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USING TRADITIONAL AND ALTERNATIVE ENERGY SOURCES AND THEIR ENVIRONMENTAL IMPACT AS A THEME FOR TEACHING HIGH SCHOOL CHEMISTRY

By

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ABSTRACT

USING TRADITIONAL AND ALTERNATIVE ENERGY SOURCES AND THEIR ENVIRONMENTAL IMPACT AS A THEME FOR TEACHING HIGH SCHOOL CHEMISTRY

By

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The purpose of my research was to increase student interest and content knowledge in chemistry by using the theme of traditional and alternative energy and their effects on the environment in my high school general chemistry courses. Students have been exposed to these ideas through the news, and the real-world connection engaged student interest. This theme involved an interdisciplinary approach, using information from courses they have already taken, such as Biology, Physics, and Earth Science. Activities and labs within the theme were used to teach conservation of mass, balancing, chemical reactions, thermochemistry, and electrochemistry.

My thesis is first and foremost dedicated to my wonderful mom and dad, who have been endlessly supportive and have always been there for me 100%. To my brother and sister, Zachary and Shannon, who always encouraged me and when I needed it most. To the greatest little brothers in the world (I have data), Gabriel and Tristan, who wanted status reports on my progress every day. I love you all so much.

This thesis is dedicated to the memory of my grandpa, Ray Holton, who passed away during my research, but was so excited for me and supportive of me in the pursuit of my degree. I love and miss you, grandpa.

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I. Introduction

Whereas many high school science classes often have compartmentalized topics, students can learn one unit, and the following unit may be on a completely unrelated topic, for the most part, high school chemistry tends to build upon itself. As my mentor teacher used to say, you are not allowed to forget anything. Students' attention may fluctuate throughout the school year, and because chemistry is so cumulative, it can be time consuming and difficult for students to "jump back in" and learn chemistry again, since often students must go back and learn previous material before being able to understand the current material.

Senioritis can be a huge grade-killer, and these poor grades can be devastating to students' college plans. Students are also missing an opportunity to build the skills they need in order to make them successful science students in college. Some students in my class do not plan to go into science and have a challenging class schedule. When the end of the term approaches and the homework becomes overwhelming, they decide to focus on classes in their future field of study. This behavior is understandable, but when they try to catch up on their chemistry, they face an even bigger challenge, as they step back to catch up on the old material before focusing on the new unit.

With an increased funding for research in different forms of energy production and our impact on the environment, we are being bombarded daily by news articles and updated information. While many of the emerging sources of energy may be considered cutting edge science, fundamentally they tend to break down into simple chemistry concepts that are taught at the high school level. (Weyman, 2009) Students are increasingly aware of the implications of human actions on the environment and what can be done in order to decrease our impact. As a result, many students are naturally curious about how energy is converted and how byproducts can harm the environment, as well as how these methods of energy conversion can be improved. As a result, this interest should translate into greater motivation and focus in the classroom. By utilizing the theme of traditional and alternative energy sources and their environmental impact, students can see a direct connection between their life and what they learn in the classroom. This connection gives students a direct context to their learning, allowing abstract concepts to become more concrete (Eick, Deutsch, Fuller, and Scott, 2008).

Prompted by seeing students last school year get very excited and interested in an environmental application, I decided to harness this interest in order to increase student motivation and learning.

As a result of this interest, the focus of my study is to assess the benefit of using traditional and alternative energy sources and their environmental impact as a theme, in order to engage student interest and increase their knowledge about the science behind these principles and the underlying content concerning chemical reactions, batteries, and thermochemistry. Student interest and knowledge about the science behind the topics in my theme were assessed using pre- and post-surveys, where common questions were evaluated with a T-Test, to determine if the change is statistically significant. The level of student understanding of chemical reactions, batteries, and thermochemistry was determined by pre- and post-test results in answering questions constructed using the Indiana State Standards. In keeping with my school and district goals, I determined whether students earned an average score of at least 70% per question.

Thematic instruction involves integrating overarching themes into the curriculum, often with real-world applications, incorporating multiple subject areas and methods of instruction. Commonly, elementary and middle school teachers utilize one comprehensive theme, which is incorporated through the entire school year. High school and middle school teachers often instruct using themes over smaller sections of the curriculum, as applicable, and may utilize multiple themes throughout the course.

Research has revealed that thematic instruction can be a powerful technique in the classroom, benefiting student interest and engagement in course content. (Focus on Effectiveness Webpage, 2005).

The literature suggests that thematic teaching also helps students make connections and organize the new material more easily in their minds (Caine & Caine, 1997). Perhaps as a result of this phenomenon, studies have shown that thematic teaching increases student achievement (Bean, 1997; Kovalik, 1994).

Thematic teaching often incorporates multiple subject areas, thus utilizing an integrated approach. Integrated instruction allows students to make connections between topics they already know, giving them a deeper understanding of the underlying principles. This contextualized knowledge allows students to answer questions faster and allow them to apply what they have learned in new ways. (Lipson, 1993)

Thematic teaching also often incorporates many different approaches to projects, taking into consideration students' different strengths, in keeping with the theory of multiple intelligences. Material was presented in a variety of ways, helping students who learn best linguistically, logically, spatially, and kinesthetically. These approaches can also give students a more rounded view of the material being covered, experiencing lessons by using different approaches (Gardner, 1993).

In utilizing my theme of traditional and alternative sources of energy and their impact on the environment, I have developed many new activities, incorporating a range of approaches and methods of assessment. The teaching theme was incorporated through labs both with given and student-generated procedures, video clips of simulations and applications, independent student research and a culminating group project, integrating and applying what they had learned in order to determine the best choices for their group. I considered the theme to be one of a range of effective teaching strategies at my disposal throughout the school year, and the theme was only used when it fit with the material being covered. As a result, the theme was taught mostly during the second semester, and it was not utilized in every lesson during that time period.

The topics taught while using the theme are not merely direct applications of Chemistry knowledge, but they also incorporated a wide range of other fields, both inside and outside of science. These interdisciplinary connections allow for practical applications to help enrich the standards-driven curriculum, which can also increase student knowledge. The literature indicates that an interdisciplinary approach is beneficial in helping students to more fully understand and learn new material (Perkins, 1986).

Within the context of my chemistry class, some terms may have more specific, limited definitions. Energy is considered the ability to do work, which includes kinetic energy, electrical, radiant, thermal, and energy stored in chemical bonds. Students also learned that energy is transferred, or converted from one type of energy to another, that this process is often not efficient, causing usable energy to change into a less useful form energy. An example of this is a traditional car engine – a chemical reaction occurs, releasing energy, but not all of that energy can be used to drive the car; some of this energy is converted to thermal energy, heating the car engine and the atmosphere.

This interdisciplinary teaching theme incorporates concepts form biology, physics, engineering, earth science, and ecology. Biological applications are inherent in the Carbon Cycle, which partially explains where carbon dioxide "comes from" and "goes to" during combustion, as well as how the biological processes of photosynthetic organisms can remove carbon dioxide from the atmosphere. Physics and engineering are required in order to develop motors, generators and other devices that run and store energy more efficiently. Engineers are developing and identifying the optimal materials for more efficient solar panels. All sources of energy utilize some form of energy conversion, from chemical reactions to mechanical and thermal energy in a traditional internal combustion engine, or from the wind's mechanical energy turning a turbine, and converting into electrical energy. A knowledge of earth science and ecology is also critical in order to more deeply understand these topics: from the effect of greenhouse gases on the planet's temperature to the potential of removing some of those gases through carbon sequestration. (Carbon sequestration can be achieved by pumping CO_2 underground basalt deposits in order for form insoluble carbonate salts such as calcite [$CaCO_3$] or dolomite [$CaMg(CO_3)_2$] at high pressure (Science Friday, 2008) Economic factors guide innovation in businesses, where the sciences are applied to solve real world problems, which should lead to a profit for the company funding research into alternative energy sources.

Because this theme encompasses multiple chemistry concepts, including conservation of mass, balancing chemical equations, reaction types, redox chemistry, predicting products, and themochemistry, the summary of the primary scientific ideas is rather long, and is summarized in the next several paragraphs.

Conservation of Mass is a scientific principle that states that matter cannot be created or destroyed. This means that the total mass of reactants will equal the total mass of the products, and that atoms will not disappear or suddenly pop into existence, as if by magic. If experimentally determined results suggest that mass may have been destroyed, then that could be due to products that were not recovered due to poor lab technique (spilled on the lab bench, coating beakers, etc.) or the formation of a gas that was not collected. The concept of conservation of mass leads to the idea of balancing chemical equations. Chemical equations are balanced by changing the coefficient in front of each molecule's formula, in order to represent how many of each molecule must react or be formed as a product. In a balanced chemical equation, the number of each atom must be the same on the reactants and products side, thus showing conservation of mass.

In my high school curriculum, students learn about the following reaction types and how to predict their products: synthesis, decomposition, single replacement, double replacement (including acid-base neutralization), and combustion. Synthesis reactions have products that are more complex than their reactants, and frequently within the scope of my class they involve the formation of a polyatomic ion or common molecules. An example of a synthesis reaction is the formation of water from hydrogen and oxygen gas.

Decomposition can be considered the reverse of a synthesis reaction, where the products are less complex than the reactants, and molecules are broken down. An example of a decomposition reaction would be the electrolysis of water, forming hydrogen and oxygen gas. Single replacement reactions involve one atom taking the place of another in a molecule, according to the activity series. When looking at the activity series, higher atoms can replace lower atoms, and cations replace cations, while anions replace anions. The general format of the reaction is $A + BX \rightarrow AX + B$. An analogy for this would be if a couple are ballroom dancing, and another man walks up, taps the male dancer on the shoulder, and asks to cut in. Now, the man who was dancing earlier is standing on the dancefloor alone. An example of a single replacement reaction is magnesium metal reacting with hydrochloric acid, forming aqueous magnesium chloride and hydrogen gas. Hydrogen was replaced by magnesium, leaving hydrogen alone. Double replacement reactions contain two binary molecules, where anions replace anions and cations replace cations. A chemical reaction occurs if a solid, liquid, or a gas is formed. The general format for the reaction is $AX + BY \rightarrow AY + BX$. An analogy for this would be two couples participating in the TV show Wife Swap. An example of a double replacement reaction is precipitating transition metals from solution, such as sodium iodide reacting with lead (II) nitrate to form sodium nitrate and solid yellow lead (II) iodide. In my chemistry curriculum, combustion reactions are limited to molecules with carbon and hydrogen reacting with oxygen gas to form carbon dioxide and water vapor. An example of a combustion reaction would be a log burning in a campfire.

Synthesis, decomposition, single replacement, and combustion are special cases of oxidation-reduction reactions, which describes an atom being oxidized and losing electrons, and another atom is gaining those electrons and being reduced. Students also learned the required parts of the electrochemical cell, how electrons spontaneously flowed in a battery from anode, where oxidation occurs, to cathode, where reduction occurs, and that they can determine what will be oxidized and reduced by consulting their Standard Reduction Potentials table, where $E_{cell} = E_{reduced} + E_{oxidized}$. If E_{cell} is positive, then the reaction is spontaneous and the battery will work as written.

The heat energy required or released in a physical change can be calculated by the equation q=mcdT, where q is heat energy, m is mass, c is the specific heat capacity, which varies according to the substance, and dT is the change in temperature. The heat energy required or released during a phase change is calculated by the constant for the latent heat of the substance being analyzed.

Most of my students take chemistry during their senior year as an elective, and have already taken biology, genetics and physics. These classes provide them with a scientific background and context to build on. These previous experiences allowed me to make connections with other subject areas without having to spend a lot of time teaching fundamental concepts from other classes. This allowed me to save time, giving me more freedom to incorporate these new activities, many of which are more time consuming than the ones they are replacing.

Talk among students in school is that my chemistry class is challenging, but that I am a fun teacher and the labs are cool. As a result, enrollment is high for my class, even though it is an "elective" science class (beyond what is required for graduation). Some of my students are capable but unmotivated, who walk into class on the first day and tell me they have no intention of doing any homework or taking notes; they just want to do the labs and "take in" chemistry.

My students are taking first year general chemistry as an elective course, mostly during their senior year. For the most part, they are college bound or career motivated students. My students attend Memorial High School in Elkhart, Indiana, one of two city secondary schools, each with a population of around 1800 students. At Memorial High School, 43% of the students are eligible for free or reduced lunch. Demographically, Memorial is 65% white, 17% black, 13% Hispanic, and 5% from a combination of other ethnic groups. (Great Schools Webpage, 2009) Geography also plays a role in Elkhart's diversity. Located within a 15 minute drive both to a Chicago commuter train line and a large Mennonite community, where horse drawn buggy is a common means of transportation, Elkhart is a city with small town values and urban problems.

Manufacturing of RVs and cabinets has been the major source of employment, and many of these jobs were lost during this school year, with unemployment skyrocketing to nearly 20%. These circumstances have changed between conducting my research for this project and teaching it. My students were accustomed to easy to find, stable, well paid employment without requiring a high school diploma, available at several businesses in town. Within this school year these opportunities have suddenly become very rare; the manufacturing industry is no longer full of secure, stable jobs. These realities suddenly are suddenly something that students must face, and try to adjust their plans for the future.

During my research for this project, I had an excellent opportunity to delve into current events and newer applications in alternative sources of energy. I also spent time learning the details about how biology, organic chemistry, general chemistry, physics, and ecology overlap with respect to the current energy science applications, as well as what my students have learned from their previous science classes. I found far fewer peer-reviewed articles that incorporated energy science lessons for a chemistry classroom than I anticipated. Of the available articles, most were at the university level or involved equipment beyond what is available to me at my school. At the time of writing this thesis, there were no published articles or resources for teachers incorporating these themes in a regular chemistry classroom.

A primary resource related to thematic teaching in chemistry was by Dr. E. Adams (2008), which was a Project Based Learning (PBL) activity coordinating university researchers with high school students studying air pollution in their homes, in the context of an independent study science course (Adams, 2008). Other related published activities included a calorimetry lab illustrating global warming (Burley & Johnston, 2007), and a demonstration where sulfur dioxide gas is produced and reacts to form acid rain (Goss & Eddleton, 2003), which I unfortunately could not adapt due to limited available supplies for my classroom.

II. Implementation

Student participants were only restricted from this study if they did not have their signed consent forms saying they would be willing to participate, or if they did not engage in the activities. My subjects consisted of a mix of students from all of my class periods; thirty-nine students and parents gave permission on the consent forms. Two students were excluded from analysis; one student due to total apathy and one missing because she was absent for most of unit. As a result, n=37 as my research group.

A. Activity Summary

Because my theme covers many different topics and approximately a semester-long period of time, I will include here only what I added to the curriculum as part of this project, listed in chronological order. This section does not contain comprehensive lesson plans covering the entire second semester.

Table 1: Summary of Theme Activities

Incorporated Activities & Instructional Goals	**Description**	**Topics Covered**
1. Pre-Survey To determine students' general attitude of students about chemistry and assess their level of motivation. *Appendix 1: Pre-Survey	Multiple choice and short answer questions.	• motivation, work ethic, willingness to do homework • interest in learning about the unit
2. Pre-Test To determine students' prior knowledge concerning the applicable Indiana State Standards. *Appendix 2: Pre-Test	Multiple choice, short answer, and free response questions covering all of the appropriate Indiana State Standards for Chemistry 1.	• balancing chemical equations • identifying reaction types • conservation of mass • predicting products and identifying phases • basic thermochemical calculations (using latent and specific heat)

Table 1 (cont'd).

3. Paper Clip Balancing To give students a hands-on balancing experience, while illustrating conservation of mass. *Appendix 3: Paper Clip Balancing	Working in groups to use paper clips to balance a given unbalanced chemical equation using the concept of conservation of mass. (Introduction to the concept of balancing chemical equations.)	• conservation of mass • balancing chemical equations (intro)
4. Reaction Type Demos To give students a physical example of each covered reaction type, while drawing a connection to the theme. *Appendix 4: Reaction Type Demos	1. *Synthesis*: formation of plastic. 2. *Decomposition*: Electrolysis of water. 3. *Single Replacement*: $Mg_{(s)}$ in HCl forming H_2 gas. 4. *Double Replacement*: Precipitation of lead ions from "drinking water". 5. *Combustion*: Whoosh bottle.	• identification of reaction types • predicting products (intro) • practice identifying products in a chemical equation by observation
5. Conservation of Mass Lab To give students a measurable example of conservation of mass, to build lab skills, and to make connections to combustion reactions where conservation of mass is still true, but more difficult to measure. *Appendix 5: Conservation of Mass Lab	Both products are solid after boiling away water solvent. $CuSO_4(aq)+Na_2CO_3(aq)\rightarrow$ $CuCO_3(s) + Na_2SO_4(aq)$ Lab tests the previously learned careful lab technique and lab analysis calculations. Also, practicing research using traditional and online sources is incorporated. Products are saved for future use.	• stoichiometry (review) • predicting products (review) • conservation of mass • reaction products & solubility • products of coal, gasoline, and incomplete combustion and their effects • clean coal technology

Table 1 (cont'd)

6. Reaction Types Lab To let students practice predicting products and experimentally confirm whether a reaction occurs. Also, I wanted them to draw the connection between reactions that occur in class and those that happen in "the real world". *Appendix 6: Reaction Types Lab	Students predict products for a series of reactions, then mix in well plates and search for evidence of a reaction and confirmation if they were correct in their predictions. Used Na_2SO_4 from Conservation of Mass Lab. Wrote out 5 reactions related to sources of energy and the environment, labeled reaction type, and explained what that reaction represents.	• identifying reaction types and predicting products. • connection between these reactions and the environment.
7. Post-Test Pt. 1 To assess student learning on covered material. *Appendix 7: Post-Test Pt. 1	Questions come from pretest. #1-9.	• balancing chemical equations • identifying reaction types • conservation of mass • predicting products and identifying phases
8. Coral Chemistry Article To show students how CO_2 in the air dissolves in water and is damaging corals. This article is useful because it incorporates several different topics the class is learning about. *Appendix 8: Coral Chemistry Article	Students read an article from Discover Magazine about the acidification of the oceans and its effect on corals and other sea creatures. Students answer comprehension and application questions based on the article, as well as doing basic research on carbon sequestration.	• carbon cycle (review from biology class) • predicting products (review) • making connections to acids, bases, and solubility equilibria. • carbon sequestration

Table 1 (cont'd)

9. Carbon Sequestration Video Clip To illustrate how this CO_2 could potentially be removed and help limit its negative effect on the environment. **There is no appendix entry for this video clip.*	Class discussion based on last assignment and video, connecting to chemistry. www.sciencefriday.com/program/archives/200807255	• chemical reactions – formation of insoluble salts (precipitation reactions)
10. Biodiesel Lab Pt. 1 To reinforce concepts about intermolecular forces, show the connection to environmental concepts, and to have prepared samples of biodiesel for lab pt. 2. *Appendix 9: Biodiesel Lab Pt. 1	Students synthesize biodiesel from waste vegetable oil and save for future thermochemical analysis.	• intermolecular forces (review) • stoichiometry (review)
11. Article To have students find and interpret the chemistry of articles in the news. *Appendix 10: Article Requirements	Students find a current event article written in the last two years about sources of energy or the environment, and students summarize the article in their own words, describe how it relates to chemistry and write their opinion or reaction to the article.	• topics are article dependent, but often they relate to one or more topics included in this theme.

Table 1 (cont'd)

12. Refining Aluminum Video To expose students to a high level chemistry explanation applying what they learned in class to understand new material. *Appendix 11: Refining Aluminum Video Questions	Students watch a short United Streaming video about the refining of Aluminum (an Indiana state standard). The video is at a high level, and is paused several times to allow students to process what was said, look things up in their book, talk in groups, and answer questions that directly connect the video to class content.	• solubility • electrochemistry (calculating Ecell, ½ reactions, spontaneous reactions)
13. Biodiesel Lab Pt. 2 Students can experimentally determine the heat of combustion of biodiesel and ethanol, to see the solid products of biodiesel combustion, and to make a logical judgement on their preferred fuel, considering their data, fuel costs, and other factors. *Appendix 12: Biodiesel Lab Pt. 2	Students devise a setup to test the heat of combustion of biodiesel and ethanol. Students compare the two fuels and determine the one they believe is the best option.	• combustion products • calculating heat of combustion from experimental data.

Table 1 (cont'd)

14. Battery Design Lab To determine if students understand the required parts of an electrochemical cell and build their own using convenient materials. If their battery doesn't work, they should problem solve to figure out how to "fix" their battery. I also wanted to engage my students by giving them the choice to design their battery with anything they want, using whatever design they want. *Appendix 13: Battery Design Lab Requirements	Students design their own electrochemical cells using anything they want. They calculate Ecell, sketch the battery and check their value actual value with a voltmeter. They propose why their value was not what they calculated. Follow up questions involve comparing modern internal combustion, hydrogen fuel cell, electric, and hybrid cars.	• electrochemistry (requirements for a electrochemical cell, calculating Ecell, • basic concept of circuits
15. Hydrogen Hopes Video from Scientific American Frontiers To get student interest, expose students to actual scientists who are currently making breakthroughs, and to be exposed to a range of different areas for advancement. Students should also be able to connect the carbon cycle to the section on CO_2 consuming algae. *Appendix 14: Hydrogen Hopes Video Questions	Video follows Stan & Iris Ovshinsky and their company's innovation in alternative energy, as well as a small amount of information about some other upcoming technologies. Students watch and take notes from the video to help them for the Alternative Energy Project.	• reaction types (review) • review of carbon cycle (biology class) • varying amounts of information about hybrid vehicles, hydrogen vehicles, solar panels, hydrogen producing and greenhouse gas consuming algae.

Table 1 (cont'd)

16. Alternative Energy Project Students consider local needs of their community and weigh pros and cons of each source of energy, while explaining the science. Students also must practice verbalizing these concepts in groups. *Appendix 15: Alternative Energy Project Requirements	Students join a group which represents the interest of: 1. The city of Elkhart 2. Elkhart Community Schools 3. Power Company (Indiana Michigan Power) 4. Local auto company 5. Rural farmer/homesteader 6. Commuters to Chicago Each student researches and addresses one energy category for their group, then they compile and share their findings.	• electrochemistry (redox, electrolysis, voltaic cells) • combustion products (CO_2, CO, H_2O, and others) • energy sources for houses, cars, the effect of greenhouse gases and recycling
17. Post-Test pt. 2 To determine students' current knowledge concerning the applicable Indiana State Standards after lessons are completed. *Appendix 16: Post-Test Pt. 2	Questions come from pretest. #10-12.	• basic thermochemical calculations (using latent and specific heat)
18. Post-Survey To determine students' current attitude of the activity's effectiveness, their motivation, and reasons for their level of motivation. *Appendix 17: Post-Survey	Multiple choice and short answer questions.	• motivation, work ethic, willingness to do homework • effectiveness of each activity • interest in learning about sources of energy and environmental impacts • perceived understanding of underlying chemistry concepts behind related news.

While several activities found in Table 1 are clearly directly connected to my theme, others are more ambiguous. The connections that are not clearly stated in the table will be explained more fully here. The *Paper Clip Balancing Activity* (Appendix 3) prepares students for environmental applications such as the *Conservation of Mass Lab* (Appendix 5) and the *Biodiesel Lab Part 2* (Appendix 12), introducing the concept of balancing and the conservation of mass. The *Reaction Type Demos* (Appendix 5) not only prepare students for the *Conservation of Mass Lab* (Appendix 5), but the demos themselves illustrate alternative energy connections, such as the production of hydrogen gas and the combustion of ethanol.

Conservation of mass is an important consideration in combustion; though carbon dioxide cannot be seen or easily weighed, it is still being released into the environment. *The Conservation of Mass Lab* (Appendix 5) allows students to react substances where both products are solid, so they can take measurements in order to more fully understand the relationships and understand how carbon dioxide is released into the environment. The *Reaction Types lab* (Appendix 6) allows students to practice predicting products, including formation of hydrogen gas. This lab also includes an application where students come up with their own environmental reactions and predict products.

B. Personal Reflections on Activities' Success

Students' focus and motivation varied throughout the activities associated with the theme, but as a rule, students were engaged throughout these activities. Below is a summary of qualitative data based on personal observations, collected to help determine the level of success for each activity.

Students took the *Pre-Survey* (Appendix 1) and *Pre-Test* (Appendix 2) seriously. I told students that they would get credit as long as they answered every question, and as a result all questions were answered. In the case of the pre-test, students did not score well, but since they had not yet learned the topics, I would suggest that this is a positive sign; if they knew the material before the lessons are taught, then my instruction should cover other topics. Students also took the post-survey and post-tests seriously. My post-test assessments were embedded in class tests, and students tend to find my tests to be challenging. Students commented that all the tested material was covered in class, but that test anxiety and lack of studying can hurt some of their scores.

The *Paper Clip Balancing Activity* (Appendix 3) required me to do three or four different examples in front of the class using paper clips so they became familiar with the procedure, and for most students the first few questions that they worked out in groups took a considerable amount of time, but the remaining questions were answered in a much quicker timeframe. I found it interesting that students said they were familiar with how to balance chemical equations, but the majority did not balance correctly without instruction. The most common mistake was to change subscripts or to put a coefficient in the middle of a molecules' formula (for example, $C\underline{2}O_2$). Students were engaged and were getting the correct answers as I walked around during the activity.

Students enjoyed the *Reaction Types Demos* (Appendix 4), and they were interested in how these reactions model uses and applications in the "real world". Analysis of these demos were broken down in a step-by-step presentation, in order to help students build their critical thinking and analysis skills and to help them identify important concepts. For the most part, my students needed a significant amount of coaching during the discussion questions for the first few demos and to identify products. Students became more confident, and more students volunteered answers as we went through the demos. Students were gaining experience in predicting products and identifying products of chemical reactions through observation.

After an uncertain start by many students, after consulting their lab partners and their notes, they began the *Conservation of Mass Lab* (Appendix 5). Students were motivated and working the whole time, and seemed excited about using their product in a future lab. Overall I think this lab was a helpful experience, both in reinforcing required concepts, and in gaining new experiences. This lab revealed that I still had have students in each class period that needed to develop better lab skills. Lab technique drastically affected data in this particular lab. In fact, some lab groups could not measure Conservation of Mass directly from their data due to significant loss of product. This lab was at the end of the third marking period and I was concerned that students would not do the lab analysis and not turn in their work, since this tends to be common behavior. Since I am gaining data on quality of student responses and not the quantity, I announced that this lab was going to worth the same number of points as a test, and that I would extend the deadline. Several students mentioned that they were so busy that if the lab weren't worth as many points they probably would not have done it. Of these students, most had commented that they were glad they did, because they were interested what they had learned during the research.

Overall, I believe the *Reaction Types lab* (Appendix 6) was effective. Students were very engaged throughout the lab, and they really enjoyed testing mini-samples, trying to observe chemical reactions. In fact, a student that I had been working hard to motivate since the beginning of the year suddenly "clicked in" during this lab. From this lab on, she would take notes, try to do homework, and even came in after school to catch up and ask questions. As a teacher, moments like this are what make it all worthwhile.

The *Coral Chemistry Article* (Appendix 8) was given to the class as a bonus opportunity on a test review day, and as a result, I got fewer back. I originally intended this as a homework assignment, but I had to change it due to a tight schedule. The participating students were very engaged. I saw students leaning over and saying, "Did you read this part yet?" or asking me questions about things not directly addressed in the article. Several days after the bonus was collected a student told me he had just read about different coral species and the harm that carbonic acid can do to them. This article is connected to my theme because it describes how carbon dioxide, a major product of combustion, is harming corals in the ocean.

The *Carbon Sequestration* clip followed a recap of the Coral Chemistry Article. Students seemed interested, and they liked the simulation of carbon sequestration. I believe this clip was most useful to students who did the Coral Chemistry Bonus, and for the others it was useful only on the level that it introduced the concept and the chemistry involved.

Of all of the lab activities, students were least excited during the *Biodiesel Lab Part 1* (Appendix 9). Students said the procedure was simple and quick, and they were impatient to start burning. "Can't we just burn it today?" This lab did not take much time to do in class, but there is a waiting period while the solution reacts completely. On the other hand the students seemed genuinely interested in burning *their* lab sample later. I think this portion of the lab is what it was meant to be – it made connections with previous topics, it did not take up much class time, and students created a sample that could be analyzed later.

The student selected *Article* (Appendix 10) seemed to work reasonably well, though it varied according to student and the article they chose. Some of my students commented that they liked finding an article they are interested in, and a few students saw me in the hallway and kept asking me if I had read their article yet, sometimes during the same day they had turned it in! On the other hand, other students most likely selected the first article they found, basically quoted the article instead of summarizing in their own words, not explaining the chemistry behind the article. I believe that because it could apply to a wide range of articles, students get out of it what they put into it.

I feel that using the *Refining Aluminum* video clip (Appendix 11) gave my students an excellent opportunity to further develop their critical thinking skills because the analysis questions demanded that students think things through and make conclusions in order to answer the questions. The questions were laid out so students could work together and make small steps, leading to larger conclusions. Several students were a little frustrated because answers were not stated explicitly in the video, but I utilized scaffolding to help keep them moving forward as necessary. I feel this was an important experience for my students, because again it helped them stretch their logical thinking skills, but I understand that my students felt it was more like work than fun. I am comfortable with that assessment. Not everything that is beneficial for students will be the most exciting thing they do that day.

My students had been waiting for the *Biodiesel Lab Part 2* (Appendix 12) since they had made their biodiesel, and they were always excited about fire and burning.

Students appreciated the freedom of designing their own lab setup for burning their fuels. The amount of soot produced through the burning of biodiesel shocked many students. I also had business-minded students that mentioned they appreciated having to consider the cost of the fuel when answering some of the analysis questions in addition to the chemistry. Students remained engaged, even through the calculations, which is where students most often would stop working on lab activities.

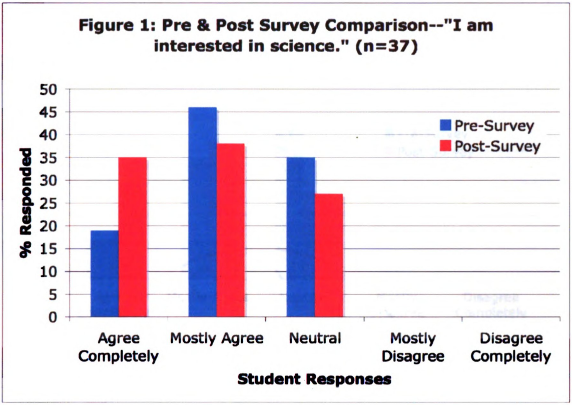
For the *Battery Design Lab* (Appendix 13), students were hesitant at first to start designing their batteries, most likely because they were overwhelmed by possibilities. I allowed students to use literally anything that was not dangerous or illegal, either in the lab or from home, and their design was completely up to them. Students made batteries using Capri Sun pouches, lab stools, pop cans, scoopulas, paper towel salt bridges, and so on. I even had a student who made an elaborate series of beakers, wiring up each successive electrode with complex loops around their metal samples. Many students were engaged and enjoyed trying out their creative theories and designs, and it really reinforced what requirements there are for electrochemical cells, such as having a salt bridge, using different metal samples as the anode and cathode. The application questions were often thoroughly answered and researched by the students, but some students only answered very generally, implying that they answered based on what they already knew or learned in chemistry class.

Students tended to be very attentive during the *Hydrogen Hopes* video (Appendix 14), and several students commented that they would like to meet Stan and Iris Ovshinsky, and that they seemed like really smart and fun people. Students expressed interest in whether the innovations are even more advanced now, after the video was produced.

Alternative Energy project (Appendix 15) was given as a bonus activity, because it was the end of the school year, and our class was out of time. Students could refer to their previous assignments and do any necessary additional research to answer the questions. Few students turned in this bonus; it was due on exam day. This is unfortunate, because the projects I did get were excellent. Students seemed to appreciate the connection to local people and their community, and I overheard students saying, "Our city should really be doing this."

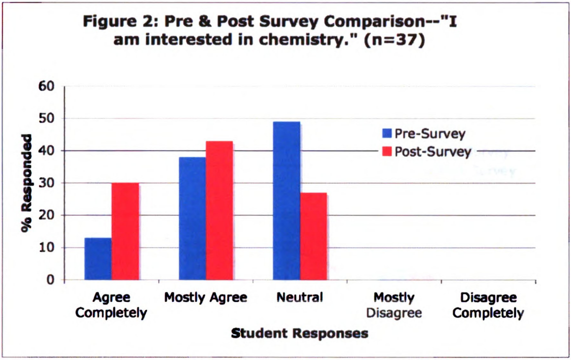
III. Results/Evaluation

In order to understand the objective data, some of my *Pre-Survey* (Appendix 1) and *Post-Survey* (Appendix 17) questions attempted to assess student interest and motivation. The Pre-Survey was given at the beginning of the school year, prior to my teaching the activities, and the Post-Survey at the end of the school year, after all lessons were taught. The data shows an increase in interest from Pre to Post Survey for each question. The five common questions were the same on each survey, the results of which will be directly compared below.



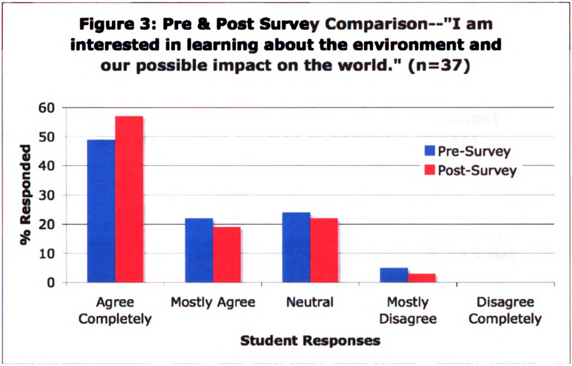
As Figure 1 reveals, all students were at least neutral in their opinion about science, and that in the Post-Survey student interest had increased, with the largest difference occurring due to the increase in students that completely agree they are interest in science. There was a 16% increase in students who agreed completely.

Figure 2 evaluates student interest specifically in the field of chemistry.



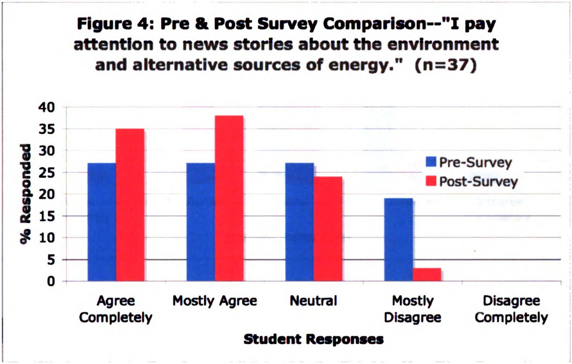
On the Pre-Survey, the majority of the responses were neutral, and at the time of the Post-Survey, the majority of students mostly agreed that they were interested in chemistry, while there was a 17% increase in students that completely agreed that they were interested in chemistry.

Figure 3 compares pre and post survey data describing student interest in learning about the environment and our impact on the world.



As seen in Figure 3, there is only an 8% increase in the number of students who completely agree that they are interested in learning about the environment and our possible impact on the world. In both Pre and Post Survey responses, the majority of students completely agree that they are interested in these topics. This is a positive finding, since I selected my research topic on the assumption of student interest. Only one student (3%) is not interested in learning about the topic on the post-test, there is an overwhelmingly positive response, in spite of the overall small difference in student opinion.

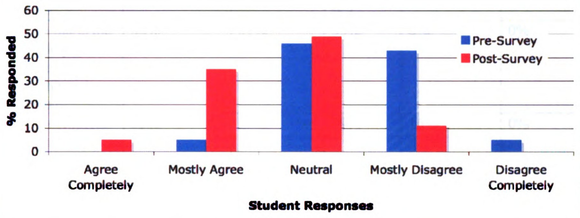
Figure 4 shows the change in responses from Pre to Post Survey, showing the level of student attention to news stories related to my theme.



Data from Figure 4 shows that there is a clear increase in students paying attention to news stories about the environment and alternative sources of energy, with the majority of the students responding that they mostly agree. The data reflects a 19% increase in positive responses on the post-test, which is a significant increase.

Figure 5 compares students' perceived understanding of the science behind news stories about the environment and alternative sources of energy, before and after my theme was taught.

Figure 5: Pre & Post Survey Comparison--"I feel like I understand the science behind news stories about the environment and altnernative sources of energy."



Though Graph 5 indicates a small number of students responded that they completely agreed with the statement during the Post Survey, there is a dramatic increase in more positive responses, with the most common responses being that they mostly agree or give a neutral response, whereas in the Pre Survey the most common responses were that they mostly disagreed or a neutral response. Overall, the post-test results show a 35% increase in students who either agree completely or mostly agree, which is a significant increase.

The remaining Pre-Survey questions were not asked in the Post-Survey, and are summarized in Table 2 below.

Table 2: Non Common Pre-Survey-Responses Organized by Percentage (n=37)

Questions	Agree Completely [A]	Mostly Agree [B]	Neutral (don't agree or disagree) [C]	Mostly Disagree [D]	Disagree Completely [F]
3. What is the grade you expect to earn in chemistry class?	38%	27%	35%	0%	0%
4. I complete homework regularly.	35%	30%	19%	16%	0%
5. I use most success periods doing my homework.	19%	30%	41%	11%	0%
6. I finish my homework at home three or more days a week.	22%	32%	30%	11%	5%
7. I don't usually get assigned homework in other classes.	3%	14%	32%	38%	14%
8. I rarely have to take homework home with me.	3%	16%	30%	38%	14%
9. I am interested in learning about the environment and our possible impact on the world.	49%	22%	24%	5%	0%

When studying the non-common Pre-Survey results (Table 2), interesting student trends emerge. According to the survey, 65% of my students expected to earn an A or a B in chemistry class, which is the same percentage of students who completely or mostly agree that they regularly complete homework. Question 5 shows that 49% of my students use success period, which is the name of Memorial High School's study period. Just because students do not use their study period for homework does not necessarily mean that they do not regularly complete their homework, since school clubs and any music meetings, such as band or orchestra, are held during this period. The data also shows that 49% of my students stated that they usually are not assigned homework in other classes, or they gave a neutral response, with a similar response from students who do not usually have to take home their homework. I find this response difficult to believe, but I do not personally have any information about the amount of homework assigned in other classes. While I understand that an incredible amount of homework does not equate to greater learning, I find this data a little troubling, since these students will most certainly have extensive, high-level homework in college.

71% of my students were interested in learning about the environment and how they may impact the world, and only 19% of my students stated that they did not pay attention to news stories about the environment and alternative sources of energy. Only 16% stated that they felt they knew a lot about the environment and our possible impact on the world, and only 5% felt like they understood the science behind news stories about the environment and alternative sources of energy. These data support my original assumption that students would be interested in my theme, and that students did not already have an in-depth knowledge of these science topics especially as they relate to chemistry.

Very interesting responses can be found in the non common post-survey results (Table 3).

Table 3: Non Common Post-Survey Responses by Percentage (n=37)

Question	Agree Completely	Mostly Agree	Neutral (don't agree or disagree)	Mostly Disagree	Disagree Completely
3. I completed all of my chemistry homework during 4th Marking Period.	49%	24%	16%	11%	0%
4. "Senioritis" hurt my chemistry grade.	3%	19%	16%	22%	41%
5. I was motivated in chemistry during 4th Marking Period.	38%	35%	16%	11%	0%
6. My motivation increased during 2nd Semester.	8%	38%	27%	24%	3%
9. I was NOT interested in the environmental connections in class.	0%	3%	22%	51%	23%

Table 3 (cont'd)

11. I feel that I benefited from how energy and the environment were worked into the chemistry lessons.	16%	57%	24%	3%	0%

When analyzing the non-common Post-Survey results (Table 3), there are several interesting findings. Of students analyzed, 49% completely agree that they completed all homework during the last marking period, 73% stated they were motivated during the final marking period in chemistry, and 46% experienced an increase in motivation during 2^{nd} Semester, which was the period of my study. This increased motivation can also be attributed to students trying to pull their grades up before the end of the school year. On the other hand, 22% of my students said that "senioritis" hurt their chemistry grade.

The collected data show that only 3% (1 student) were not at all interested in the class's environmental connections, and they also did not feel that they benefited from the integration of these topics in my lessons. All other students were interested and felt they benefited, or they gave a neutral response.

My post-survey also included a list of theme activities, which students sorted according to perceived helpfulness (Table 4).

Table 4: Post-Survey Evaluation of Activity "Helpfulness" (n=37)

Activity	Very Helpful	Helpful	A Little Helpful	Not Helpful	Did Not Do This Activity
12. Paper Clip Balancing	0%	43%	57%	0%	0%
13. Reaction Types Demos	8%	46%	35%	5%	5%
14. Conservation of Mass Lab	16%	49%	30%	5%	0%
15. Reaction Types Lab	27%	38%	32%	0%	3%
16. Coral Chemistry Article Bonus	24% (53% of participants)	19% (41% of participants)	3% (6% of participants)	0%	54%
17. Carbon Sequestration Video	19%	38%	43%	0%	0%
18. Biodiesel Lab Pt. 1	0%	30%	49%	22%	0%
19. Article	3%	62%	19%	3%	12%
20. Refining of Aluminum Video Clip & Questions	16%	3%	22%	30%	0%
21. Biodiesel Lab pt. 2 – Combustion	35%	38%	19%	5%	3%
22. Battery Design Lab	22%	57%	14%	8%	0%
23. Hydrogen Hopes Video	16%	30%	27%	14%	14%
24. Alternative Energy Bonus	8% (57% of participants)	11% (43% of participants)	0%	0%	81%

Generally, I think this information is useful, but student perception of "helpfulness" may be influenced by how much they enjoyed an activity, or their responses could be skewed if they did not complete the activity they are ranking. Keeping these limitations in mind, these data suggest that students found all of the activities helpful. Due to lower participation for the *Coral Chemistry Article* (Appendix 5) and *Alternative Energy Project* (Appendix 5) bonus assignments being much lower, it is more difficult to collect reliable data. Also, many who participate in bonus activities may be more diligent and self-motivated students, so results for these activities may be skewed.

The *Paper Clip Balancing activity* (Appendix 3) was considered to be helpful overall, giving students a visual means to understand balancing chemical equations, but no students classified it as very helpful. Since students had been exposed to balancing three years ago in Biology, they already had a head start on the topic covered. *The Reaction Types Demos* (Appendix 4) and *Conservation of Mass Lab* (Appendix 5) were well received, with only 5% feeling they were not helpful. The student driven analysis during the demos was pretty rigorous, as seen in the related Appendix, and the Conservation of Mass Lab contained many calculations. It appears that a few students may have felt left behind or did not make the desired connections during these activities.

All students who participated in the *Reaction Types Lab* (Appendix 6) classified it as at least a little helpful, with 65% considering the activity to be either helpful or very helpful. All students who participated in doing the *Coral Chemistry Article* activity (Appendix 8) and the *Alternative Energy Bonus* (Appendix 15) found it helpful, but participation was extremely low, with the Coral Chemistry Article having 54% not participating and 81% not participating in the Alternative Energy Project. Of the students who have participated in the Coral Chemistry activity, 94% found it helpful or very helpful, with the remaining 6% finding it a little helpful. Of the participants in the Alternative Energy activity, 100% found it helpful or very helpful. The *Carbon Sequestration video* was considered 57% helpful and very helpful, and the remaining 43% found the activity a little helpful.

The *Pre-Test* (Appendix 1) and *Post-Test* questions were identical, and were written based on the Indiana State Standards for chemistry. In multi-step problems partial credit was awarded, one point for every step, including a point for correct significant figures and units, following the answer-key rubric I wrote. Data was collected for each question utilizing t-test analysis, where n=37, and for each question student improvement is statistically significant (Table 6). For the pre-test, I offered points to students who attempted to answer all questions, even if they were not sure or gave the wrong answer.

Table 6: Comparison of Pre & Post Test Results (n=37)

Question Topics	T-Test Results	Meaning
1. Balancing, Rxn Type & Ox. # MC (1 pt.)	-4.48	P = 0.000; statistically significant
2. Balancing, Rxn Type & Ox. # MC (1 pt.)	-5.84	P = 0.000; statistically significant
3. Balancing, Rxn Type & Ox. # MC (1 pt.)	-3.97	P = 0.000; statistically significant
4. Describe a procedure for determining conservation of mass (5 pts)	-14.1	P = 0.000; statistically significant
5. Predict Products, balance, write phases and rxn type (4 pts)	-16.9	P = 0.000; statistically significant
6. Predict Products, balance, write phases and rxn type (4 pts)	-12.8	P = 0.000; statistically significant
7. Predict Products, balance, write phases and rxn type (4 pts)	-11.4	P = 0.000; statistically significant
8. Predict Products, balance, write phases and rxn type (4 pts)	-13.4	P = 0.000; statistically significant
9. . Predict Products, balance, write phases and rxn type (4 pts)	-13.4	P = 0.000; statistically significant
10. q = mcdT calculation (5 pts)	-15.3	P = 0.000; statistically significant
11. dHvap calculation (5 pts)	-3.43	P = 0.002; statistically significant
12. dHt = q + dHvap calculation (5 pts)	-7.72	P = 0.000; statistically significant
13. Electrochemical Cell (5 pts)	-8.66	P=0.000; statistically significant

Questions 1-3 are multiple choice questions that require students to identify the correct reaction type, oxidation numbers, and balance chemical equations. Commonly selected incorrect answers included balancing while changing the subscripts or misidentifying the oxidation number due to not using molecule charges and ensuring they add to zero.

Question 4 allowed students to write a procedure for determining the conservation of mass where no gas is produced. Pre-test answers tended to be vague. One such example was a student that said "Mix ingredients together and they react, so you get your masses." A common mistake was to explain a detailed procedure but not state that they need to mass reactants or products. One particularly good student response was: "Weigh all containers before placing any reactants inside of them. Weigh reactants. Add water, mix the chemicals and water mixture to create a reaction. Filter solid product and boil away water. Weigh everything after it has reacted and subtract out the mass of the containers holding the chemicals. Hopefully you end up with the same number as the mass of the reactants before the reaction. Remember, you cannot create or destroy any matter in a reaction. If the mass is more than before then something was contaminated or wet. If the mass is less than before then some chemicals must have spilled out of the beaker."

Questions 5-9 required students to predict products, balance, write phases and reaction types. In the pre-test, students tended to jam atoms together into one large compound. (For example, Zn + HCl → ZnHCl was a common answer.) In the post-test, most common errors were to forget common ion charges or not make the atom charges in the molecules add to zero. ("$1Zn_{(s)} + 2HCl_{(aq)} \rightarrow 1H_{2(g)} + 1ZnCl_{(aq)}$", where the charge of zinc in ZnCl has a charge of +1 in their response instead of the correct response, $1Zn_{(s)} + 2HCl_{(aq)} \rightarrow 1H_{2(g)} + 1ZnCl_{2(aq)}$, where Zn has a +2 charge in $ZnCl_2$.) Another repeated error was found in #6, where some students noticed the reaction is decomposition, but did not write the most common product [$1KClO_{3(s)}$ + Heat →

$1KCl_{(aq)} + 1O_{3(g)}$, instead of the correct answer of $2KClO_{3(s)}$ + heat → $2KCl_{(s)}$ + $3O_{2(g)}$.]

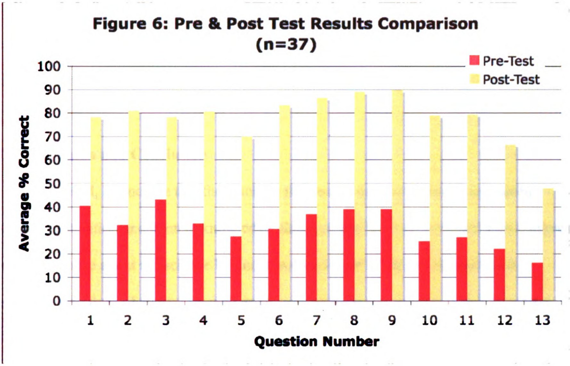
Questions 10-12 are thermochemistry calculations. On the pre-test, most students who earned points got them based on writing the correct number of significant figures and units, rather than doing the calculations correctly. Students who had previously taken physics were at a distinct advantage, if they remembered the equation and concepts. In order for students to answer question 10 correctly, they must remember and use the equation q=mcdT, and several students wrote this equation on their paper, earning at least partial credit. Post-test results were much improved, with more students using the correct equation, or on occasion solving for dT, even if they did not remember the equation or used the equation incorrectly.

Question 11 is a calculation involving dH_{vap} as a conversion factor, with the constant provided with others on the question sheet in a list of useful information. Of the responses that earned points on the pre-test, students often wrote the correct units, since the question specifically asks for energy. Since dH_{vap} is also used in physics class, it was surprising to me that only 3 more points were earned on question 11 of the pre-test than question 10. In my experience, for whatever reason, my students tend to latch on to the "easy to remember" q=mcdT equation, and they have a harder time calculating dH_{vap}, since there is no equation involved, and students feel like there should be an equation they are not remembering. In actuality, question #11 should be even easier to solve correctly, since students to not have to memorize anything, dH_{vap} is provided, and students just need to use the units to tell them how to solve.

Question 12 is a three-step problem, where the solution is the sum of q=mcdT from 22.0-100.0 ^{o}C and 100.0-110.0 ^{o}C plus the energy calculated from dH_{vap}. Since this question is a combination of concepts from questions 10 and 11, it is logical that this score is lower than the previous questions. The most common mistake for this question is to only solve for q=mcdT, where dT was solved from 22.0-110.0 ^{o}C, completely missing the amount of heat energy required to boil the water.

Question 13 asks students to draw and label a picture of an electrochemical cell or battery. During the pre-test, students often drew a picture of an AA battery, with arrows pointing to the "+" and "–" end of the battery. In the post-test, most students showed beakers, as represented in our textbook, with a wire connecting the anode and cathode. Salt bridges or labeling anode, cathode, and the flow of electrons were the most common missing parts of the electrochemical cell.

Pre and post-test results were analyzed using a result comparison per question, and in each case, students demonstrated marked improvement (Figure 6).



There is an increase in scores for each question when comparing pre- to post-test, with an increase from 32% up to 54% average. The average percentage when comparing post-test responses ranges from 48% to 90%. My students achieved the goal 70% minimum per question goal for 11 of the 13 questions, with several questions scoring within the 80%-90%. As stated above, students commonly did not solve Question 12 as a multi-step thermochemistry problem. Though the individual calculations in this question are no harder than those found in questions 10 and 11, which students scored 79% and 80% for each of these questions respectively, and an average of 67% for question 12. This result may be due to the fact that students who solved question 10 correctly did not necessarily solve question 11 correctly, As a result, any student who incorrectly solved number 10 or number 11 would mean they may also miss points in question 12.

Students scored only 48% on question 13, with the lowest pre-test score of only 16%. One potential reason for the lower score on this question could be that there was no list provided of everything they must draw and label, and so students might not remember everything to label, even if they did completely understand the components in the electrochemical cell.

IV. Discussion and Conclusion

Overall, I conclude that the teaching theme was quite effective in increasing student motivation and content knowledge. Students indicated an increased focus, interest, and knowledge about the science behind news stories about the environment and alternative sources of energy, as well as an increased interest in science and chemistry, with statistically significant results. Students also reached the 70% minimum goal on 11 out of the 13 questions.

My subjective impressions confirm these data. Student interest was high for all activities, and even a few students who rarely do any homework completed the majority of the assignments in this theme. Students would come to me and ask me about the chemistry of things they had thought about more deeply, or tell me about stories they had heard on the news or from other students. One such example is the previously discussed student who told me what he discovered about how carbonic acid harms a particular type of coral. Students would also want to discuss and find out more information about local environmental stories such as methanol being collected from the dump to power the county jail, and a local business using biodiesel to power their delivery vehicles.

I found that my teaching theme required more planning and preparation than I originally anticipated. In a sense, the amount of work is greater than reinventing the traditional chemistry curriculum "wheel", because there are several other considerations than just chemistry content. Integration with previous courses required delving into curricular content for multiple classes, as well as researching current developments in my theme, finding resources and creating activities to reflect and forge connections to the theme. While developing the theme, I found I had to constantly question whether the activities would help increase my students' knowledge and understanding of the required chemistry content, or if it would only be interesting and fun, but not directly tied to the required chemistry curriculum. There was no time in the curriculum for a teaching theme of solely enrichment activities. Time is an important consideration, as the Indiana State Standards for chemistry are very difficult to cover within this limited amount of time in an engaging way (using labs and activities, not just lecture).

I attempted to accommodate more theme-based content by adding some application materials on as homework, and for the most part I feel this was successful. Most students completed these assignments in their entirety, even though the research portion was more time consuming, involving online research and analysis outside of the classroom. Some students clearly copied off of their friends' paper, and I had some concerns about students plagiarizing. In the future I will ensure that I go over how to avoid plagiarizing at the beginning of the school year, and will make it clear that they can approach me with help or questions, but if I find that they had copied material that they would fail the assignment.

Even given the precautions I took to save as much time as possible, I still found that we were running out of time and had to turn two activities into bonuses. After teaching my theme this year, I have learned more about what slows down the pace of these activities, and with slight adjustments next year, I believe I will be able to teach the entire theme as originally intended, without having to convert activities into bonus assignments.

In the future would also modify some of the theme-based activities. The pre and post-test question 13 will be rewritten in order to ensure that I have clear information to determine exactly what students do and do not know about the structure and components of an electrochemical cell, as it was difficult to draw conclusions about why students scored so poorly as written.

In order to more smoothly incorporate my theme and ensure my students make the connections, I would add five more reactions at the end of the pre-lab on the *Reaction Type Lab* (Appendix 6), where students predict products, and I ask a question where they explain the reactions and how they apply to our classroom theme. Since completion of the pre-lab is required in order to perform the lab, this would ensure they actually make this connection, and it does not get overlooked. Also, for the Biodiesel Lab Pt. 2, I would limit the sources students use for determining the costs of ethanol and biodiesel, in order to gain more consistency in student responses and make the values more closely tied to our community. In the future, only sources published within the last month within fifty miles of the school will be allowed.

It is very tempting to describe my theme as Green Chemistry, but that would not be an accurate description. According to the EPA, green chemistry is the "design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances." (EPA, 2009) I carefully collected and disposed of products in a responsible way, and I believe these demos and labs helped increase student awareness, which may help shape their personal choices in the future. Though my teaching theme encourages awareness and understanding about chemistry's environmental impact, for the most part, the labs could not be considered environmentally friendly. I would like to "green" my labs as much as possible, incorporating more microscale activities and limiting the use of polluting chemicals such as transition metals when possible. I would also like to revamp the entire chemistry lab sequence, taking the products from one lab and using it as a reactant for a future lab, in order to limit the number of chemicals to be purchased and disposed of.

After my research was completed, several interesting, new articles were published that I will use in the future. One such article gives links to new internet resources can be used to teach environmental chemistry, which contains many possible resources with which to create or modify my theme-based activities (Diener, 2009). Another new resource I would like to use is found on the National Science Teacher Association web page, where an excellent Power Point presentation entitled "The Heat is On! Climate Change and Coral Reef Ecosystems" can be found. This resource contains excellent, clear information, including an astonishing amount of clear data linking chemistry and biology concepts to the environment. Portions of this Power Point could even be used directly in a chemistry lesson to illustrate these connections (Gledhill, 2009). By utilizing these new resources, modifying the theme-based activities described out above, and adapting the classroom labs to be "greener", my teaching theme of traditional and alternative energy sources and their impact on the environment should be even more effective.

APPENDIX 1: PRE-SURVEY

Answer the following questions using the following scale:

A – Agree completely! B- Mostly agree C- Neutral (don't agree or disagree)

D- Mostly disagree E- Disagree completely!

OR for questions about grades:
A = A B = B C = C D = D E = F

1. I am interested in science.
2. I am interested in chemistry.
3. What is the grade you expect to earn in chemistry class?
4. I complete homework regularly.
5. I use most success periods doing my homework.
6. I finish my homework at home three or more days a week.
7. I don't usually get assigned homework in other classes.
8. I rarely have to take homework home with me.
9. I am interested in learning about the environment and our possible impact on the world.
10. I feel like I know a lot about the environment and our possible impact on the world.
11. I pay attention to news stories about the environment and alternative sources of energy.
12. I feel like I understand the science behind news stories about the environment and alternative sources of energy.

APPENDIX 2: PRE-TEST

Choose the answer with the correct balanced equation, reaction type, and oxidation numbers for every atom. (C.1.9, C.1.10, C.1.22, C.1.27)

1. $Cu + O_2 \rightarrow CuO$

   a. $Cu_2 + O_2 \rightarrow Cu_2O_2$ Combustion — Cu=+2, O=0
   b. $2Cu + O_2 \rightarrow 2CuO$ Synthesis — Cu=0, & O_2=0→ Cu^{+2} & O^{-2}
   c. $Cu_2 + O_2 \rightarrow Cu_2O_2$ Synthesis — Cu=2+ & O_2=-2→ CuO=0
   d. $2Cu + O_2 \rightarrow CuO_2$ Synthesis — Cu=0, & O_2=0→ Cu^{+2} & O^{-2}
   e. None of the above

2. $Al + O_2 \rightarrow Al_2O_3$

   a. $Al_2 + O_2 + O \rightarrow Al_2O_3$ SR — Al=3+ &O2=0→Al3+& O=2-
   b. $Al_2 + O_3 \rightarrow Al_2O_3$ Decomp. — Al=0 & O=2- → Al3+& O=2-
   c. $4Al + 3O_2 \rightarrow 2Al_2O_3$ Synthesis — Al=0 & O=0 → Al3+& O=2-
   d. $2Al + 2O_2 \rightarrow 2Al_2O_3$ Comb. — Al=0 & O=0 → Al3+& O=2-
   e. None of the above

3. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

   a. $C_2H_6 + 3O_2 \rightarrow 2CO_2 + 3H_2O$ SR — C4-& H+ & O-2→ C+4 & O-2 & H+2
   b. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ Comb. — C4- & H+& O2=0 → C4+ & O2- & H+
   c. $C_2H_6 + O_2 \rightarrow C_2O_2 + H_6$ SR — C4+ & H-1 & O2=0→ C+2 & O2- & H+1
   d. $2C_2H_6 + 6O_2 \rightarrow 4CO_2 + 6H_2O$ Comb. — C4- & H+& O2=0 → C4+ & O2- & H+
   e. None of the above

4. Describe IN DETAIL a possible procedure for determining the conservation of mass of a chemical reaction where no gas is produced. (C.1.12 & C.1.13) (5)

Reaction Types – Predict products, balance, write phases and reaction type. (C.1.19, C.1.10, C.1.11, C.1.35)

5. $Zn + HCl \rightarrow$

6. $KClO_3$ + heat $\rightarrow$

7. $C_6H_{12} + O_2 \rightarrow$

8. $Pb(NO_3)_2 + Na(OH) \rightarrow$

9. $HCl + NaOH \rightarrow$

Solve problems involving heat flow and temp changes (specific heat and latent heat) (C.1.39)

10. If 2.3g of iron is heated from 22.1 deg C to 87.0 deg C, what is the enthalpy? (5)

11. How much energy is required to boil 200.0 mL of pure water at 100.0 deg C? (5)

12. How much energy is required to heat 100.0 mL of pure water from 22.0 deg C to 110.0 deg C? (5)

13. Draw and completely label a picture of an electrochemical cell (battery). (5)

Possibly Useful Information

dH_{fus} H_2O = 6.01 kJ/mol

dH_{vap} H_2O= 40.7 kJ/mol

c_{Fe}= 0.449 J/g K

c_{H20}= 4.19 J/g degC

K = deg C + 273.15

1 mole = $6.02x10^{23}$ things

APPENDIX 3: PAPER CLIP ACTIVITY

We are going to balance chemical equations using the conservation of mass. Matter cannot be created or destroyed, so all atoms in products must have come from the reactants.

For each reaction below, write the color you want each atom to represent as a paper clip. Make one "paper clip reactant" using the colored paper clips provided. For each question, use your "paper clip reactants" to form the stated products by unclipping and reclipping them as necessary, breaking bonds and forming new bonds. If you cannot make the products as written, form a new "paper clip reactant" containing the needed atoms, then break it apart to form products. Repeat this breaking apart of reactants until there are no "extra atoms", and only "paper clip products" remain.

The number of each "paper clip reactant" used is its coefficient, and the number of each "paper clip product" is its coefficient.

Let's try one together:

_2_ Na + _1_ Cl_2 → _2_ NaCl   Na = blue   Cl = pink

| | | | |

In groups, use the method above to balance the following questions. Once you've completed each one, show me and I will check it for you.

1. ___ Mg + ___ Cl_2 → ___ $MgCl_2$

2. ___ Cu + ___ $AgNO_3$ → ___ Ag + ___ $Cu(NO_3)_2$

3. ___ SO_2 + ___ H_2O → ___ H_2SO_4 (FYI: This reaction describes how acid rain can be formed.)

4. ___ H_2O → ___ H_2 + ___ O_2 (FYI: This reaction can be used to produce hydrogen for hydrogen fuel cell vehicles.)

5. ___ CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O (FYI: This is a combustion reaction, which is similar to how your car burns gasoline.)

APPENDIX 4: ENVIRONMENTALLY THEMED REACTION TYPE DEMOS

In each case, I do the demonstration, students tell me what reaction type this represents and how they know. We also look at reactants, what they see in the demo, and write out the balanced chemical equation.

Reaction Type	**Demonstration**	**Discussion Questions (students talk in groups, then class discussion)**
Synthesis	*Silly Putty Synthesis* [This is an easy classroom example to give the idea about how plastics are formed.]	-What evidence is there of synthesis? -Where do most commercially produced plastics come from? -What are some concerns about the uses of plastics?
Decomposition	*Electrolysis of Water* [This is a source of H_2, which could be used to run hydrogen fuel cell powered vehicles.]	-What evidence is there of decomposition? -What end is producing H_2? What end is producing O_2? How can we test it? (Students discuss and come up with theories, then we test them next class period.)
Single Replacement	*Single Replacement using a eudiometer* $Mg_{(s)}$ in HCl forming H_2 gas. [Another reaction that produces H_2!]	-How can you identify the bubbling gas? -Where does the Mg (s) go?! What magnesium based product must be formed?

Appendix 4 Table Continued

Double Replacement	*Precipitation of Lead Ions in "Drinking Water"* Double replacement reaction to show how transition metal ions can precipitate, which removes those ions from solution. For example: $Na_3PO_4(aq)$ + $Pb(NO_3)_2(aq)$ → $NaNO_3(aq)$ + $Pb_3(PO_4)_2(s)$	-What is the solid product formed? -What environmental benefits could this reaction type have?
Combustion	*Whoosh Bottle:* Combustion of EtOH vapor in a 5 gallon empty water bottle. [EtOH is used as an alternative to gasoline in vehicles.]	- What are the products? -What evidence is there of these products? -How can we test it? (Test it according to class ideas.) -Endo or exothermic process? -Can I do this demo again right now? Why not?

APPENDIX 5: CONSERVATION OF MASS LAB

Whenever a chemical reaction is carried out you must be concerned with the separation and identification of the products. According to the Law of Conservation of Mass, the total mass of the reactants must equal the total mass of the products. When coal is burned at a power plant, or gasoline is combusted by your car, there is still conservation of mass, but it is more difficult to measure due to the gases formed.

The reaction between aqueous copper (II) sulfate and sodium carbonate forms solid copper (II) carbonate and aqueous sodium sulfate.

$$CuSO_4\,(aq) + Na_2CO_3\,(aq) \rightarrow CuCO_3\,(s) + Na_2SO_4\,(aq)$$

Solid copper carbonate product in this reaction can be easily collected by filtering. The aqueous sodium sulfate product can be collected by boiling away the water, causing it to become a solid.

You should recognize that the water does not enter into this reaction; it is to be considered as the medium for the reaction to proceed. You will make separate solutions of copper (II) sulfate and sodium carbonate in your procedure in order to allow even mixing of ions.

Procedure:

1. Rinse and then dry the graduated cylinder with distilled water. Transfer 40.0 mL of distilled water into a beaker and then add **1.06 g** of sodium carbonate (use the centigram scales). Stir till all solute is dissolved (add a few drops of distilled water down the stirring rod to rinse it). Add 1.6 g of copper (II) sulfate to 40.0 mL of distilled water and mix the two solutions. Stir till the reaction is complete.

2. Mass a 250 mL Erlenmeyer flask and a piece of filter paper. Record this data. Prepare the funnel and filter paper for filtration into this flask.

3. Pour the reaction mixture into the funnel carefully. Collect the filtrate in the Erlenmeyer flask. Keep the level of the mixture at least 2 cm below the top of the filter paper. If any solid material remains in the beaker, use some of the filtrate, or a small amount of water to rinse out **all** the solid into the funnel.

4. When the filtration appears complete, remove the filter paper and residue from the funnel. Open up the folds and place it on a sheet of notebook paper with your names and station number. Give this to me to dry overnight.

5. Begin to evaporate the water from the filtrate by gently heating the solution. **CAUTION**: Excessive heat will decompose your solid, or cause it to leave the flask.

6. Allow the flask to cool fully, then mass and record. Mass and record the dry solid on the filter paper the next class period.

Conservation of Mass Lab Calculations:

$$\% \text{ recovery (total)} = \frac{\text{total mass of products}}{2.66 \text{ grams}} \times 100 =$$

$$\% \text{ error (total)} = \frac{|2.66 \text{ g} - \text{total mass of products}|}{2.66 \text{ grams}} \times 100 =$$

$$\% \text{ error for each product} = \frac{\text{mass of one product weighed}}{\text{calculated possible yield}} \times 100 =$$

Questions: **(Q1-8: 20 pts & Q9: 20 pts)**

1. What effects would melting, freezing, or boiling have on the conservation of mass? (2)

2. Explain IN DETAIL why would it be more difficult to get accurate measurements if we did a combustion conservation of mass lab. (3)

3. Using the rules for solubility, explain why one product became insoluble and precipitated and the other remained in solution. (2)

4. Describe what happened when you added the copper sulfate solution to the sodium carbonate solution. (2)

5. Why did we heat the sodium sulfate solution? (2)

6. Why were the original solutions homogeneous? (2)

7. Suggest ways in which your experimental technique could be improved. (2)

8. By looking at the balanced chemical equation can you suggest a possible way to predict what the results should have been. Calculate these actual values and check your percentage errors. (5)

9. **RESEARCH**: Using textbooks, magazines, or ***trustworthy*** sites on the internet (NOT wiki, yahoo answers, etc.), research and write at least a few sentences answering the following questions:

   a. What is your solid product, copper (II) carbonate, known for/used for? (4)

   b. What is your dried product, sodium sulfate, known for/used for? (4)

   c. Are there any solid products of combustion when a power company burns coal or when your car combusts gasoline? What are they and how might they affect the environment? (5)

   d. What are the gaseous products of combustion when a power company burns coal or when your car combusts gasoline? What are they and how might they affect the environment? (5)

   e. What is "Clean Coal Technology" generally speaking and how does it attempt to "clean" the emissions? (5)

DO NOT FORGET TO LIST YOUR SOURCES! (2)

APPENDIX 6: REACTION TYPES LAB

Pre-Lab: Reaction Types and Predicting Products

Predictions: Predict what will happen when the following reactants are mixed together. You may use a list of solubility rules and the activity series to help you. Balance each of the equations below.

Reactants	**Predicted Products**
$Pb(NO_3)_2$ (aq) and KI (aq)	
$NiCl_2$ (aq) and NaCl (aq)	
$CuSO_4$ (aq) and Na_2SO_4 (aq)	
$AgNO_3$ (aq) and NaCl (aq)	
NH_4Cl (s) and water	
$NaC_2H_3O_2$ (s) and water	
$NaC_2H_3O_2$ (s) and H_2SO_4 (aq)	
Na_2SO_3 (s) and HCl (aq)	
$NaHCO_3$ (s) and HCl (aq)	
Zn metal and $Cu(NO_3)_2$ (aq)	
Zn metal and HCl (aq)	
Cu metal and HCl (aq)	
Mg metal and HCl (aq)	

Reaction Types & Predicting Products Lab

Introduction: When two ionic solutions are mixed, a **double replacement reaction** may occur. (Don't forget: positive can replace positive, and negative can replace negative.) The products of this double replacement reaction may be a **precipitate** (solid), a gas, or a liquid such as **water** (like in an acid base neutralization, which is a special case of double replacement). A neutralization reaction is a little more difficult to observe in the lab, but there should be a slight change in smell or temperature.

It is POSSIBLE that an observable **neutralization reaction** will happen in our lab. In these reactions the salt reacts with the water to form either **a weak acid solution** or **a weak base solution**. Like other neutralization reactions, these reactions are a little difficult to observe directly since the only observable change will be a small change in smell or temperature.

In this lab you should also observe **single replacement** reactions, when metals react with ionic compounds. Frequently in these reactions, the ionic solution's **cations** get reduced to a zero oxidation state (charge) while the **metal atoms** get oxidized (lose electrons) from their zero oxidation state to a higher oxidation state (charge). This results when "active metals" (metals with no charge) lose electrons, forming cations, and the while the ionic solution's cations are "kicked out" and are all alone, gaining electron(s) and forming a neutrally charged metal. (Remember, H^+ is not a metal, but because of its positive charge, it can replace/be replaced by metals according to its position on the activity series.)

Safety Considerations:

- Wear goggles and aprons at all times in the lab.
- Use caution when smelling any substance. Waft at a distance.
- The acid solutions are corrosive. Rinse your hands with water after handling the containers.

Use CLEAN well plates for all chemical tests. Wash each well with tap water and dry with a paper towel before use.

Procedure: ***Record the following observations for each reaction:***

SIGHT - Look for the presence of a solid precipitate either as a solid in the bottom of the well or as cloudiness in the solution. Note that a color change alone does not indicate the formation of a precipitate. If a solid metal changes color at its surface (particularly to black), this generally indicates the precipitation of another metal on the surface. You should also look for the formation of bubbles since this indicates a gaseous product has formed.

TOUCH - Touch the bottom of each well to note any temperature change that may occur.

ODOR - Sometimes a chemical reaction produces a product with a distinct odor. These are usually gases, although many gases have no odor. To detect an odor, waft the vapors by holding the well plate in one hand and waving the other hand above the top of the well plate towards your nose. Perform this carefully; some vapors are irritating. Be sure the odor is due to the product, not a reactant!

Part 1: Mixing of Ionic Solutions: Mix about 15 drops of each of the solutions specified and <u>record your observations</u>.

1. 0.1 M $Pb(NO_3)_2$ with 0.1 M KI
3. 0.1 M $CuSO_4$ with 0.1 M Na_2SO_4
2. 0.1 M $NiCl_2$ with 0.1 M NaCl
4. 0.1 M $AgNO_3$ with 0.1 M NaCl

Part 2: Mixing of Solid Salts and Water: Mix a small scoop of each solid with about 15 drops of water and <u>record your observations</u>.

5. solid NH_4Cl with water
6. solid $NaC_2H_3O_2$ with water

Part 3: Mixing of Solid Salts with Ionic Solutions. Mix a small scoop of each solid with about 15 drops of the solution specified. <u>Record your observations</u>.

7. solid $NaC_2H_3O_2$ with 3M sulfuric acid
9. solid $NaHCO_3$ with 3M HCl
8. solid Na_2SO_3 with 3M HCl

Part 4: Metals and Ionic Solutions: Mix a small scoop of each metal with 15 drops of the solution below. <u>Record your observations.</u>

10. zinc metal with 0.1 M $Cu(NO_3)_2$
11. zinc metal with 3M HCl
12. copper metal with 3M HCl
13. magnesium metal with 3M HCl

Observations

Mix	Sight	Touch	Smell
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

Writing reaction equations: For each mixture write an ionic equation and a net ionic equation. If no reaction was observed, write "no reaction."

Mix	Ionic	Net Ionic
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

APPLICATION QUESTION: Write FIVE reactions that relate to the environment or alternative sources of energy. State the reaction type and how it relates.

<Used and adapted from a lab handed down to me. Origin unknown.>

APPENDIX 7: POST TEST PART 1

Choose the answer with the correct balanced equation, reaction type, and oxidation numbers for every atom. (C.1.9, C.1.10, C.1.22, C.1.27)

1. $Cu + O_2 \rightarrow CuO$

   a. $Cu_2 + O_2 \rightarrow Cu_2O_2$ Combustion   Cu=+2, O=0

   b. $2Cu + O_2 \rightarrow 2CuO$ Synthesis $Cu=0, \& O_2=0 \rightarrow Cu^{+2} \& O^{-2}$

   c. $Cu_2 + O_2 \rightarrow Cu_2O_2$ Synthesis $Cu=2+ \& O_2=-2 \rightarrow CuO=0$

   d. $2Cu + O_2 \rightarrow CuO_2$ Synthesis $Cu=0, \& O_2=0 \rightarrow Cu^{+2} \& O^{-2}$

   e. None of the above

2. $Al + O_2 \rightarrow Al_2O_3$

   a. $Al_2 + O_2 + O \rightarrow Al_2O_3$ SR   Al=3+ &O2=0→Al3+& O=2-

   b. $Al_2 + O_3 \rightarrow Al_2O_3$ Decomp.   Al=0 & O=2- → Al3+& O=2-

   c. $4Al + 3O_2 \rightarrow 2Al_2O_3$ Synthesis   Al=0 & O=0 → Al3+& O=2-

   d. $2Al + 2O_2 \rightarrow 2Al_2O_3$ Comb.   Al=0 & O=0 → Al3+& O=2-

   e. None of the above

3. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

   a. $C_2H_6 + 3O_2 \rightarrow 2CO_2 + 3H_2O$ SR   C4-& H+ & O-2→ C+4 & O-2 & H+2

   b. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ Comb.   C4- & H+& O2=0 → C4+ & O2- & H+

   c. $C_2H_6 + O_2 \rightarrow C_2O_2 + H_6$ SR   C4+ & H-1 & O2=0→ C+2 & O2- & H+1

   d. $2C_2H_6 + 6O_2 \rightarrow 4CO_2 + 6H_2O$ Comb.   C4- & H+& O2=0 → C4+ & O2- & H+

   e. None of the above

4. Describe IN DETAIL a possible procedure for determining the conservation of mass of a chemical reaction where no gas is produced. (C.1.12 & C.1.13) (5)

Reaction Types – Predict products, balance, write phases and reaction type. (C.1.19, C.1.10, C.1.11, C.1.35)

5. Zn + HCl →

6. $KClO_3$ + heat →

7. C_6H_{12} + O_2 →

8. $Pb(NO_3)_2$ + Na(OH) →

9. HCl + NaOH →

APPENDIX 8: CORAL CHEMISTRY ARTICLE

Go to http://discovermagazine.com/2008/jul/16-ocean-acidification-a-global-case-of-osteoporosis/article_view?b_start:int=0&-C= and answer the following questions **on your own sheet of paper:**

1. Diagram & explain the carbon cycle as it relates to the oceans. (Where does it come from and go to?)

2. Explain and write the chemical equation for "ocean acidification."

3. Explain the chemistry of why "ocean acidification" affects corals and shelled animals.

4. How does the increase in temperature affect the ocean acidification?

5. Why can the increasing levels of CO2 harm animals? How can these animals be harmed?

6. Scientists are considering carbon sequestration under oceans, deep in the ground, etc. a) What does "sequestration" mean? b) Explain what carbon sequestration is. c) What is it meant to do? d) describe the chemistry of carbon sequestration (including reaction type, equilibrium & solubility). e) What are the possible benefits and risks? f) Do you think carbon sequestration is a good option? Why or why not?

APPENDIX 9: BIODIESEL LAB PART 1

Introduction: In today's world of skyrocketing fuel prices, more attention is being drawn to the possibility of alternative fuel sources. Vegetable oil (which is made of fatty acids connected by oxygens), either from the store or the local "greasy spoon" fryer, can be reacted with ethanol to form biodiesel and glycerol (which is used to make soap). In this lab you will be forming biodiesel, and we will save it in order to test the amount of energy that can be produced.

Pre-Lab Questions:

1. Italian salad dressing (Oil and Vinegar dressing) separates into layers. One layer is the oil layer and the other is a water layer.

   a. What causes the layers to form? Discuss how intermolecular forces are related

   to this idea.____

   ____

   b. What determines which layer is on top?________________________

   c. The oil layer is the top/bottom layer (circle one), and I know this because

   ____

   ____.

2. Calculate the mass of KH2PO4 required to make up 100.0 mL of 0.1 M KH2PO4.

3. Calculate the mass of NaCl required to make 100.0 mL of 1.0% NaCl.

Procedure:

1. Write your name and hour on a 250 mL Erlenmeyer Flask with a Sharpie.
2. Pour 100 mL of Vegetable Oil into an Erlenmeyer flask. Heat with stirring to 120° F (_____°C).
3. TURN OFF THE HEAT.
4. Add 25 mL of Methanol/KOH solution to the vegetable oil and cover the flask with aluminum foil.
5. Stir the mixture for 10 minutes.

6. Remove stir bar.
7. Put your flask in the labeled bin, and we will continue next class period.

NEXT DAY

1. Remove the glycerol layer (bottom layer) with a disposable pipet. (The glycerol layer should be a darker brown color.) Tip the flask to the side to remove ALL glycerol.)

   Lemon has seen BOTH of the layers (separated glycerol and biodiesel. _________(Get Lemon to initial it)

2. Pour the glycerol into the labeled jug on the supply bench.

To remove extra OH- from the solution:

3. Pour 100.0 mL of 0.1 M KH2PO4 into your biodiesel. Swirl for 30 seconds and then allow to settle. Remove the bottom layer and pour into "aqueous wash" jug.
4. Pour 100.0 mL of 0.01 M KH2PO4 into your biodiesel. Swirl for 30 seconds and allow to settle. Remove the bottom layer and pour into "aqueous wash" jug.
5. Check the pH of your biodiesel using pH paper. The pH should be near 7. If it is not, then you will need to pour more KH2PO4 and repeat the process until the pH is near 7. Ask me if you have any questions.

   pH = ______
   Did you have to add additional KH2PO4?_____ How much?_____

To remove any water from the biodiesel:

6. Pour 100.0 mL of 1.0% NaCl solution into your biodiesel. Swirl for 30 seconds and allow to settle. Remove the bottom layer and pour into "aqueous wash" jug.
7. Scoop solid NaCl into the flask and swirl until the NaCl does not clump and looks grainy.
8. Fold filter paper, place in the funnel, and filter out the NaCl.
9. Let the biodiesel sit and look for additional water (bubbles) in the bottom of the flask. If it is there is any water, then fill a new funnel lined with filter paper with new, solid NaCl. Gently pour biodiesel through the funnel.

   Lemon has seen the biodiesel. ______ Comments______________

10. Measure 10.0 mL of your dried biodiesel and place in the burner container. Label your burner with your name and hour, and place it into the storage box for a future lab.
11. Pour the remaining biodiesel into the jug labeled "biodiesel".

APPENDIX 10: ARTICLE

Find an article (online, in a magazine or newspaper *from a reliable source*) that discusses a current event related to alternative energy sources or the environment. Turn in a copy of the article, and write a short Simple 4 essay addressing the following:

- A summary of the article
- How it relates to chemistry
- Your reaction (opinion) on the article

APPENDIX 11: REFINING ALUMINUM VIDEO QUESTIONS

<http://player.discoveryeducation.com/index.cfm?guidAssetId=B3E4D435-13AD-4AB8-A2FB-EDD55C4E736B>

PRE-MOVIE – Al2O3 (aluminum oxide) – soluble in water?!
DURING MOVIE – Think about the steps required to purify Aluminum….

1. Why was aluminum so expensive in the past?

2. STOP: 1:32 –
   Q: Does Aluminum need to be oxidized or reduced for it to be isolated?

   Water Vs. Al

   Standard Reduction Potentials:

   Write the ½ reactions and label anode and cathode

   Water:

   Al:

   So WHY would it be hard to use water
   To dissolve Al2O3 and then use electrolysis?

3. STOP 2:48
   Q: Write the overall reaction of the Hall-Heroult Process. Label what is being being oxidized and reduced.

4. STOP 3:09
   Q: Aluminum was EXPENSIVE in 1855 (before the Hall-Heroult process), but it was for sale for the right price. Explain how there could have been ANY Aluminum available before the Hall-Heroult process.

5. What financial reason is there to recycle aluminum? (Why is refining aluminum more expensive than recycling?)

APPENDIX 12: BIODIESEL FUEL LAB PART 2: HEAT OF COMBUSTION OF BIODIESEL AND ETHANOL

Introduction: Reactions can be endothermic (requiring heat energy to occur) or exothermic (giving off heat energy). Combustion is an extothermic process, and this heat energy can be used to run vehicles. Biodiesel and Ethanol, two alternatives to old-fashioned gasoline, will be analyzed in this lab, and the amount of heat given off by each reaction will be compared. This will give us an idea of which fuel will give us more energy for our vehicles.

We will be testing our samples using the burner you filled in part 1 and heating our pop can calorimeter setup like in our previous lab. As we know from our previous lab, heat energy will be transferred to the air as well as the pop can of water. Before we begin this lab, your lab group will have to come up with a way of containing the heat energy.

Pre-Lab:

1. When our car "burns gasoline", that means that it is combusting the fuel. What are the products of complete combustion? (1) ____________________________.

   What are some of the products of incomplete combustion? (1)_______________.

2. What are some other substances that can be formed in the incomplete combustion in a car? (*Use your book or online resources if necessary.*) (2)________________

   ____.

3. What is the current price of Biodiesel and Ethanol per gallon? Make sure you

   write down your source(s). (3)____

   ____.

4. Draw and describe your plan and materials needed to help contain heat energy. (Remember: you need oxygen gas to easily get in there, and you need to be able to see inside to confirm the flame has not gone out yet.) (3)

   Lemon's initials_________ (1)

5. Write out a step-by-step procedure for how you will do this lab on the back and have Lemon initial it BEFORE you start your lab. If you do NOT get things initialed, you will have to STOP and start this lab again during Success!

YOU WILL BE TESTING ETHANOL AND YOUR BIODIESEL

Procedure YOU Have Written: (5)

1.

2.

3.

4.

5.

6.

Lemon's Initials___________

Safely Following Laboratory Procedures (5)

Observations: (2)

Ethanol Combustion

Biodiesel Combustion

Post Lab Questions:

1. Calculate the heat of combustion of Ethanol and your Biodiesel. (6)

2. Calculate the % Difference of the heats of combustion calculated in #1&2. (3)

3. Taking into account the cost of Biodiesel and Ethanol found in the Pre-Lab, the observations, and your calculations above, explain which fuel is better, and explain your reasoning. (Simple 4 rules apply!) (8)

APPENDIX 13: BATTERY DESIGN LAB

Your group will design and test FOUR different batteries, created from <u>anything</u> you want, as long as it is not dangerous, illegal, or destructive to property. You may bring items in, or use items collected from the classroom or lab area.

You must:

1. Draw out and fully label what you would like to make. Calculate Ecell for your battery. If you don't see the appropriate standard reduction potentials in your textbook you can research a value. Ask me for help or advice on this if you like. **Remember:**
   - Some electrodes are not oxidized or reduced, they are just allowing for a flow of electrons.
   - If a metal is an alloy, it may not have a recorded standard reduction potential. If that is the case, use the standard reduction potential for the most prominent metal, for the sake of calculation practice.
2. Show me your picture and calculations.
3. Go into the lab and try out your batteries. Test voltage with the multimeter on the center lab table, and record your value. If your battery "isn't working", review what must be present for an electrochemical cell. If you modify your battery from the original drawing, write the actual battery you created, drawing ONE LINE through your other picture and stating why it did not work.
4. Did your recorded voltage agree with your calculated battery voltage? If not, how can you explain any possible voltage differences?

<u>Battery Design Applications</u> Answer the following questions for **1)** modern "traditional" cars (internal combustion engine) using <u>catalytic converters</u> **2)** hydrogen fuel cell cars **3)** electric cars **4)** hybrid cars. **These answers will be used later for a future assignment!** *<u>Don't forget to list your sources!</u>*

a. How does ___ work, chemically speaking? (Don't forget to talk about Redox!)

b. Where do they get the reacting chemical/energy required in each case? (In other words, where do they get the gasoline, hydrogen, and the original "electricity" for the electric cars?)

c. What are some concerns critics have about the current sources of these starting materials listed in part b?

d. What are the current strengths and weaknesses of using ___?

----

5. Given the current state of these cars, which type of vehicle is right "for you"? Why? (Imagine that cost is no object!)

APPENDIX 14: HYDROGEN HOPES DVD

(Alda, Alan [Host]. Hydrogen Hopes (2005). *Scientific American Frontiers.*)

The video shows everyday, real people using their knowledge of chemistry, biology, and physics and business sense to try to solve real world problems. There is a lot of money to be made for those that develop the best and most cost effective technologies.
Write down any notes for yourself about the strengths and weaknesses of hybrid vehicles, Hydrogen Vehicles, solar panels, and the hydrogen producing/greenhouse gas cleaning algae.

(Do NOT write these in class notes – scrap paper or a new sheet of paper ONLY – you will be using it for a future assignment.)

Your notes should include:

- What seems to work better for each type of technology? Why?
- What are still some limitations or problems with the technology?
- What was not explained fully and I need more information?
- Think – who would these technologies benefit most?
- What is the Chemistry behind these technologies? Be as specific as possible - talk about specific reactions or reaction types - or more generally only if absolutely necessary.

AFTER THE VIDEO – 5 minutes to chat with your neighbor to add to your list.

APPENDIX 15: ALTERNATIVE ENERGY PROJECT

In this project you will imagine you are a member of the assigned group listed below. With the cost of gasoline and power continuing to climb, and with an increased focus on the environmental impacts of our choices, your group is considering its options for energy sources.

Possible Groups:
*Elkhart City Council
*Elkhart Community Schools
*Power Company (Indiana Michigan Power)
*Vehicles – Local Automotive Company
*Rural Farmers/Homesteaders – Crops/Animals & Self Sufficient Power
*Commuters to the city

Refer to what we have already learned about the following topics:
Chemical reactions including Redox Electrolysis/Voltaic Cells/Electroplating, combustion and "other products of combustion" (other than CO_2 & H_2O), Conservation of mass, etc. **EVERYTHING MUST BE BACKED UP BY CHEMISTRY!**

Make sure your group addresses:
Limitations/Strengths/Weaknesses of each method… method of energy transfer… efficiency….conservation of mass… method of storing energy… the future… cost… chemical reaction/process…

ENERGY SOURCES: (2)

Wind	Natural Gas
Solar	Coal
Geothermal	Nuclear Energy

ENERGY FOR CARS: (8)
Biofuels – from veg oil
EtOH – AT LEAST 3 sources (rapeseed, corn, algae, switchgrass, sugar cane/ beet, etc.)
Gasoline/Diesel
Hybrid vehicles
Electric Cars
Hydrogen Fuel Cells (consider sources of H, infrastructure, and the chemical process)
Natural Gas

RECYCLING/REFINING: (2)
Plastics – Making/recycling
Aluminum – Mining/refining/recycling

APPENDIX 16: POST TEST PART 2

Solve problems involving heat flow and temp changes (specific heat and latent heat) (C.1.39)

10. If 2.3g of iron is heated from 22.1 deg C to 87.0 deg C, what is the enthalpy? (5)

11. How much energy is required to boil 200.0 mL of pure water at 100.0 deg C? (5)

12. How much energy is required to heat 100.0 mL of pure water from 22.0 deg C to 110.0 deg C? (5)

13. Draw and completely label a picture of an electrochemical cell (battery). (5)

Possibly Useful Information

dH_{fus} H_2O = 6.01 kJ/mol

dH_{vap} H_2O= 40.7 kJ/mol

c_{Fe}= 0.449 J/g K

c_{H20}= 4.19 J/g degC

K = deg C + 273.15

1 mole = $6.02x10^{23}$ things

APPENDIX 17: POST-SURVEY

Answer the following questions using the following scale:

A – Agree completely! B- Mostly agree C- Neutral (don't agree or disagree)
D- Mostly disagree E- Disagree completely!

OR for questions about grades:
A = A B = B C = C D = D E = F

13. I am interested in science.

14. I am interested in chemistry.

15. I completed all of my chemistry homework during 4^{th} Marking Period.

16. "Senioritis" hurt my chemistry grade.

17. I was motivated in chemistry during 4^{th} Marking Period.

18. My motivation increased during 2^{nd} Semester.

19. I am interested in learning about the environment and our possible impact on the world.

20. I pay attention to news stories about the environment and alternative sources of energy.

21. I was **NOT** interested in the environmental connections in class.

22. I feel like I understand the science behind news stories about the environment and alternative sources of energy.

23. I feel that I benefited from how energy and the environment were worked into the chemistry lessons.

MORE QUESTIONS ON THE BACK! ALMOST DONE! ☺

For the following, choose the answer that best represents your thoughts on some of the activities we did this year:

A – Not Helpful B – A Little Helpful C – Helpful D – Very Helpful
E – Did Not Do This Activity (Absent, etc.)

12. Paper clip balancing

13. Reaction Types Demos

14. Conservation of Mass Lab

15. Reaction Types Lab

16. Coral Chemistry Article Bonus

17. Carbon Sequestration Video

18. Biodiesel Lab Pt. 1

19. Article

20. Refining of Aluminum Video Clip & Questions

21. Biodiesel Lab Pt. 2 -- Combustion

22. Battery Design Lab

23. Hydrogen Hopes Video

24. Alternative Energy Project Bonus

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