Teaching Chemistry through Experimentation, Demonstration, and Cooperation

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This curriculum unit is recommended for:
Science/Grade 8

Keywords: Chemistry, Introduction to Chemistry, Properties of Matter, Atomic Structure, Periodic Table

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

Synopsis: Introducing students to chemistry is an important turning point in the Science curriculum. By this time, students have learned about most important scientific concepts that are not considered difficult or complicated (such as Physics or high school Chemistry). This curriculum unit explores the introduction of chemistry concepts, making use of multiple styles of learning, but focusing mostly on experiments and demonstrations that students can make inferences and apply the scientific method. With additional support from technology to cover concepts before and after experimental learning, students will get a clear picture of chemistry. Specific information covered includes the following: atomic structure, the periodic table, physical and chemical properties, and compounds. The activities and experiments can mostly be recreated with information contained within this unit as well as fairly cheap materials that can be purchased at a dollar store. Teachers looking for student engagement and building on their limited understanding, but definite interest in chemistry will find this unit to be engaging while also applying scientific inference and understanding.

I plan to teach this unit during the coming year in to 136 students in Science/Grade 8.

Introduction and Rationale

The students I teach are typical 13 to 14 year olds that are obsessed with anything and everything they are not ‘allowed’ to experience at their age: driving, making all the choices in their lives, and doing things that more mature individuals deem dangerous for those still maturing mentally, physically, and socially. The third point is related directly to chemistry and the student’s limited understanding of what it means. In the mind of a middle school student, chemistry always translates to ‘blowing stuff up’. This correlation in their minds between chemistry and explosions can be used to build on their expectations to make chemistry as interactive as they would like it to be.

Of all the areas of science that I teach (all of the subjects within the earth, life, and physical disciplines) the excitement is almost palpable when I even mention chemistry. In the first few days of school, when students are still getting used to me and vice-versa, the number one question from every class and every creed is ‘Do we get to blow stuff up?’. In my mind, I translate that to being interested in the excitement of a subject but perhaps not in the actual information behind it. Excitement at being at school in general is never very high, but using this as a tool, I believe I can make learning chemistry not only an experience every child can comprehend, but enjoy while doing so.

The important principles for students to understand in the three core lessons of this curriculum unit are mostly focused around the basic understanding of how atoms work and their structure, their interaction with other atoms, and using the periodic table to identify certain atoms and why they are located where they are. It is to this level of understanding of the knowledge that students will need to be taught in order to facilitate understanding the more complex concepts later. In a 21st century world, students will be able to use multiple learning styles (visual aids, audio, and kinesthetic models), and they will integrate technology to attain information. But doing the science is also critical in truly understanding the science.

Students that complete my curriculum unit and subsequent chemistry related lessons are being prepared for high school. Most students will be in either Biology or Environmental Science. While neither of these classes are specifically geared for implementation of chemistry concepts, the focus of this lesson will be to make chemistry from 8th grade so memorable, that when students take their formal chemistry specific year-long class by 10th or even 11th grade year, they will be ready for the fast pace and complex knowledge that comes with it. This focus on chemistry will form a foundation for college classes for those students that want to continue in the field of science. All of this requires a strong, solid foundation in 8th grade which this curriculum unit aims to achieve.

I teach 8th grade Science at Bailey Middle School in Cornelius, North Carolina, a suburb of Charlotte. Bailey is an Honors School of Excellence, a recognition that requires 90% of students to be at grade level and that the school met all 27 of its performance targets. I moved to Charlotte after a year of teaching science in Louisiana for a year in 2011. Though originally a Social Studies Education major, I became certified in science through testing and have enjoyed it far more than I thought I would. I have come to understand science as a gateway for critical thinking in all subjects and as a necessity in education.

My classroom is the only non-science classroom in 8th grade. I do not have resources such as science tables, running water, or a station that I can perform demonstrations on. I feel this lack of a proper scientific environment pulls the students out of the wonder they should experience when compared to entering into the lessons with a classroom specifically engineered for the subject. To make up for this deficit, I began my year by hitting students with experiments daily, from density to area to states of matter. This experimental introduction to science gets their attention and has them asking for experiments daily. This is the excitement I had hope to mold into a functioning chemistry class that learns by experimenting themselves and observing the more "dangerous" demonstrations performed by me.

There are aspects in this curriculum unit that integrate basic knowledge required in any science curriculum. Students will need to be able to competently follow the scientific method to make inferences and develop hypothesis to answer questions posed, critically think about concepts and information learned to deduce the next part of higher level knowledge, and use technology to facilitate bringing the information to their peers and their instructor. Students should also be able to build off of previous concepts (possibly taught prior to chemistry during the 8th grade year or concepts taught in a previous year), such as why some organisms use oxygen and others can only process carbon dioxide. Students have most likely covered a concept like this, but have never delved further into why exactly these specific elements and molecules are necessary or how they developed to use these specific compounds. Additionally, concepts taught later in the school year (such as evolution of life and cell structures in biology) are easier to understand due to student comprehension of the chemical basics presented earlier in the year.

The information in this curriculum unit is meant to provide a teacher with not only the tools to achieve student success and interest, but the reasoning behind their implementation. The intended audience is 8th grade teachers of chemistry, though anyone between grades 6 and 9 can make use of the information contained. The information in this curriculum unit is meant to provide a teacher with not only the tools to achieve student success and interest, but the reasoning behind their implementation.

My curriculum consists of three units that take place during my first few weeks of chemistry. Students will use information taught previously on critical thinking, observation, and performing labs to supplement this curriculum unit. The sub-units include:

1. Lesson 1: Chemistry Introduction to Atomic Theory and Structure
2. Lesson 2: Compounds, Molecules, and Mixtures
3. Lesson 3: The Periodic Table and Physical/Chemical Changes

Background

Merriam-Webster defines chemistry as a "science that deals with the structure and properties of substances and with the changes they go through."[1] This definition of chemistry is an apt explanation of what students should think when they complete their chemistry unit. Chemistry can mean explosions, but understanding the why of an explosion is more important than the spectacle of the explosion itself. Fires are something everyone has seen and can create, air is thought about only in the context of breathing, and water is just a necessity for life. These three simple examples are so much more than that basic understanding and chemistry is the means and gateway into thinking deeper about these processes.

Chemistry dates back to the early days of Greece and the assertions of one, Aristotle. Aristotle's tale begins with the basic idea that there were four main elements and they were: fire, water, earth and, air. Aristotle displayed these elements in a basic circular structure and explained their movement pertaining to where they were in said structure. This is a very simple description, but for over 2000 years ago, it was groundbreaking in chemistry. [4]

Still in Greece, though much later, Democritus, a philosopher by trade, made an interesting assertion about everything. He said that atoms or atomos, Greek for undivided, make up everything; this served as the first historically credited example of atomic theory in chemistry, and the idea that 'everything' was made of atoms. However, Democritus went well beyond that in his other assertions about atoms: that atoms are only physically, not geometrically, indivisible, atoms only have empty space between them, and are indestructible. To the modern scientist or even middle school science teacher, these observations are very close to our modern understandings. There is another assertion made by Democritus, however; the assertion that atoms are always in motion. Democritus almost seems like a psychic who could deign the identity of an object we only now finally able to see. Democritus is the origin of all atomic theory, in essence, and his philosophical views are much more scientifically true than anything else at this time. Additional scientists that are important for students to learn include Dalton, count Rumford, Lavoisier, and Mendeleev.[2, 3]

The basest of chemical knowledge comes from several hundred years of research and development. Atoms are the basic building blocks of matter, constructed of a single to multiple particles that are even smaller than the atom itself. These subatomic particles have three simple forms that are used in basic atomic structure, the neutron, proton, and electron. The proton and electron both are charged oppositely, protons being positive with electrons being negative. A neutron is much as its name implies: neutral. Neutrons have no charge. The protons and neutrons are clustered together in the nucleus of an atom whereas the electrons are moving around the nucleus and along the outside of the atom.[3,5]

The total number of protons and neutrons in an atom are called the mass number. The number of protons in an atom determines its atomic number and determines what element it is. Electrons in an atom are also useful for more complicated transitions between atoms, such as reactions and why they occur. In conjunction, these sub-atomic particles form that variety of unique elements we have and their structure determine their placement and arrangement in what we call the Periodic Table. Elements always have the same numbers of protons (per element, i.e. Carbon has 6) and generally can have the same number of electrons but its neutrons can vary. These differing atoms of the same element are called isotopes. The number of neutrons and protons in an element, the mass number, can be written after its chemical symbol, which is a letter or two that represents the elements name. For example, Carbon can have a mass number of 12 or 14, in which case it is referred to as either C-12 or C-14.[3, 5]

How these atoms react with one another leads to compounds and molecules. Compounds and molecules are very different but similar in the same way all rectangles are squares but not all squares are rectangles. Most elements are not found in their pure form in nature, but bonded to another element. A compound is when two or more elements are combined in a specific ratio or proportion. A molecule is two or more atoms combined together. The specific difference between the two is that a compound is made of different elements, whereas a molecule can be the same element bonded to itself as well.[4]

Elements and compounds are pure substances, or substances that have a constant composition and consistent constitution throughout the entire sample. For example, water is H_2O. Anytime water is found on the planet, it will be in the proportions of 2 parts hydrogen to 1 part oxygen. When pure substances are placed in the same place at the same time, but don’t chemically combine thus assuring that you have the same composition throughout, are called a mixture. There are two kinds of mixtures: homogenous and heterogeneous. An evenly distributed amount of items in a mixture (for example salt in water solution) is homogenous. A solution is a mixture that is well combined and exactly the same density throughout the mixture, thus homogenous. In a heterogeneous mixture, there is no rhyme or reason to why or where items are located (such as a pizza or beach sand).[4, 5, 6] In this mixture, density differences can be found.

The periodic table is a key tool for understanding chemistry. The periodic table is arranged in several regions based on the atomic number and the structure of the electrons around the atoms. Elements in the same regions have properties specific to them. The vertical rows of the periodic table are called groups or families. These families tend to contain elements with similar physical properties and act similarly in chemical reactions. The horizontal rows of the periodic table are called periods. The periods are organized by the number of electron shells present, starting with one shell at the top and seven shells at the bottom. The outermost electrons are called valence electrons and the number of these increases as you go from left to right across the table. Valence electrons are the key in that they are the ones that participate in the chemical reactions between elements.[4, 6]

Elements in the periodic table are also arranged based on more general properties they exhibit. Three general classifications of all the elements on the periodic table are metal, non-metal, and metalloid. These three types of classification have physical properties they may or may not exhibit such as malleability, shininess, ductility, and hardness. Metals tend to have opposing properties to those of non-metals; metalloids can have a mixture of properties similar to both the metals and non-metals.[4, 6]

Every element on the periodic table can also be classified based on a state of matter. Most of the periodic table is metal and solid, with a few gases and only two naturally occurring liquids. One more point of note, each group has a specific name that can hint at its properties of all the elements contained within it.[4, 6]

There are changes that occur on an atomic level that are not always visible on the level that the human eye can see on. These changes can be classified as either physical or chemical. A physical change occurs when the composition of a substance (atoms, compounds, etc) is not changed in some way. Cutting paper or melting ice are examples of physical changes. A chemical change is when the composition of a substance is altered chemically (the bonds of atoms are formed, broken, or rearranged). The chemical change is more the focus of chemistry and the subsequent information in this paper.[3, 4]

A chemical change can take place in several types of reactions, the most simple of which is a synthesis reaction. In a synthesis reaction, two atoms or molecules combine to form a single compound or a different molecule (example $2H_2 + O_2 \rightarrow 2H_2O$). This chemical equation is balanced, meaning that the number and kind of elements that are in the reactants are the same as in the products. Sometimes, chemical equations are not balanced and require balancing in order to receive the correct result. There is also a decomposition reaction in which the reverse of a synthesis reaction occurs, and several types of replacement reactions that involve the movement of one or more elements within the different reactant and product compounds.[3, 4]

Endothermic and exothermic reactions are classifications of reactions as to whether they are releasing energy or absorbing it in these physical or chemical changes. It is important to know which is occurring in a reaction to determine how or why reactions are progressing the way they do.[4]

Finally, the Law of Conservation of Mass is a concept that states that the amount of matter in a chemical reaction does not change so that the mass of the reactants equals the mass of the products. The Law of Conservation of Mass keeps everything equal on both sides of a chemical equation so that there is no room for error in measuring out which element ended up where (such as a carbon reaction with oxygen which produces energy and CO_2).[4]

Teaching Strategies and Content Objectives

Students will be expected to do their own research utilizing materials provided at school, such as laptops, IPads, textbooks, and related websites. The real goal here is to promote hands-on learning for students by performing their own experiments or by direct observation of demonstrations performed by the teacher in the classroom. Students will also be given any materials they needed that is related to the core of the content they will be expected to know. Materials will be provided through the CMS, Charlotte-Mecklenburg School, system for labs and experiments, with possible supplementary materials made available through colleges such as UNCC or Davidson College's chemistry departments. Materials not able to be obtained in either of these ways will be supplied by the teacher. Students will need to be able to present their findings and work in several formats including, but not limited to: group presentation, single presentations, kinesthetic examples, visuals, auditory, lab reports, the scientific method, and presentation technologies to convey the information.

Students should be able to explain the basic structures of atoms, how they interact with each other and other types of atoms, and what they are (elements). Students should be able to identify the different types of atoms based on atomic structure, location on the periodic table and the chemical properties among their groups. Students should be able to recognize why elements are arranged the way they are on the periodic table, what similar structures they share, and what the thought was behind the formation of the periodic table. Students should be able to demonstrate a physical change as opposed to a chemical one and identify and explain which change occurred in the process.

Activities

Lesson 1 Activity 1 and 2 – Relating to Atomic Structure, an Introduction

Students will be given a brief explanation of atomic structure and the key parts of the atomic design. An example will be shown of an atom referencing the amount of empty space it has. Students will then be instructed to draw a scale model of an atom large enough to fit on a quarter piece of paper. The atom given to students will be one of the first 8 elements. Students will then be given multiple colored spice drops to illustrate protons, neutrons, and electrons. Using these drops and toothpicks, students will be asked to create a model of their atom using them and explain each part of their model. Students will be allowed to eat their models only after answering questions on the structures of the atom and what the limitations are of their representations of when compared to an actual atom.

To illustrate the concept of atoms via empty space, students will be shown a demonstration (or possibly experiment themselves) with a cup of rubbing alcohol and a cup of water. They will be told to measure each out individually at one cup and then port the rubbing alcohol into the water. It will come up to less than 2 cups total and students will have to formulate a theory as to why this would occur and explain each step of their experiment in a lab report using the scientific method as the basis.

<u>Materials:</u> Long Toothpicks, Spice Drops, Rubbing Alcohol, Measuring Beakers, Scales, Water, Lab Sheet, Computer Paper

Lesson 2 Activity 1 and 2 – Organizing the Elements

To illustrate and let students learn how they organize things, I will give them 4 sets of paper. One of each set would be a different color and have a different number, 1-10 on them. The numbers would be piled on top of each other, all face up, and a student would ask a partner to get 'x' color and 'x' number. The student that requested these particular papers will time how long it takes for their partner to find them. They would repeat this step four more times to get a running average.

The students will then organize the strips by both color and numbers then repeat the color and number location step an additional five times. The times will be compared to illustrate the ease at which a table of organization can facilitate gathering the knowledge quickly in comparison to gathering the knowledge from a disorganized jumble of information.

The teacher will review the concepts of what elements are and composed of as well as what symbols and numbers mean on the periodic table. The teacher will also test student knowledge of atomic structure for specific elements. Once the teacher has confirmed students understand the basics of the periodic table, students will be given 10 note cards that describe several of the first 20 elements. Each card will have a different description on it that gives a hint as to which element it could be talking about.

Students will be broken up into groups of 2-3 and asked to place the cards they think are the element into an envelope under the representation of the element on the board. The first team to finish with all the correct elements wins. All cards will need to be laminated for multiple uses and given special colored paper clips to represent which group placed them in the envelopes for tallying.

Materials: Strips of Colored and Numbered Paper, Envelopes, Elements Cards (laminated), Periodic Table, Lab Sheet

Lesson 3 – Balloons: Atoms (Elements) vs. Compounds

I would like to get a balloon filled with hydrogen (and possibly oxygen in the same balloon). I would use this next to a regular balloon of the same size inflated with my breath (oxygen, carbon dioxide, and nitrogen). Students would make an inference as to what would happen based on the fact that there is oxygen in the air. I would use a lighter at a safe distance to combust the carbon dioxide balloon first to show students how oxygen can react with certain elements and compounds. The balloon would harmlessly pop due to the rubber of the balloon being superheated. Students would look at the chemicals involved and make an inference as to why no explosion occurred. I would then light the hydrogen filled balloon a safe distance away again, this time with a large explosion. All of these experiments would be done outside. Students will then make an inference as to why the hydrogen reacted quickly and violently with the oxygen in the air compared to the previous balloon.

Finally, I would pull out a water balloon and not tell students what is in it, only that it is the same elements that made the second balloon explode. They would make an inference (hopefully an incorrect one) that the balloon will explode with a large amount of force again. Upon lightning the balloon it will harmlessly pop, drenching the match in water. Students will need to explain why the same elements that make an explosion can also have a completely opposite effect when combined. The purpose is to not only show students how facts can sometimes lead to incorrect inference, but to give an example of elements and compounds comparatively.

Materials: Balloons, Hydrogen Gas, CO_2 Gas, Water, Lighter, String and a Weight, Lab Sheet

Lesson 4 – Law of Conservation of Mass and Reactions Lab

Using small plastic, sealed bags and specific instructions, students will use baking soda and vinegar to produce an exothermic reaction and yeast and hydrogen peroxide to produce an endothermic reaction. In addition, students can measure the individual parts before they combined them together, and then re-measure the mass. This will show students that mass in both reactions was neither created nor destroyed. As a third part, students should be able to visibly see the reaction occurring in both bags which should convince them that a chemical reaction is occurring as opposed to a physical reaction. This will all be commented on and theorized about on their lab sheet.

Materials: Vinegar, Baking Soda, Plastic Bags, Small Graduated Cylinders, Yeast, Digital Scale, Lab Sheet

Lesson 5 – Periodic Table Superhero Project

To complete their knowledge of the periodic table and the general introduction to chemistry, students will be given a project on the periodic table. They will be given several different options as to how to present this project. Students will be given instructions on what they need to do, what kind of presentations needs to be given, and which information is important. The four presentations students can choose from are: poster activity, live skit, comic book, or recorded skit. All students must present their project and answer questions in order to receive a grade.

Students will need to complete the following in completing their project: choose a superhero or villain, choose an element before 92, choose which type of presentation they will be giving, and make their character relatable not only to the audience but to their element. In addition to these, they will need to give all relative chemical information on the element they chose (atomic mass, atomic number, valence electrons, states of matter, physical and chemical properties, and what kinds of compounds it forms.

Conclusion

To reiterate, students learn by doing, this is my teaching philosophy. A mind can be molded to pass certain standardized tests without knowing the true art of discovery and inference. To quote William Butler Yeats: “education is not the filling of a pail, but the lighting of a fire.” This fire can only be lit if all of the elements are present, just like an actual fire. Students need a strong foundation of knowledge on which to experiment. The knowledge is gained through reviewing concepts and notes (fuel), they need a stimulating exercise to use this knowledge and build on it (heat), and they need to be genuinely interested in what they are doing for the trifecta (oxygen). Only when these three criteria are met, will a student soar and achieve a level of critical thinking that no book or person can teach, and this is what I am aiming for in completing this curriculum unit.

Appendix I – Common Core

Standard Integration

In the *Key Ideas and Details* section, students will be required to use the internet, texts, and independent notes taken to support any claims they make through inference in their lab work. The lab work itself will be done stringently along the lines of a uniform lab sheet that follows the scientific method. Students will need to know scientific terminology that they have learned in class and apply it to their experiments and activities. Student reasoning is also important in Science and the logical steps leading up to a correct inference. Students will also attain these inferences by using the materials available to them from the teacher.

Key Ideas and Details

CCSS.ELA-Literacy.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Craft and Structure

CCSS.ELA-Literacy.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics*.

Integration of Knowledge and Ideas

CCSS.ELA-Literacy.RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

CCSS.ELA-Literacy.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Appendix II – Student Work (Lab Sheets)

Problem:
____
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Materials List: ____________________________ ____________________________
____________________________ ____________________________
____________________________ ____________________________

Hypothesis:

I think that the following will occur:
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____
____
And I think that will happen based on the following observations or inferences:
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____
____
____

Procedure (Design an Experiment):

Write down every step of what you will do in order.

1) ____
2) ____
3) ____
4) ____
5) ____
6) ____
7) ____
8) ____
9) ____

Test your experiment. *Only after work before this section is done should you test your experiment.*

Analyze Data:

What happened? *(Be specific)*
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Draw a Conclusion:

Explain whether your hypothesis was right or wrong. How could you design this experiment to make it better?

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End Example Lab Sheet

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