question should be approved by the teacher. Once the question has been formed, students will create a hypothesis. Afterwards, students will design an experiment through prompting questions on their lab sheet. Scholars will select their materials, their variables, their process, and a method to record data. Once this has been approved by the teacher, students will acquire their materials and begin collecting data. Groups that are struggling may have their communicator ask the teacher focused questions and the communicator may be sent to other groups to examine what their classmates are doing.

Lesson 5: Assessment and Discussion (Appendix 6)
On the fifth day, students should have a discussion about what they accomplished the day before. Each group should be prompted to share a brief summary of their experiment and their results. Students will be able to learn about the variety of variables and the directions that their classmates chose to go in. Students should also have a discussion about their frustrations and failures and how they were able to overcome them, finally, students should take the unit test to assess their mastery.

Appendix 1: Implementing Teaching Standards

8.P.1 Understand the properties of matter and changes that occur when matter interacts in an open and closed container:

- 8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include
  changes in temperature, color, formation of a gas or precipitate.
- 8.P.1.4 Explain how the idea of atoms and a balanced chemical equation support the law of conservation of mass.

Essential Standard 8.P.1 requires that students understand the properties of matter and changes that occur when matter interacts in an open and closed container. In the first unit of the year, we covered the first objective of the standard, 8.P.1.1 classifying atoms as elements, compounds, and mixtures based on how the atoms are packed together in an arrangement. It is important to lay the foundation of matter and atoms before you can discuss chemical reactions and the law of conservation of mass. Unit 2 covers the second objective of this standard, 8.P.1.2 which reviews the periodic table. The unit that I will be focusing on covers the third and fourth objective of standard 8.P.1, which focuses on observing chemical reactions and the physical and chemical changes that occur as a result. More specifically, this lab is honed in on 8.P.1.4, which requires students to explain how the idea of atoms and a balanced chemical equation support the law of conservation of mass in an open and closed container.

Appendix 2: Lesson 1 Resources

Camping Story:
As the teacher reads the story, students should identify each of the underlined changes as chemical or physical.
Over the summer, the 8th grade science teachers went on a camping trip to the mountains. When they arrived at the campsite, Ms. Davis realized she was cold so Mr. Amos chopped down a tree for firewood. He carried it back to the campsite so that Ms. Johnson could start a fire. The burning wood allowed all the teachers to warm up. Ms. Bonner decided that she was hungry so she began to boil some water to make mac and cheese. As Ms. Bonner was preparing the food, Ms. Snyder retrieved some water from the nearby river and began to filter the water. Mr. Williams mixed together the water, Kool-Aid powder, and sugar to go along with the meal. After dinner, the teachers set up their tents. Mr. Conner cut ropes so that the tents could be tied to the ground. All the teachers relaxed by the fire while watching fireworks go off in the distance.

Chemical Reactions Structured Lab:
For each experiment, record your observation in their folders and determine if the change is chemical or physical. Justify your answer.

- 10 mL of sugar dissolving in 100 mL of water-*Physical*
  - Observations:
  - Chemical or Physical?
- 25 mL of silver nitrate mixing with 10 mL of potassium iodide-*Chemical*
  - Observations:
  - Chemical or Physical?
- ¼ cup of yeast mixing with 50 mL of hydrogen peroxide-*Chemical*
  - Observations:
  - Chemical or Physical?
- ¼ cup of yeast mixing with 50 mL of water-*Chemical*
  - Observations:
  - Chemical or Physical?
- 1 Alka-Seltzer tablet added to 100 mL of water-*Chemical*
  - Observations:
  - Chemical or Physical?
- 1 tablespoon of baking soda and 50 mL of vinegar-*Chemical*
  - Observations:
  - Chemical or Physical?
- 3 drops of food coloring and 50 mL of water-*Physical*
  - Observations:
  - Chemical or Physical?

Appendix 3: Lesson 2 Resources

Rate of Reactions Minilab

Watch as I dissolve a whole tablet of Alka-Seltzer in water. This will be the control. Record the time it take to react.

Question: Can we change the rate of a chemical reaction?

Materials: hot plate, room temperature water, ice, graduated cylinder, beaker, mortar and pestle, stopwatch

Background questions:

1. How do you know that a chemical reaction has occurred?

2. How will you be able to tell how long the reaction is occurring for?

3. What are some possible variables that you can test (remember our control is the whole tablet in room temperature water)?

Hypothesis:

Design a procedure:

When you are done creating your procedure, raise your hand to receive the materials.

Data:

Variable	Observations	Time of Chemical Reaction
Room temperature water and 1 tablet of Alka-Seltzer		

Conclusion: Which variables changed the rate of reaction? Which variables increased the rate? Which variables decreased the rate?

Appendix 4: Lesson 3 resources

Sum of the Parts Mini Lab

Materials:
Scales, cups, ice

Procedure:
1.Place some ice into a cup.

2. Weigh the cup of ice and record its mass.

3. Let the cup of ice melt. While you are waiting, continue with the lesson. Give the ice about 10-15 minutes to melt.

4. After the melting period, make a prediction. What will the mass of the cup of melted ice be? Will it weigh more, less or stay the same? Why? Discuss.

5. Weigh the cup of melted ice and record the mass.

Conclusion
Answer these questions:
1.What happened in this experiment? Write a short summary.

2. Were you surprised at the results? Why or why not?

Appendix 5: Lesson 4 Resources

How to Develop a Testable Question Worksheet

Not every question is a good question that can be tested. In this class, we're going to focus on "testable" questions, or questions that we can do experiments on.

These are questions that can be answered by doing a laboratory investigation. They are NOT opinion questions or questions that can be answered by doing research in a book or on the internet. Developing a good question is important because it gives your experiment direction and lets other people know what question you are trying to answer in your experiment. It must be clear. A question such as "How do students learn best?" is not clear because there are too many different ways to test it. A better question might be, "Do students learn better before or after eating?" because it only tests one particular thing. TIP: YOU MUST BE ABLE TO MEASURE THE RESULTS IN SOME WAY FOR IT TO BE CONSIDERED A TESTABLE QUESTION.

"Questions" PRACTICE

Circle the questions which are testable using scientific experimentation.

1. Are there more seeds in Fugi Apples or Washington Apples?
2. What types of apples grow in Missouri?
3. Why do people smoke?
4. How does talking to a plant affect a plant's height?
5. Where are whales found in the world?
6. What happens if you do not eat breakfast?
7. Which planet is the most interesting one to study?
8. Which objects are attracted by a magnet: paperclip, penny, foil?
9. Will larger or smaller seeds germinate faster?
10. Do larger or smaller seeds make prettier flowers?
11. Do flying saucers really exist?
12. Which pill design – tablet, caplet, or capsule – will dissolve faster?
13. Does the color of a surface affect its temperature?
14. Why does doing homework help your grades?
15. How does the size of a helicopter's blade length affect the speed and number of rotations?
16. Does the temperature of a classroom affect student performance?

Change 2 of the NON-testable questions to TESTABLE questions in the space below or on the back of this page.

"Questions" Practice Part 2

Write a testable question for each of the following ideas for experiments.

1. You want to figure out how many pine cones are on the average branch of a pine tree.

2. You want to know whether or not a McDonald's super-sized fry has more fries in it than a large fry.

3. You want to know whether or not people can taste the difference between different colored M&Ms.

4. You want to know what the most popular color for a car is.

5. You want to know what type of soda is preferred by students in your grade.

Open Inquiry Lab

Law of Conservation of Matter: According to the law of conservation of mass, atoms are not created or destroyed in a chemical reaction. The components and mass of the reactants will be the same as the product, with the exception of a reaction taking place in an open container.

Materials: Food coloring, hot water, cold water, water, yeast, hydrogen peroxide, Alka-Seltzer, beakers of various sizes, balloons, container with lids, containers without lids, vinegar, baking soda, Legos, ice, gumdrops, toothpicks.

Design and conduct an experiment to test the law of conservation of mass. Before you begin, complete the follow.

1. Identify the problem you will be testing by coming up with a testable question. When you have one, raise your hand.
2. Identify your variables
3. Generate a hypothesis in the form of an If-Then statement.
4. Outline your procedure including the materials you will use. When this step is complete, raise your hand to receive your materials.

Question:

Hypothesis:

Materials:

Procedure:

As you conduct your experiment, document your results on a data table. Once the experiment is complete, summarize your findings by writing a conclusion paragraph. What worked/what didn't work? What did you change?

Appendix 6: Lesson 5 Resources

8th Grade Science Unit 3 Test: Chemical Reactions

LEQ #1: Chemical vs. Physical Change

1. Adding heat to ice cubes causes them to melt. What kind of change is this?
   a. Chemical change
   b. Physical change
   c. Energy change
   d. Thermal change

2. Which is an example of a physical change of a substance?
   a. Burning of coal
   b. Formation of new compound
   c. Sugar dissolving in tea
   d. Rusting of metal

3. A science teacher mixes calcium chloride and vinegar in a test tube. He passes the test tube around for his students to feel. The students notice that the test tube is hot. The science teacher asks the students to decide if the mixing of the two chemicals involved a physical or chemical change. Which student gave the correct answer?
   a. Student 1: The change was physical because a temperature change occurred
   b. Student 2: The change was chemical because a temperature change occurred
   c. Student 3: The change was physical because the two chemicals mixed
   d. Student 4: The change was chemical because the two chemicals mixed

4. Which of the following is an example of a chemical change?
   a. Crushing a piece of paper up into a ball
   b. Baking soda reacting with vinegar and producing bubbles
   c. Breaking a piece of candy
   d. Boiling a pot of water

5. Denise left her bike out in the rain for several days. After several weeks, she discovered that rust had formed on her bike. What had taken place?
   a. Physical change
   b. Conservation of energy
   c. Chemical change
   d. Diffusion

6. During her chemistry lab, Betsy mixed two liquids together. A solid formed and fell to the bottom of the beaker. What is the solid that formed called?
   a. A precipitate
   b. A solute
   c. A solvent
   d. A solution

7. Which of the equations below represents a physical change?

a. $S_8 + 12\ O_2 \rightarrow 8\ SO_3$
b. $8\ SO_3 \rightarrow s_8 + 12\ O_2$
c. $S_8 + 12\ O_2 \rightarrow S_8 + 12\ O_2$
d. None of the above

LEQ #2: Chemical Reactions

8. Based on the reaction $2Na + Cl_2 \rightarrow 2NaCl$, what is/are the reactant(s)?
   a. Na
   b. Cl
   c. Na and Cl
   d. NaCl

9. In an experiment combining vinegar and baking soda, gas is given off. In this chemical reaction, the vinegar and baking soda are:
   a. reactants
   b. products
   c. elements
   d. mixtures

10. What does a catalyst do in a chemical reaction?
    a. It slows the reaction down
    b. It speeds the reaction up
    c. It becomes a product
    d. It is a reactant

11. During a chemical reaction which of the following is true?
    a. Bonds are broken and a physical change occurs
    b. Bonds are broken and a chemical change occurs
    c. Bonds are broken and reformed and a physical change occurs
    d. Bonds are broken and reformed and chemical change occurs

LEQ #3: Law of Conservation of Matter

12. Which of the following is true about the law of conservation of matter?
    a. Atoms are rearranged, but are neither created nor destroyed.
    b. Only a small amount of matter is lost during every reaction.
    c. Reactant atoms are destroyed, but product atoms are created.
    d. People can use chemical reactions to protect natural resources.

13. Bob learns about the law of conservation of matter in chemistry. He tries to disprove this law by burning a log. He weighs the log before he burns it and finds it has a mass of 25 grams. After burning the log, he weighs the ashes and finds that they have a mass of 17 grams. According to the law of conservation of matter, the mass of the reactants must equal the mass of the products. What has happened to the missing 8 grams of log?
    a. They blew away before Bob could weigh them.
    b. They were released as smoke and gases while the log was burning.
    c. They were given off as heat.

d. They are not missing; Bob's scale was incorrect.

14. During a chemical reaction, methane (CH_4) and oxygen (O_2) combine to produce carbon dioxide (CO_2) and water (H_2O). The balanced chemical equation identifies the reactants and products for this reaction along with some of their masses. What mass (in grams) of oxygen (O_2) is required for this reaction to occur?

CH_4	+	**O_2**	→	**$2CO_2$**	+	**H_2O**
16g		**?**		**44g**		**36g**

a. 16
b. 36
c. 44
d. 64

15. Sam places 5 g of baking soda in 5 g of liquid vinegar, and notices fizzing. After all the fizzing stops, 5 g of liquid remains. How much gas escaped during the reaction?
a. 10 g
b. 5 g
c. 2 g
d. 0 g

16. Mandy left a bottle of fizzing hydrogen peroxide on the counter. Over the opening she attached a lid, which created a tight seal over the opening of the bottle. At the beginning of her experiment, the total mass of the balloon and liquid was 305 g. What will be the mass of her experiment be after the peroxide stops fizzing?
a. 290 g
b. 300 g
c. 305 g
d. 310 g

17. A chemical reaction produces two new substances, and **EACH** product has a mass of 25 grams. What was the total mass of the reactants?
a. 25 grams
b. 50 grams
c. 75 grams
d. 100 grams

Endnotes

(1) Dabney. “Out-of-school time science activities and their association with career interest in STEM.”
(2) Stohr-Hunt. “An analysis of frequency of hands-on experience and science achievement.”
(3) Durlak. “The Impact of Enhancing Students’ Social and Emotional Learning: A Meta-Analysis of School-Based Universal Interventions.”
(4) Franzle. “Periodic Table of Elements.”
(5) Myers. “The Basics of Chemistry.”
(6) Petrucci. “General Chemistry.”
(7) Cracolice. “Basics of Introductory Chemistry.”
(8) Wenning. “Levels of Inquiry.”
(9) Jacobs. “A comparison of two note taking methods in a secondary English classroom.”
(10) Donohoo. “Learning how to learn: Cornell notes as an example.”
(11) Bhatia. “A generic view of academic discourse.”
(12) Schoenbach. “Reading for understanding: A guide to improving reading in middle and high school classrooms.”
(13) Fisher. "Writing Instruction for Struggling Adolescent Readers: A Gradual Release Model."

Annotated Bibliography:

Bhatia, V. K. (2002). A generic view of academic discourse. In J. Flowerdew (Ed.), *Academic discourse* (pp. 21–39). London: Longman.

This book discusses the importance of conversations in classrooms.

Cracolice, Peters. Basics of introductory Chemistry An active Learning Approach. Second ed. Belmont, CA 94001:Brooks/Cole, 2007.

This resource discusses the law of conservation of mass.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., & Hazari, Z. (2012). Out-of-school time science activities and their association with career interest in STEM. International Journal of Science Education, Particle B, 2(1), 63–79. doi: 10.1080/21548455.2011.629455[Taylor & Francis Online]

This report shows the connection between interest in science in middle school and the likelihood of choosing a STEM career.

Donohoo, J. (2010). Learning how to learn: Cornell notes as an example. Journal of Adolescent & Adult Literacy, 54, 224–7. doi: 10.1598.

This article discusses the uses of Cornell Notes.

Durlak, J. A., Weissberg, R. P., Dymnicki, A. B., Taylor, R. D. & Schellinger, K. B. (2011), The Impact of Enhancing Students' Social and Emotional Learning: A Meta-Analysis of School-Based Universal Interventions. Child Development, 82: 405–432. doi:10.1111/j.1467-8624.2010.01564.x

This reference discusses the importance of Social Emotional Learning and how to implement it.

Fisher, Douglas, and Nancy Frey. "Writing Instruction for Struggling Adolescent Readers: A Gradual Release Model." Journal of Adolescent and Adult Literacy 46.5 (2003): 396-405.

This reference provides a model of how to gradually release responsibility from the teacher to the student.

Fränzle, S., Markert, B. and Wünschmann, S. (2012) Periodic Table of Elements, in Introduction to Environmental Engineering, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany. doi: 10.1002/9783527659487.oth1

This resource walks through the organization of the Periodic Table.

Jacobs, K. (2008). A comparison of two note taking methods in a secondary English classroom. Retrieved from http://soar.wichita.edu/handle/10057/1388

This reference discusses the uses and importance of Cornell Notes.

Myers R (2003) The basics of chemistry. Greenwood Press, Westport, Connecticut, London.
This reference explains the difference chemical vs. physical changes and properties.

Petrucci, Bissonnette, Herring, Madura. General Chemistry: Principles and Modern Applications. Tenth ed. Upper Saddle River, NJ 07458: Pearson Education Inc., 2011.
This book provides background information on general chemistry.

Schoenbach, R., Greenleaf, C., Cziko, C., & Hurwitz, L. (2000). *Reading for understanding: A guide to improving reading in middle and high school classrooms*. San Francisco: Jossey-Bass.
This reference shows to how to implement a close read method.

Stohr-Hunt P.M. (1996). An analysis of frequency of hands-on experience and science achievement. Journal of Research in Science Teaching, 33, 101–109.
This reference is a report connecting hands-on science activities to science achievement.

Wenning, C. J. (2005). “Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes.” Journal of Physic Teacher Education Online, 2 (3), 3-11.
This reference walks through the levels and the importance of inquiry based learning.