HANDS ON LEARNING AND PROBLEM BASED LEARNING ARE CRITICAL METHODS IN AIDING STUDENT UNDERSTANDING OF ALTERNATIVE ENERGY CONCEPTS

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A Thesis

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Physical Science-Interdepartmental

2011

ABSTRACT

HANDS ON LEARNING AND PROBLEM BASED LEARNING ARE CRITICAL METHODS IN AIDING STUDENT UNDERSTANDING OF ALTERNATIVE ENERGY CONCEPTS

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Today's students must be prepared to deal with a world that may not always be dependent on traditional fuels. To adequately address these future problems students will need to be prepared to solve real life problems. This unit provided students with the unique opportunity to learn about alternative energy while solving engineering problems. The research reported in this document highlights an Alternative Energy curriculum taught using problem based learning coupled with hands on activities.

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Introduction

Alternative energy has come to the forefront of national and global discussion. It has become a topic with which the average citizen has become familiar. This is largely due to the current oil crisis, turmoil in the Middle East, as well as evidence supporting large scale climate change. As Ray Mabus, Naval Secretary and former Ambassador to Saudi Arabia, said "The United States will move from a dependence on fossil fuels to using alternative sources for energy in much the same way that technology transformed the way people communicate," when he spoke at the Naval War College. He also went on to say that using alternative sources was critical to national security and should not be thought of as some passing fancy. (McDermott, 2011) Because alternative energy has garnered such political and commercial attention, there is sufficient reason to believe it is a major source of jobs in the coming generation. For this reason, Laingsburg Community Schools developed a class specifically dealing with alternative energy.

Laingsburg is a city about 25 miles Northeast of Lansing, located in Shiawassee County with a population of 7901 people. The town is a mix of subdivided neighborhoods, rural farmland, and a small city area. The median household income for Laingsburg residents is $56,713. Approximately 2.7% of the population is unemployed and 4.8% lives below the poverty line. 89% of the adult population has a high school degree or higher and 22% hold a bachelor's degree or higher.

Laingsburg Community Schools consist of four schools: an early elementary that houses prekindergarten and kindergarten students, an elementary school that is for first through fifth grade, a middle school comprised of sixth through eighth grade, and a high school with ninth through twelfth grade. The middle school is made up of 312 students. Approximately 96% are Caucasian, 2.5% are Hispanic, 1% are African American, and 0.3% are Asian.

This was the third year the course had been offered. The study was performed with two different groups of students. Each group took the course for nine weeks, a quarter of the school year. The class consisted of 25 students one quarter and 23 the next quarter. Nineteen total students from both quarters participated in the study. The curriculum was identical for the two groups despite the opportunity to adjust instruction during the school year.

The class was taught in the Tech Ed room which enabled the use of tools for design and plenty of space for experimentation. The location of the class coupled with the fact that a substantial amount of hands-on activities can be performed with alternative energy topics has led to design a curriculum that was largely hands-on and problem-based learning. The hypothesis was that hands on learning and problem-based learning are critical to the enhancement of student understanding of concepts underlying alternative energy.

Problem-based learning is a process in which students gain knowledge of a subject relatively independently and work as a team to solve a particular problem that is similar to a realistic version of the problem encountered in the field of interest. As defined by Dr. Howard Barrows and Ann Kelson of Southern Illinois University School of Medicine, PBL is both a curriculum and a process. The curriculum consists of carefully selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies, and team participation skills. The process replicates the commonly used systemic approach to resolving problems or meeting challenges that are encountered in life and career. (Barrows and Kelson, 1997) Problem-based learning has been used in training medical students for over 25 years now and experts agree that it is an extremely effective form of instruction. “Problem-based learning (PBL) is grounded in the belief that learning is most effective when students are actively involved and learn in the context in which knowledge is to be used”. (Kwan, 2000)

Because there was no set curriculum for this course this was an ideal opportunity to invoke problem-based learning and hands-on approaches into a stand-alone curriculum. These two forms of teaching take a substantial amount of time and this course was not guided by set standards or benchmarks. Instead, a set of objectives were created to guide the course. For each type of fuel source the students were expected to know the advantages and disadvantages as well as how they can be used as a means of energy. This made the course an ideal opportunity to include problem-based learning as the backbone for instruction.

This study allowed an opportunity to introduce a relevant topic in a meaningful way. Alternative energy is important to scientists, educators, and politicians as it will be important to everyone in the coming years. “Now is the time for scientists and educators alike to work toward the common goal of kicking the petroleum habit. While researchers are exploring new methods and approaches to alternative fuels and renewable energy, educators can do their part by ensuring that our education system produces citizens who are aware of the need for alternative energy sources and equipped with a comprehensive understanding of the science behind them, “(King and Wright, 2007)

This statement signifies the urgency with which most are viewing alternative energy. In fact the current administration referenced it during the 2008 presidential campaign. "America can be the 21st century clean energy leader by harnessing the power of alternative and renewable energy, ending our addiction to foreign oil, addressing the global climate crisis, and creating millions of new jobs that can't be shipped overseas." (Obama, 2008) How Americans will accomplish the goals set by President Obama lies largely in the hands of teachers. We must make sure our students are equipped to handle such issues and the earlier and more often we can teach them the better prepared they will be for the 21st Century.

The unit of focus was comprised of three types of alternative energy. The unit consisted of the chemical energy stored in biomass, solar energy, and wind energy. It is important to note that other relevant forms of alternative energy were introduced in the course, but were not part of the study reported here. Each of these forms of energy has positive and negative aspects associated with it, but the forms chosen for the study are illustrated below in further detail along with the reasons why they were viewed as most relevant.

Chemical energy derived from biomass was selected as part of the unit because of the fact that it is most relevant in the Midwest and rural areas. In a rural school district such as Laingsburg, a form of energy that can be obtained from farmland is quite significant. These facilities are being built in communities just like theirs. In fact, environmentalist Ken Cook explains that Midwest rural communities are so excited about ethanol plants because they are viewed as the future to their economy. (Siegel and Joyce, 2007)

Wind energy and solar energy were used primarily because of their visibility as forms of alternative energy. Wind energy is also very prevalent in the Midwest, but a little more focused in the Great Plains States. It can be harnessed in Michigan and more specifically rural Michigan. It is the fastest growing form of alternative energy. In 2007, 35 percent of all the new electricity generation installed in the U.S. -- over 5,200 megawatts (MW) -- was wind generated. Its growth is second only to natural gas. (Provey, 2009) This makes it ideal for discussion because it's very relevant at the moment.

Solar energy is the initial source of energy for virtually every other type of energy source we will study. This makes it not only important enough to be included in the unit, but also a very good starting place for the entire course. The power possible from incoming solar radiation is astounding. The sun provides the earth with 85000 terawatts of energy every year. (Roberts, 2009) It's important to include the most powerful source of incoming energy and show how it is strong enough to power all these other forms of energy. This will undoubtedly prompt students to question why we don't get our energy directly from the source.

Theoretical Framework

Problem-based learning is a method of learning which allows students to solve a particular problem associated with a topic they are learning as opposed to more traditional methods such as lecture and homework. In this manner, students usually work in groups and must solve an intricate problem in which there may be more than one correct response. The students are expected to do much of their own research to obtain any information that can assist them in their pursuit of solving their problem. The instructor does not give answers in this style of teaching. Instead the teacher is there to guide the students to their ultimate goal.

Problem-based learning is multifaceted. It can give students a broad range of skills. Cindy Hmelo Silver (2004) in the Department of Educational Psychology at Rutgers identifies five different skills students gain while participating in a problem-based learning environment. “The goals of PBL (problem-based learning) include helping students develop 1) flexible knowledge, 2) effective problem-solving skills, 3) SDL (student directed learning) skills, 4) effective collaboration skills, and 5) intrinsic motivation.” These are all worthwhile skills for students to develop, but the research reported here will focus on intrinsic motivation. Intrinsic motivation is driven by intrinsic *needs* according to Deci and Ryan (1985). They go on to say that these needs provide an organism the energy to act on desire. In this manner organism view stimuli as opportunities to satisfy needs. This can be applied to a motivation to learn. If the students are intrinsically motivated they will perform better based on the need to satisfy a desire. The hypothesis centers on the fact that problem-based learning will supply students with intrinsic motivation and thereby drive them to succeed and retain the information obtained in class.

The research of this study was designed to show that problem-based learning is important in motivating kids to take some ownership in their learning and ultimately come away with a better understanding of the material and ability to do science. Through their research Jungert and Rosander (2009) have shown that problem-based learning programs generally increase teacher-student relationships and increase the students' involvement in the course. The expectation is that the students will be more involved in the course because he or she is responsible for the science to solve the problem. In the end, problem based learning should cause the process of learning itself to be more meaningful.

Scientific teaching that is problem based is generally seen as more effective than traditional methods such as lecture and notes due to the fact that it allows students to use skills in a multitude of areas. Specifically problem-based learning can lead to an increase in subject knowledge and skills. According to Downing et al (2009), ".....when we are faced with finding solutions to a problem whether posed by the teacher as part of a problem-based curriculum or a new social environment, we are more likely to develop generic, as well as subject specific skills." Problem based learning has also been shown to increase students' ability to develop their critical thinking abilities. (Sendag and Odabasi, 2009)

Not only is much of the unit problem-based it is also rooted in hands-on activities, designed to allow the students to become part of the science they are trying to learn. Through Piagets' teachings on constructivism (Ginsburg and Opper, 1969), which he called schemata; one realizes that children construct knowledge out of personal experience. According to Piaget, children do not obtain knowledge when it is recited and then asked to be recalled. Instead they formulate their views about the world when working with people and things, as stated by Ginsburg and Opper (1969) while they collaborated on explaining Piaget's theories. Working with people and things defines hands-on learning. "Hands-on quite literally means having students 'manipulate' the things they are studying - plants, rocks, insects, water, magnetic fields - and 'handle' scientific instruments - rulers, balances, test tubes, thermometers, microscopes, telescopes, cameras, meters, calculators. In a more general sense, it seems to mean learning by experience" (Rutherford, 1993)

Nowhere is hands-on learning more critical than in science. "Scientific content knowledge is often abstract and complex. Examining and manipulating objects may make this abstract knowledge more concrete and clearer. Through hands-on science students are able to see real-life illustrations of the knowledge and observe the effects of changes in different variables." (Ruby, 2001) Students with a richer and more positive experience with science in middle school are more likely to continue to like it in high school. The more students are interested in science the greater the likelihood they will pursue it as a career. Gibson and Chase (2002) found in their studies, regarding an inquiry-based, hands-on approach to teaching science; that students were more likely to work toward a career in science. This is important today more than ever with America's ever increasing gap with performance in high school sciences as compared to the rest of the world. This leads one to think that we may be losing our standing as the leader in scientific progress. It is my duty as an educator to make sure my students have the ability to compete for science-based jobs in the coming decade. Hands-on learning is one way to keep them interested in science. Keeping students interested in science increases the likelihood they will lean toward science based careers or at the very minimum become scientifically literate. “Our data suggest that more hands-on high school science research programs could help increase the number of students entering and maintaining scientific careers, relieving the growing concern that North America is losing its leadership status in the international scientific community.” (Roberts and Wasserburg, 2009) Even if a student chooses not to pursue a science career, a positive attitude toward science based on their experience with science will make them a lifelong learner. A population that is comprised of those who have a general affinity for science and an understanding of how it works will support science and aid in its progress.

Students in this class will be the citizens and voters of the future. An active class devoted to teaching alternative energy while being problem based and providing the students with many hands-on opportunities will mesh all the aforementioned goals. Not only will I be educating tomorrows’ leaders, I will be educating them on something that will keep America competitive in this ever-changing world. “The 21st century can be the next great American century if we make the necessary investments in our children’s education. We will prepare the next generation for success in college and the workforce, and ensure that American children lead the world once again in creativity and achievement.” (Obama, 2008)

Science Taught

Alternative energy is energy derived from any source other than fossil fuels or nuclear fission. *Fossil fuels* is the collective term that describes all of the fuels obtained from the remains of ancient organisms: coal, petroleum, and natural gas. Nuclear fission is a process in which a material containing unstable atoms, such as uranium, is allowed to decay into two smaller nuclei. In this process tremendous amounts of energy are released.

Coal and natural gas are burned in power plants in order to generate electricity. When these fuels are oxidized via combustion, a tremendous amount of heat is liberated which can be used to boil water. The resulting water vapor begins to rise and is lead to an area in which they move the blades of a turbine. The turbine is connected to an electromagnet which is forced to continuously spin once the turbine is set in motion. The giant magnet spins within a chamber that houses other magnets. As the electromagnet is moved within this housing an electric current is produced by the alternating polarity of the magnets. This electric current can be increased by the use of a transformer. A transformer is device that increases current by reducing voltage. The increased current is then sent through power lines to the surrounding areas. Nuclear fission is used for the same purpose; however, the tremendous amount of energy from the nuclear chain reaction is used to boil the water.

Petroleum products can also be used to generate electricity, but they are more widely used in transportation. Petroleum is also known as crude oil. It can be refined to make gasoline which most vehicles use as their fuel source. When gasoline is burned in an internal combustion engine it delivers a great deal of energy. The energy released in this reaction produces gases that move with an incredible amount of force. This force is contained within the cylinders of an engine. As the cylinders are moved by the increasing pressure a crankshaft rotates the wheels and propels the car forward. Diesel engines work much like standard combustion engines and the fuel is still currently derived from crude oil.

Alternative energy is devoted to finding different methods of performing these tasks. Essentially a source, other than fossil fuels or nuclear fission, must be developed to turn a turbine for the production of electricity and turn a crankshaft in an automobile. The methods concerned with addressing these two main issues are developing or utilizing alternate fuels or using different processes.

Electromagnetic energy from the sun is energy in its most pure form on earth. Almost every other type of fuel source initially got its energy from the sun. For example, the fossil fuels are remains from organisms. Because these organisms had to have energy in order to live they mostly acquired it from the sun, which they use to build their bodies and store as chemical energy. The energy was obtained either directly, in the case of plants, or indirectly, as in the case of animals. This means the sun is responsible for a great deal of energy. It is *potentially* the most powerful source of energy for the planet. According to Greenpeace There is enough energy produced by the sun in 30 minutes to power the electricity for all homes on earth for an entire year. Not only powerful, solar energy is free once a facility has been constructed. No additional money or resources go in to obtaining additional fuel. Solar energy is also desirable because it is the ultimate renewable energy source. As long as there is life on earth there will be a sun. Finally, solar energy does not produce any harmful emissions.

Solar energy does have limitations. The incoming energy from the sun is dispersed across the entire planet. The potential power of the sun is spread out and therefore largely unusable as a direct source for transportation. It can be indirectly used for the transportation of electric vehicles. Herein lies solar energy's potential. It can be used to generate electricity in two main ways. The first method is known as photovoltaics, which is the conversion of sunlight directly into electrical energy. This can be done by using solar cells, devices that are designed to absorb incoming light. They are made with a semiconductor, usually silicon. The incoming photons, produced by the sun or some other light source, knock an electron free of a silicon layer. This frees other electrons to move and try to replace where the initial electron had been. Subsequently this causes more electrons to flow, thus inducing current. Photovoltaics have had a very low efficiency in the transfer of sunlight into electricity. Constant production and refinement has seen their efficiency rise to near 30%. Photovoltaics seem like the ideal solution because there is only one type of energy conversion, light to electricity; however, the solar cells are expensive to produce and have only recently become more durable.

In the second method solar energy can be used in a process described as solar thermal. Incoming solar energy is used to heat a substance using plates or mirrors. The light is converted into thermal energy by concentrating the incoming rays. People can use solar thermal individually to cook substances. On a much larger scale solar thermal is used to boil water at a power plant. This boiling water is used to turn the turbine that generates the electric current needed for electricity in homes. When a significant amount of solar energy is needed, as in a power plant, the incoming radiation must be focused from a large area to a much smaller area. Multiple lenses or mirrors are usually used to concentrate the incoming sunlight in an effort to boil water. The mirrors can break easily and have traditionally been expensive. There are recent breakthroughs that have driven down the price of the mirrors and increased their durability.

Another alternative to current energy sources is the use of biomass. Biomass is defined as energy obtained from living organisms or recently deceased organisms. This distinguishes biomass from fossil fuels in the sense that fossil fuels are not obtained from *recently* deceased organisms. Some forms of biomass, such as wood, have been used for centuries and still have their use today. It does not solve the huge concerns about energy because of its relatively small energy released when burned. Other forms of biomass have become of great interest largely due to the fact that biomass can be turned into liquid fuels. This is important because most of our current modes of transportation rely on liquid fuel. Using biomass to power vehicles would allow us to keep the current infrastructure related to auto mechanics. Substances such as ethanol and biodiesel can be used to power vehicles without producing many harmful emissions. Biomass can also be used to generate electricity. In waste-to-energy plants municipal waste is burned in an effort to boil water thereby generating electricity via turbines.

Ethanol is the most well-known biofuel currently being used. It is currently being produced with ethanol derived from corn starch. This idea has changed dramatically in the last 5 years due to possible food shortages resulting from using corn as fuel rather than food. New methods have been developed in which ethanol is obtained from other sources such as switchgrass and miscanthus. These are two common grasses from which ethanol can be derived. In the case of grasses and other plants ethanol is generated from the cellulose. Ethanol is advantageous because many current vehicles can run on a blend of ethanol and gasoline. Older engines can be updated to run on ethanol with very few modifications. Ethanol derived from corn is reported as only having 10-20% the efficiency of traditional gasoline. There is some speculation that ethanol production is currently energy negative. In fact, Patzek and Pimental (2005) have calculated that ethanol from corn starch provides roughly 29% less energy than goes into producing it while ethanol from switch grass currently produces 45% less energy in contrast to the amount of fossil fuels that go into creating the biofuel. The U.S. Department of Energy disputes these claims citing that corn ethanol currently yields an energy ratio of 1.3 to 1 while ethanol from cellulose has the potential to range anywhere from 2 to 36 times the amount of energy required to produce it. (Conway et al, 2008) This debate has led to the thought that even if ethanol is a possible solution it could never become the sole solution to the energy crisis.

Biodiesel is not as well publicized as ethanol, but it can be used without any modifications to current diesel engines. Biodiesel can be made from the transesterification of fatty acids. This means biodiesel can be produced from common cooking oils such as vegetable oil and canola oil. It burns extremely cleanly and the biodiesel itself is completely benign besides its combustibility. Biodiesel has about 90% the efficiency of diesel made from petroleum. The major problem surrounding biodiesel is that most vehicles do not have diesel engines and there is some debate as to its financial efficiency at the present time. It is currently only proven to be cost-effective when using spent oil (oil is free.)

Wind energy is the process in which electricity is obtained by wind currents in an effort to convert mechanical energy into electrical energy. The flowing winds cause propellers to rotate. These propellers are attached to an axle which causes an electromagnet to spin thereby creating an electric current. In the same manner as the turbine in a traditional power plant, wind turbines generate their electricity by rotating an electromagnet; however, no fuel is needed to burn. This means no additional sources of fuel are needed because winds are fairly constant. The wind energy is being converted directly into electricity, so there are very few energy transformations associated with wind energy. Wind energy is completely renewable because as long as we have an atmosphere there will be wind. Finally, wind energy produces no harmful emissions.

Wind energy does have limitations. Like solar energy it is also a very diffuse source of energy that requires many turbines to generate electricity. These turbines are expensive to install and maintain. The turbines are often noisy. Wind energy is only directly responsible for electricity, and thus a vehicle cannot run on the wind energy itself. Wind is also not present at strong enough velocities everywhere in the world. This means wind energy requires improvements to the current energy grid before electricity can be produced for a significant part of the population.

Implementation

The course was comprised of all the major forms of alternative energy. It was a 9 week course and there was roughly a week and a half devoted to exploring each topic. The term was broken into two units, one of which was problem-based and hands-on to specifically address the hypothesis related to this project. The other half of the class was done in a more traditional manner of reading, note taking, and reading-based homework assignments. This equates to the thesis-related work covering about four and a half weeks.

In addition to the creative freedom allowed by the lack of state benchmarks or standards for this course, there is also creative freedom possible for the students. Because alternative energy is an emerging field many of the technologies associated with it are still in their infancy. This allows students to experiment with design and other aspects surrounding the cutting edge technology without many preconceived notions of how alternative energy is currently being used. This makes problem based learning ideal because the students are challenged to develop unique ideas and experiment with the viability of these ideas. This mimics the real world model of the application of science for the students in which engineers experiment with designs to obtain the optimal performance for their particular energy source.

The format of the unit was problem-based. This correlated to three main problems, one dealing with solar cars, one dealing with wind turbine design, and one comparing oils for biomass. Each of these problems consisted of a week of experimentation. In addition, each form of energy studied within the unit, solar, wind, and chemical energy from biomass, were preceded by an overview of the energy source. The unit began and concluded with a test. The tests were multiple choice and short answer and identical to one another. The tests, surveys, and lab activities are included in the Appendices. An overview of the unit is provided in Table 1.

Data collection for the study was based on the pre-test and post-test part (Appendix XIV), as well as a pre and post survey (Appendix XIII). All students were asked to take the surveys and tests. Only students and parents that consented to the study were used in the statistical analysis of the study. Nineteen parents and students consented for the study and data for tests and surveys was comprised of these nineteen students only. To contribute to the anonymity of the study the principal administered the surveys and consent forms. He also collected and stored all forms until the course was completed.

Table 1. Overview of the Unit

Activities	Objectives	Appendix
• Facts about Solar Energy • Building a Solar Car	Students are expected to discover the advantages and disadvantages associated with solar energy. Students will be responsible for determining the differences between photovoltaics and solar heating. They are also expected to explore the process of experimental design.	**Appendix VI** **Appendix V**

Table 1. Overview of the Unit (cont'd)

• Wind Turbine Webquest • Build your own Windmill	Students are expected to discover the advantages and disadvantages associated with energy created by wind. Students will be responsible for optimizing the amount of electricity created by a windmill.	**Appendix VII** **Appendix VIII**
• Biomass Overview • Biomass Worksheet • Making Biodiesel	Students will be expected to create biodiesel from different cooking oils and compare the energy released when they are burned. Students will also be expected to compare biodiesel to ethanol. They will also be expected to follow proper lab procedures for producing biodiesel and repeating the steps for other oils. In addition, they will be expected to learn about various forms of biomass and how they are used.	**Appendix IX** **Appendix X** **Appendix XI**

When building their solar cars students were allowed the ability to create the body and frame of the car out of any material they chose. Cardboard and a lightweight plastic were provided for the students, but they were also allowed to bring in any materials they could find to build the car. Wheels, eyelets, and dowels were also provided to build the axels while DC motors, gears, and photovoltaic cells were provided for the power train. The track consisted of seven flood lights with 100 watt bulbs that were suspended by wood beams along a ten foot track.

The goal of the solar car design was for each group to design a car that could complete the race course in the shortest amount of time. The students were able to vary their designs in order to increase the speed of their vehicles. This allowed them the opportunity to discover the disadvantages associated with solar cells as the power source for a vehicle. In particular, the lack of power provided by the cells lead to cars that needed to be very light or some that were unable to overcome static friction and even move at all. In addition, when the cars passed in between lights students were able to see the lack of power generated by the cells when not exposed to direct light. The lab was specifically tied to photovoltaics, so it was important that the preceding assignment about solar energy facts was important for introducing solar thermal energy to the students and comparing it to photovoltaics. The advantages to solar energy were certainly present in the activity, but not always so obvious because design did not necessarily highlight these advantages.

For the second problem, students were to build windmills in which the numbers and shapes of blades could be varied in order to generate the maximum amount of electrical current. They were given the general design of the wind turbine and then expected to experiment with their blade designs. Cardboard was provided for the blade material, but students were permitted to use materials of their own. Blade material, blade length, blade shape, and blade angle were all variables that students could manipulate in an effort to maximize their power output. As in the case of the solar car, the advantages to wind power were the same in every design. Thus the advantages to wind power were not necessarily made clear by solving the problem. This emphasized the need to provide the students with an introduction to wind energy prior to the activity.

One major disadvantage to wind energy was stressed in the activity, the fragility of blades when exposed to strong winds. Fans were used to provide wind, so the lack of consistent winds in certain areas was not explicitly expressed while solving the problem.

The third problem was for the students to create biodiesel using cooking oil, sodium hydroxide, and methanol. Because students at the seventh grade level would not be able to discover this reaction on their own a procedure was given to them for the initial step of the problem. Each group used a transesterification reaction to convert vegetable oil into biodiesel. The biodiesel was then burnt in a calorimeter to measure the amount of energy released. Once groups took note of their results they were to compare them to biodiesel derived from other types of oils. They performed the same procedure with the oils of their choice.

It was also necessary to front-load this problem with plenty of background information on chemical energy derived from biomass. As opposed to wind and solar energy, the students were unfamiliar with many types of fuels derived from biomass. In particular, biodiesel and ethanol derived from corn starch were discussed prior to the problem because there were many questions that compared the fuels in the post lab assessment piece. Specifically, it allowed an opportunity to discuss non-traditional oils, such as, those used in biodiesel production, cellulosic ethanol, butanol, dimethylfuran (DMF), and methane from waste.

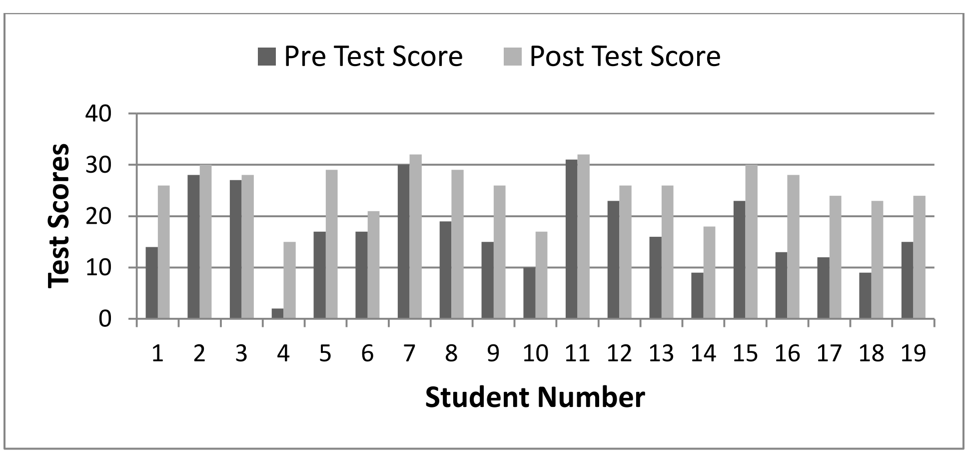
The third problem did address the accessibility of biodiesel, but it was specific to biodiesel. The activity did not address other biofuels, such as ethanol, which can be more difficult to produce. This may have led to the implication that all biofuels are easy to derive with common household items. The carbon dioxide emissions released in the combustion of the biofuels was never directly observed. Students were made aware of this disadvantage in the pre-lab discussion and reminded of it when they were burning the fuel. Other disadvantages, such as transportation costs associated carrying biofuels to other regions, were discussed in the pre-lab.

Results

Pre and post-tests (Appendix XIV) were graded and survey data were compiled prior to my knowledge of those who participated in the study. Furthermore, all students had completed the course before I was able to analyze the data of the study, thereby eliminating any biases I may have had when calculating grades.

All students that participated in the analysis showed an increase in their understanding of alternative energy concepts. Scores increased by an average of 8.1, from 17.4 to 25.5 points out of a possible 34 points from pre-test to post-test. This correlates to an increase of 24% by the classes. Figure 1 shows the pre and post test scores of all nineteen students that participated in the study. Appendix I has a detailed account of each students' performance. It includes the increase in percentage of each individual. At the bottom of each column the mean scores of the pre and post tests have been calculated. The percentage correct of each test has also been calculated along with the corresponding means. The final row includes the standard deviation of each column.

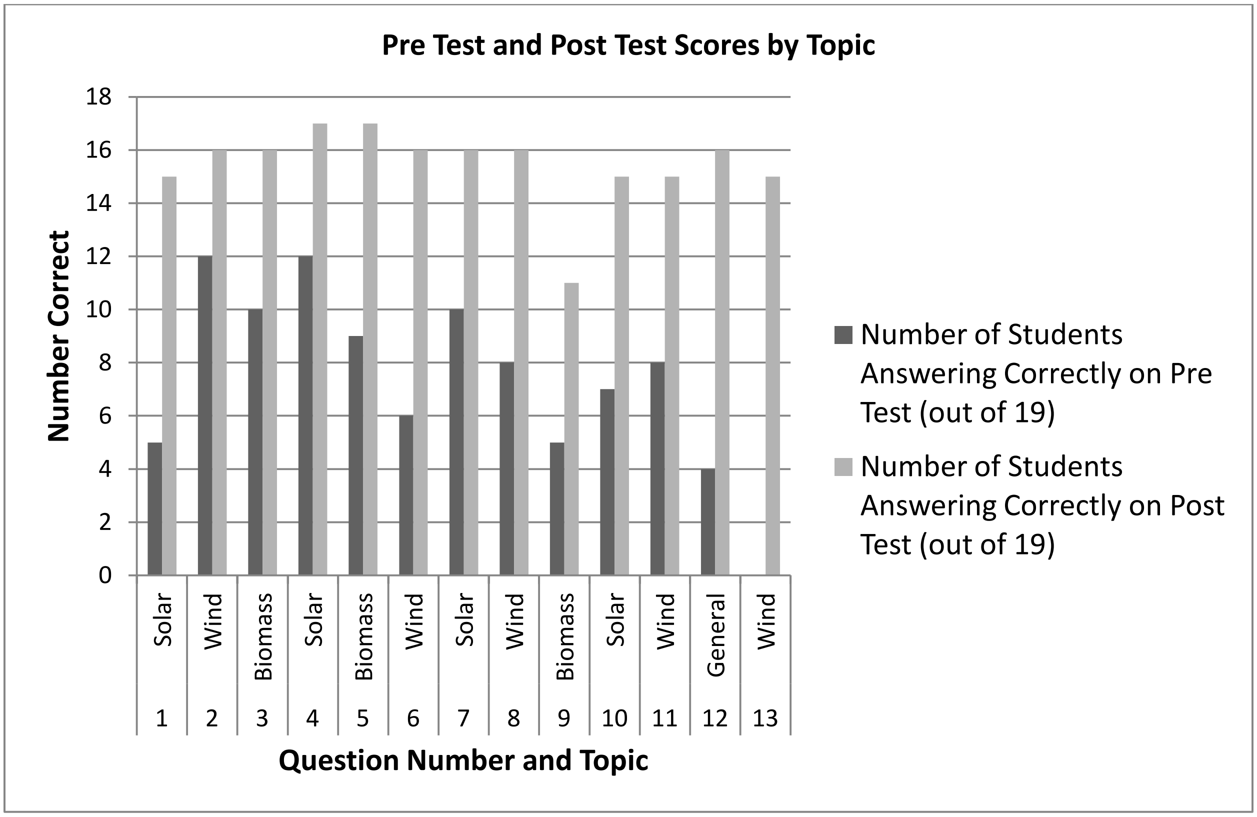
Figure 1 The pre and post test scores for all 19 students



A t-test was performed to determine if the data was statistically significant. The null hypothesis states that an increase in the scores is due to chance and is not significant enough to attribute to the methods in which the course was taught. In order to calculate the t-value it is necessary to know the variance of differences, standard error of differences, and the degrees of freedom. The values for this study are 21.66, 1.07, and 18 respectively. The t-value is therefore, 7.59. This is significantly greater than the critical value of 3.1 for 18 degrees of freedom, $p=0.005$. This means the null hypothesis is rejected and the results should be attributed to the experiment. The data used in the calculation of the t-value is shown in Appendix II.

The data was also analyzed based on topic. Of thirteen questions, four were solar energy questions, three were biomass questions, and five were wind questions. One question was a general alternative energy question. Appendix IV shows the number of students answering each question correctly on both the pre-test and post-test. In addition, the percent increase is calculated for each question. Data shows that scores pertaining to biomass questions increased the most from pre-test to post-test with an average increase of 54%. Wind energy questions exhibited the second highest jump in average percentage with 46%. Finally, solar based questions had an increase of 38%. A graph of the data can be found in Figure 2.

Figure 2 Pre and Post Test Scores by Topic



The students also completed a survey before and after the unit. This was designed to give the students a chance to comment on their own understanding, enjoyment, and interest in alternative energy as a result of the problem-based unit. Questions one through five deal with comprehension, Questions six, seven, and eleven through thirteen correspond to Scientific Literacy, and Questions eight through ten relate to student enjoyment of the course. The results for the pre survey and post survey are shown in Appendix III. The survey itself is also in Appendix (XIII).

The results of the surveys suggest the students believe that problem based learning and hands on activities contribute to their understanding of the concepts. However, many reported this prior to the course. The average response to comprehension based questions was 3.9 on the pre-survey and increased to 4.1 on the post-survey questions. While most agreed that these activities were helpful the results were mixed when they were responsible for developing their own procedures to complete the lab activities. This is not surprising when we take in to account the age of the students. Seventh grade students have not had much lab experience and the expectation to develop their own procedure was often thought of as overwhelming as opposed to an opportunity to enhance comprehension.

The results of the surveys also indicate that the students think about environmental issues more after completing the course. These results were more pronounced than the questions that related to understanding. The average response value for science literacy was 2.4 on the pre-survey compared to 4.1 on the post-survey. Students across the class thought that environmental issues, in particular alternative energy issues, were important enough to follow in the news. In addition, most students in the class reported an interest in all areas of science as a result of the Alternative Energy unit.

Conclusion

The results of the study suggest that curriculum centered on problem based learning and hands on activities can lead to an increase in students' understanding of science and particularly alternative energy. The data suggest an increase in both the students' enjoyment of the subject matter as well as their confidence in their mastery of the concepts, as evident by the 24% increase in student scores from the pre-test to post-test. It has also lead to the desire of students to become more actively involved in science related issues that are shaping the world of today according to the results of the survey.

Data taken before and after the study revealed an increase in all students' scores on a test dealing with alternative energy topics such as biomass, solar energy, and wind energy. As mentioned earlier the mean increase is 8.1 on a test consisting of 34 points. This is equal to an average increase of 24%. These data are significant as indicated by the t-test. This implies that the increase in student performance is beyond chance. Data from the study could be attributed to the methods by which the class was taught, however it is not a completely controlled study and an increase in performance should be expected.

The surveys show that students preferred the hands on activities and problem based learning to more traditional methods. While even this course was supplemented by some textbook reading and note taking, it was not centered on these methods as the primary means for students obtaining understanding of alternative energy. The manner in which the course was presented increased the students' enjoyment and their ideas about science specifically. These kinds of data are so important because they suggest the students will continue on with positive thoughts of science and how science can be taught. This is the kind of impact all teachers hope to make on students. It is why we are in the profession. We want to make the greatest impact on the lives of young people and we hope that our love of science is transferred to them.

The survey results also suggest that students have taken a greater interest in scientific issues that are also current events. The students in the study expressed their interest in alternative energy issues specifically. This is exactly what is intended anytime a unit or lesson is taught. In the case of this course, it is particularly satisfying that the students believe that they will follow alternative energy issues more closely. Following the theme of the entire study, this is an issue of the 21^{st} century. If we can't inspire the students to pursue a career in science we can at the very least lead them to understand the importance of science. This is critical when it comes to alternative energy. Our students will be part of the voting population soon and will help shape policy. Their initial desire to pay attention to alternative energy issues suggests a population that is better equipped to make decisions regarding their future.

While the results of this study are positive it by no means alleviates the need for further studies using similar methods. A problem based learning method of teaching complete with many opportunities for hands on experience does not hurt student understanding, and could therefore be considered an effective option when planning a similar unit. From personal observations, I would conclude that it increased student participation. It also contributes to a more exciting experience and a student base that is genuinely inspired and ready to partake in science in their everyday lives.

Teaching a unit that is centered on problem based learning is not an easy transition. One has to let go of the idea that it is the teacher's responsibility to convey all information to the student. This definitely left me worrying as to whether or not the students had grasped all the objectives I had hoped they would learn. It is more leg work and requires a lot of set up and clean-up time. All activities have to be planned out ahead of time and the instructor must go through them and try to troubleshoot all possible problems, which are not always predictable given the Problem-Based Format.

I would teach this class in a problem based manner again, however, I would change some of the lab activities to reflect shortcomings we encountered. Specifically, in the biodiesel lab I would have tried to contact a school for mechanics to obtain a desktop diesel engine to give the students a real life experience with their fuel working in an engine as opposed to burning it in a calorimeter. Poor lab technique produced many fuel samples that would not burn. This led to some students that were more consumed with the failure of the lab as opposed to the importance of the lab, producing a viable fuel from household items. I believe that the biodiesel lab is much better suited to the high school student.

The windmill problem could be improved via suggestions I have learned since the course ended. Using pieces of compact discs instead of cardboard leads to sturdier blades that are more resistant to damage and able to move with greater speed. Also creating a wind farm from all groups and wired in series could give the students a better idea of how wind turbines generate a significant amount of electricity.

The solar cars worked well, but the activity could be enhanced by comparing photovoltaics with solar thermal. Having the students heat water with an array of mirrors would give them insight into solar energy's main real world use at this time. This could also allow the students an opportunity to design their own solar power plant which would be a powerful activity.

This study has led me to understand the importance of exploring new methods of instruction. Problem based learning may not be suitable for every lesson, unit, or course, but it allows students the opportunity to imitate real life problems. This had a positive effect on my experience and I can carry that to all my classes and lessons. Always finding the most effective way to promote science literacy is the most important part of my job and that will never be static.

Appendices

Appendix A

Table 2 Student Data

Student Number	pre test score	post test score	Difference d_i	Pre test %	Post test %	% Increase
1	14	26	12	0.41	0.76	0.35
2	28	30	2	0.82	0.88	0.06
3	27	28	1	0.79	0.82	0.03
4	2	15	13	0.06	0.44	0.38
5	17	29	12	0.50	0.85	0.35
6	17	21	4	0.50	0.62	0.12
7	30	32	2	0.88	0.94	0.06
8	19	29	10	0.56	0.85	0.29
9	15	26	11	0.44	0.76	0.32
10	10	17	7	0.29	0.50	0.21
11	31	32	1	0.91	0.94	0.03
12	23	26	3	0.68	0.76	0.09
13	16	26	10	0.47	0.76	0.29
14	9	18	9	0.26	0.53	0.26
15	23	30	7	0.68	0.88	0.21
16	13	28	15	0.38	0.82	0.44
17	12	24	12	0.35	0.71	0.35
18	9	23	14	0.26	0.68	0.41
19	15	24	9	0.44	0.71	0.26
MEAN	**17.4**	**25.5**	**8.1**	**0.51**	**0.75**	**0.24**
Standard Deviation	7.9	4.9		0.23	0.14	

Appendix B

Table 3 Calculation of the Standard Deviation

Student Number	$(d_i - \bar{d})$	$(d_i - \bar{d})^2$		
1	3.9	15.21		
2	-6.1	37.21		
3	-7.1	50.41		
4	4.9	24.01		
5	3.9	15.21		
6	-4.1	16.81		
7	-6.1	37.21		
8	1.9	3.61	Variance of Differences (S_d^2)	21.66
9	2.9	8.41		
10	-1.1	1.21		
11	-7.1	50.41	Standard Error of Differences (S_d)	1.07
12	-5.1	26.01		
13	1.9	3.61		
14	0.9	0.81	t value	7.59
15	-1.1	1.21		
16	6.9	47.61	Degrees of Freedom	18
17	3.9	15.21		
18	5.9	34.81		
19	0.9	0.81		
Sum	0.1	389.79		

Appendix C

Table 4 Pre and Post Survey Data for all students

Pre Survey

Student Number	Question # 1	Question # 2	Question # 3	Question # 4	Question # 5	Question # 6	Question # 7	Question # 8	Question # 9	Question # 10	Question # 11	Question # 12	Question # 13
1	5	3	5	3	4	2	2	5	5	3	2	2	3
2	5	4	5	3	3	2	2	3	5	3	1	2	3
3	4	4	5	4	4	3	1	3	5	4	1	2	2
4	5	5	4	3	3	3	1	3	5	4	1	1	2
5	5	3	5	4	3	3	1	2	5	2	3	1	2
6	4	3	4	5	3	3	2	4	5	2	3	2	4
7	4	4	4	4	4	4	4	4	4	4	4	4	4
8	5	5	4	4	3	3	2	2	5	5	3	3	3
9	3	3	5	3	3	1	1	4	5	3	3	2	3
10	5	5	5	3	5	2	2	5	5	3	2	2	5
11	5	3	3	4	5	4	2	5	5	3	1	3	5
12	4	3	3	4	4	2	2	4	5	2	3	2	2
13	4	4	4	4	4	4	4	4	4	4	4	4	4
14	4	2	5	3	4	3	1	2	5	5	3	2	3
15	5	2	3	4	3	2	1	1	5	3	3	1	3
16	3	3	3	3	3	3	3	3	3	3	3	3	3
17	5	5	5	5	5	1	1	3	4	1	1	1	4
18	5	4	3	3	4	3	2	2	5	3	3	1	3
19	5	4	5	4	3	2	1	1	5	3	1	2	4

Appendix C (cont'd)

Post Survey

Student Number	Question # 1	Question # 2	Question # 3	Question # 4	Question # 5	Question # 6	Question # 7	Question # 8	Question # 9	Question # 10	Question # 11	Question # 12	Question # 13
1	5	3	5	4	4	4	3	5	5	3	3	4	4
2	5	5	4	5	3	5	5	3	5	3	2	4	4
3	4	4	3	5	3	5	4	3	5	3	3	4	5
4	5	3	5	3	3	4	3	3	5	4	4	4	4
5	5	3	5	3	4	3	4	3	5	2	4	5	5
6	4	3	4	5	3	5	4	4	5	2	5	4	5
7	4	5	5	5	4	5	5	3	4	3	5	4	4
8	5	4	4	3	3	5	5	4	5	3	3	5	4
9	3	4	4	5	3	5	5	4	5	2	3	4	3
10	5	5	4	2	4	4	4	5	5	1	5	5	4
11	5	3	4	3	5	3	3	5	5	3	4	4	5
12	4	5	4	4	5	4	5	4	5	2	4	3	3
13	4	5	5	3	5	4	3	3	4	2	4	4	5
14	4	4	5	4	4	4	4	2	5	3	5	4	4
15	5	4	4	5	4	5	4	5	5	3	4	5	4
16	3	5	3	5	2	3	4	3	5	3	3	4	4
17	5	4	4	5	4	5	5	2	4	3	4	3	5
18	5	4	4	4	2	4	5	2	5	3	3	5	4
19	5	5	5	4	3	4	5	4	5	2	4	4	5

Appendix D

Table 5 Question Performance by Topic

Question Number	Topic	Number of Students Answering Correctly on Pre Test (out of 19)	Number of Students Answering Correctly on Post Test (out of 19)	Percent Increase (%)
1	Solar	5	15	53
2	Wind	12	16	21
3	Biomass	10	16	32
4	Solar	12	17	26
5	Biomass	9	17	42
6	Wind	6	16	53
7	Solar	10	16	32
8	Wind	8	16	42
9	Biomass	5	11	32
10	Solar	7	15	42
11	Wind	8	15	37
12	General	4	16	63
13	Wind	0	15	79

Table 6 Solar

Question Number	Topic	Number of Students Answering Correctly on Pre Test (out of 19)	Number of Students Answering Correctly on Post Test (out of 19)	Percent Increase (%)
1	Solar	5	15	53
4	Solar	12	17	26
7	Solar	10	16	32
10	Solar	7	15	42
			Average Percent Increase	38

Table 7 Wind

Question Number	Topic	Number of Students Answering Correctly on Pre Test (out of 19)	Number of Students Answering Correctly on Post Test (out of 19)	Percent Increase (%)
2	Wind	12	16	21
6	Wind	6	16	53
8	Wind	8	16	42
11	Wind	8	15	37
13	Wind	0	15	79
			Average Percent Increase	46

Table 8 Biomass

Question Number	Topic	Number of Students Answering Correctly on Pre Test (out of 19)	Number of Students Answering Correctly on Post Test (out of 19)	Percent Increase (%)
3	Biomass	10	16	63
5	Biomass	9	17	53
9	Biomass	5	11	45
			Average Percent Increase	54

Appendix E

Building a Solar Car rules and follow up questions

Solar Car Contest

In this lab we will be building solar cars. Each group will have access to 2 solar panels. We will be racing them on the track with the flood lights. All groups are responsible for their own design. This means that you may use anything found in the classroom to design your car. The key is that each group gets no more than 2 solar panels and their car is completely powered by solar energy.

Materials:

- 1.5 volt or 1 volt solar panels
- alligator clips
- balsa wood dowels
- copper wire
- cardboard (different sizes for car frame)
- dc motor
- gears
- toy wheels

Procedure:

1) Using the listed materials (or any you have gotten approved by Mr. Z) you will need to design a solar car.
2) As a reminder the electric current produced by the solar panel is used to power the dc motor.
3) The dc motor will need to be used to turn the wheels of your car. (hint you may want to experiment with the gears)
4) You can test your design on the track. The car will probably only move on the track due to the intense light given off by the lamps.

Questions

1) Draw a picture of your design and label the parts of your car.

2. How was the motor able to work? (mention the conversions of energy that take place in order to operate the motor)

4. What are some advantages to using solar energy, as opposed to gasoline, to power a vehicle?

3. What are the disadvantages to using solar energy to power a vehicle?

5. The branch of solar energy that we dealt with in this lab is called ______________________________.

6. Name 2 other ways solar energy could be used as an alternative to traditional fuels.

Appendix F

Facts About Solar Energy is a worksheet completed before the Solar Car Contest.

Facts about Solar Energy

Using the internet you need to find answers to the following questions. This information will help prepare you for the Solar Car Contest. You may use the following website, or any other source you find helpful:
http://www.eia.doe.gov/kids/energyfacts/sources/renewable/solar.html.

1. Solar energy can be converted into ___________________ and ____________________ energy.

2. Solar energy can be converted directly into heat energy. This is useful for many things. Two main things that are heated using solar energy are water and air. List 2 ways water is heated with solar energy and 2 ways in which solar energy is used to heat the air.

3. Solar energy can be converted into electricity in two ways:
   a.
   b.

4. Which of the two from question 3 converts solar energy directly into electricity?

5. Which of the two from question 3 creates electricity in a power plant?

6. What element are photovoltaic cells primarily made from?

7. Most photovoltaic cells only have an efficiency of about _________ for converting sunlight to electricity.

8. Name 3 things that currently use photovoltaic cells for their power source.
   a.
   b.
   c.

9. What are some advantages of using photovoltaic cells to generate electricity.

10. ________________________________ is used for heating swimming pools, heating water used in homes, and space heating used in buildings.

11. Solar thermal energy that is used to heat homes and buildings is often classified into these two categories:
    a.
    b.

12. Of the two listed in question 11 which one requires a collector to be used on the building?

13. Of the two listed in question 11 which one is responsible for cars being warm on sunny days?

14. Explain how a solar power plant creates electricity.

15. What are the 3 different types of technologies used to concentrate the sun’s rays at a solar power plant?

16. Name 3 advantages created by using solar energy rather than fossil fuels.

17. Name 3 disadvantages surrounding solar energy.

Appendix G

Wind Turbine Webquest was designed to give students a chance to become familiar with the parts of a windmill before constructing one.

Wind Turbine Webquest

We will be starting a lab on wind energy. Before we start the lab you must figure out the parts of a wind turbine and how they help generate electricity. These two websites can help you, but feel free to use any other sites:
http://www1.eere.energy.gov/windandhydro/wind_how.html or
http://windeis.anl.gov/guide/basics/index.cfm

Draw a picture of a wind turbine. Label and explain the roles of following components: tower, nacelle, blades, rotor, generator, shaft

Appendix H

Build Your Own Windmill is the set of rules and follow-up questions for the windmill competition.

Build your own windmill

The objective is for the students to build a windmill that will register a reading on the voltmeter. They will be given the supplies and told to build the windmill without a set design. They may vary the number of blades along with the shape of the blades and blade angle. The design of the windmill is completely up to the students. The goal is to find an optimal design for the production of electricity. The only instruction is that the cardboard is intended to be the blades of the turbine. Any additional materials are subject to the approval of the instructor.

Materials

- size 3 cork
- dc motor
- toothpicks
- cardboard
- alligator clips
- copper wire
- voltmeter
- Fan
- Ruler or tape measurer

Procedure

1. The students will be challenged to design a windmill with the above materials. The windmill should be able to register a voltage on the voltmeter.

2. The next step is for the students to experiment with their design and increase the voltage produced. They may use different numbers of blades comprising the turbine or change the angles or shapes of the blades. The students are encouraged to experiment with the set-up of the entire windmill.

3. The rotor of the windmill (cork) must be 20 cm from the fan. This standard distance gives everyone the same force from the incoming fan.

4. Taking their best design the students will compete to produce the most voltage.

Data Collection

Students need to be sure to include a copy of their data for the different trials. Things to be included are the number of volts generated by each design. Each design refers to the number of blades, the shape of the blades, and the angle of the blade to the incoming wind.

Follow Up Questions

1. How is electric current being produced by your set up? Explain what is generating the current.

2. How many blades were optimal in your experiment?

3. Most windmills use 3 blades. If your windmill did best with 3 blades try to reason why. If your windmill did better with a different number of blades explain why that design is not used for current wind energy technology.

4. We used a fan to generate wind. Where does wind come from on earth?

5. What are some advantages to obtaining electricity from windmills?

6. What are some disadvantages to obtaining electricity using windmills?

Appendix I

Biomass Overview is the background information of all forms of biomass that we would be discussing.

Biomass Overview

Biomass is an energy source that is derived from living or recently deceased things. Wood is the first form of biomass that was used in large amount by human beings. The chemical energy stored in the bonds of organisms is the source of energy. Plants get this energy directly from the sun in a process called photosynthesis. Animals get this energy from the sun, but indirectly. They either eat the plants, or animals that eat plants in an effort to obtain energy and store it.

After the discovery of coal as a fuel source biomass, such as wood, were not used as much as they had in the past. Coal released so much more energy so it could be used to do many more things than wood. Recently there has been increased interest in other forms of energy due to the decline of fossil fuel reserves and there potentially harmful effects on the environment. Biomass has been explored again as a possible fuel source. Some interesting organisms and production of fuels have occurred in the last 15 years as we try to decrease our dependence on foreign oil.

Ethanol

The most well-known fuel being used is ethanol. Ethanol is an alcohol that is created during fermentation. It has been known for a long time that ethanol could be used as a fuel, but there was no need with the cheaper, more powerful gasoline in great supply. Currently the United States creates most of its ethanol from corn. Corn is fermented. Ethanol is created. This ethanol is mixed with petroleum-based gasoline. The most common mixture is called E85 because it is 85% ethanol and 15% gasoline. Our current automobiles can run on E85 with a few modifications. New automobiles are being made that can run on E85 without additional modifications. This makes ethanol an ideal substitute to gasoline. It works in our current vehicles. It is a liquid fuel and can be easily transported. It burns cleaner than gasoline.

There are some problems with ethanol though. Ethanol is made from corn. Corn is important as a food source. There is a worry that large scale production of ethanol from corn would cause a food shortage and possible famine. Ethanol from corn is not as powerful as gasoline. In fact it’s not even close. Ethanol is currently, at its peak, only about 30% the available energy of traditional gasoline. Corn-based ethanol has what is called a very low energy density. This means there is very little energy available compared to the amount of land needed to produce it. It has been estimated that if we turned our entire corn supply into a source for ethanol it would only meet 17% of our fuel needs.

This caused the need to obtain ethanol from a source other than corn. Brazil has been producing ethanol from sugar cane for over 30 years. this is more efficient because there is an extra step in creating ethanol from corn. The corn has to be processed into sugar first. In Brazil they can skip this step. This causes sugar cane to have an energy balance 7 times that of corn ethanol. This means the energy that comes out of ethanol from the sugar cane compared to the energy that went into making it is 7 times more efficient than when we make corn ethanol in the US. Brazil is the world's largest exporter of ethanol and stabilized their economy while freeing them of a large dependence on foreign oil This has even lead some to question whether corn-based ethanol is even an energy efficient fuel at all. Some figures suggest that producing ethanol from corn takes more energy than the fuel we get from it. This has also pushed the US to rethink their own ethanol ideas.

Because the US cannot grow sugar cane in most of its territory we are searching for new ways to make ethanol. One of those is to make it from cellulose. Cellulose is simply a huge molecule found in plants that is made up of many sugar molecules. If the cellulose can be broken down into its simple sugar units they can be fermented into ethanol. The problem is that current methods in breaking down cellulose are still being perfected. If they can be perfected we could get ethanol from plants that take up a fraction of the space as corn, as well as waste from plants like corn itself. This leads to an increase in energy density of the source. Some of the plants that have been proposed and being worked with are switchgrass and miscanthus. These plants can be grown in the US and they have a large ratio of cellulose making up their structure.

Biodiesel

Another solution to this problem has been to create different fuels. One of the fuels that is used has also been around for a while. When the diesel engine was created it was known that it could run off of many combustible products. One of those products was diesel fuel obtained from petroleum. This became the preferred diesel fuel when petroleum was cheap. With the increase in crude oil there has been a renewed interest in diesel, but it's the fact that diesel can be made from plant and animal oils. In this process called transesterification, an oil such as vegetable oil is turned into methyl esters, better known as biodiesel. Biodiesel is an attractive alternative to ethanol because it has about 90% the efficiency of petroleum-based diesel. This accounts for a very small dip in gas mileage when compared to the E85 dip. Biodiesel is also a clean burning fuel that requires absolutely no modification to a diesel engine. This is the biggest problem, however. Diesel engine only account for a small portion of automobile engines. This is coupled with the fact that the process is only energy efficient if the oil is used or free.

The most promising discovery regarding biodiesel has to do with algae. The algae Botryococcus braunii has been shown to give off oils. These oils can be converted into biodiesel. Obtaining biodiesel from algae would make its production cost effective because plant and animal oil would not have to be created. The algae secretes the necessary oils, so there is no need to harvest the algae. This means the same algae can be used over and over again. The oils secreted by Botryococcus braunii have the ability to be used as jet fuel, as well.

Dimethylfuran (DMF)

DMF is a product that scientists developed when experimenting with ethanol. There has been a large push to develop ethanol from cellulose. When experimenting with methods scientists were able to create DMF. If chemical and biological means are combined to degrade cellulose the fuel was created. DMF can be used as a liquid fuel in transportation because of its combustibility. The exact percentage is not known, however, it is thought to be energy dense. Because it is in the early stages of experimentation the environmental risks are not known.

Butanol

Butanol is an alcohol that is created by fermentation much like ethanol. Even though butanol is created in the same manner as ethanol it has some different properties than ethanol. One of those is the fact that it is more combustible than ethanol. Thus it releases more energy when burned. It has about 85-90% the efficiency of gasoline which means a very little drop in gas mileage would occur. It burns just as clean as ethanol. The problem is butanol is more toxic than ethanol before burning which cause storage concerns. Butanol is also a more minor product in fermentation. Only a few organisms can produce butanol thus making it harder to obtain.

Methane

Methane is a gas given off by decaying plant and animal waste. Because it is a gas it is not ideal for transportation. It can be used, however, to generate electricity. If methane can be captured it can be shipped to power plants for use as their fuel source. Methane is main ingredient in natural gas, so it has similar combustibility to a fossil fuel we already use. Methane is mostly being sequestered from landfills. This doesn't lead to a very large supply at the moment.

Waste to Energy Plants

In a waste to energy plant garbage is burned in an effort to generate electricity. This falls under the category of biomass because many of the combustible products in garbage are derived from organisms. When this waste is burned the energy given off can be used much like any other fuel used in a power plant. This eliminates the waste while generating electricity. The downfall is that the plants aren't completely emission free. This means some pollution will be released. The garbage only has a fraction of the energy that coal does.

Appendix J

Biomass Worksheet has the follow up questions that correspond to the Biomass Overview

Biomass Worksheet

Read the packet pertaining to biomass and answer the questions below.

1. What was the first form of biomass used by humans?

2. What source does America currently get most of its ethanol from?

3. What is a major problem of making fuel out of corn?

4. What is cellulosic ethanol?

5. What is the current problem with creating ethanol from cellulose?

6. ________________________ can be used without any modifications to a current diesel engine.

7. Biodiesel can be created from ______________, which is a small plant that is found in water.

8. Name 3 benefits associated with biodiesel as a fuel source.

9. Biomass energy is the burning of ___________ and ____________________ waste as fuel. This energy is stored as ____________________ energy in the bonds of the organism. This energy was originally created by the _________________.

10. _______________________ is the leading exporter of ethanol.

11. When chemical and biological methods are combined in breaking down cellulose _____________________ is created.

12. ___________________ is a type of fuel that is 85% ethanol and 15% gasoline.

13. Compare butanol to ethanol. List 2 advantages for butanol as a fuel source and 2 advantages for ethanol as a fuel source.

14. Compare biodiesel to ethanol. List 2 advantages for biodiesel and 2 advantages for ethanol as a fuel source.

Appendix K

Biodiesel Lab consists of the instructions for making biodiesel from vegetable oil, as well as the rules for the students to create biodiesel from another oil.

Biodiesel Lab

Introduction: In this lab we will be making biodiesel from vegetable oil. I will provide you with the directions on how to make it. We will set up a calorimeter to see how much energy is produced by each group's fuel. Finally each group will experiment with different oils to determine who can come up with the best (most energetic) recipe for biodiesel.

Part 1: Making the calorimeter

1. Take a pop can and lift the tab so that it is standing straight up.
2. Set up the ring stand.
3. Hang the pop can from the ring stand by sliding the stir rod through the tab.
4. Place the holder for the tea light candle underneath the pop can. Adjust the ring stand so the can is about 5 cm from the candle holder.
5. Tear off some steel wool. Use enough so that the candle holder is filled, but don't over fill the holder.

Part 2: Making Biodiesel

6. Write your group number on 2 250 mL Erlenmeyer Flasks with a piece of tape and a permanent marker
7. Pour 100 mL of veggie oil into one of the flasks. Heat while stirring until oil has reached 60˚ C. Heat at about 3 on the burner. Turn the burner down to low when the oil reaches 55˚ C.
8. Call Mr. Z over to check your temperature when you have reached 60˚ C. He will add 25 mL of the methanol/KOH mixture. (methanol is 30% of the total volume of vegetable oil and KOH is about 3.5 g for every L of veggie oil used)
9. Stir the mixture for 10 minutes.
10. Cover the flask with aluminum foil.
11. Let the flask sit for 24 hours.
12. Remove the glycerol that has settled at the bottom with a pipette. This layer should be darker in color than your biodiesel. (Tilting the flask on an angle while

you pipette off the glycerol makes its removal easier) Add any glycerol to a waste beaker.

13. When you think you have removed all the glycerol call Mr. Z over so he can see that your biodiesel is ready for the next step.
14. Add 100 mL of 0.1 M KH_2PO_4. Swirl for 30 seconds. (this solution can be made ahead of time by adding 6.8g of Potassium Phosphate to 500 mL of distilled water)
15. Let the mixture settle and pipette off the bottom layer.
16. Add 100 mL of 0.01 M KH_2PO_4. Swirl for 30 seconds. (this solution can be made by diluting down the 0.1 M potassium phosphate. Add 10 mL of 0.1 M of KH_2PO_4 to a beaker for every 90 mL of distilled water)
17. Let the mixture settle and pipette off the bottom layer.
18. Check the pH of your biodiesel. If it is around 7 then go to the next step. If it is still too basic then repeat steps 11 and 12 until the pH reaches 7.
19. Pour 100 mL 1% NaCl solution into your flask. Swirl for 30 seconds. (this solution can be made by dissolving 1g of salt for every 100 mL of distilled H_2O)
20. Let the mixture settle. Pipette off the bottom layer.
21. Place 5 g of solid NaCl into the solution. Swirl for 30 seconds.
22. Filter with a funnel and filter paper. Fold the filter paper to make sure it fits in the funnel. Place this set up atop your second flask. Pour your mixture into the funnel. This will take until next class period.
23. Throw away the filter paper. Add a new piece of filter paper to the funnel. Sprinkle on some salt grains. Pour your biodiesel through the funnel and back into your original flask. This will take about half the hour, so you should begin to answer the questions at the end of the lab.

Part 3: Creating your own biodiesel

24. Obtain all the materials from the previous part of the lab. Make sure they have been cleaned and dried.
25. Repeat the procedure from above, however, you may change the type of oil or vary the amount of ingredients.
26. Make sure to take note of the amounts of ingredients and what steps you changed, so you can compare your recipe for the final portion of the lab.
27. After you have created your own fuel bring it to Mr. Z so we can test it. We will pour 10 mL into the tea light candle with steel wool.
28. I will attempt to ignite it. It should burn without continually adding heat.
29. Place a thermometer in the can along with 100mL of water. Let your fuel burn underneath the can for 5 minutes. Whichever fuel raises the temperature the most in 5 minutes will be awarded with the best experimental design.

Questions

1) After making biodiesel, what are some advantages that you can see when comparing it to fossil fuels such as gasoline and petroleum diesel?

2) What are some problems you could see arising from making biodiesel?

3) The energy from biodiesel comes from the chemical energy stored in the bonds of the triglycerides like vegetable oil. Where did that chemical energy come from?

4) What are some differences between the vegetable oil and the end product of biodiesel?

5) Why don't you think you could add vegetable oil to a normal diesel engine, but you could add biodiesel?

Appendix L

Consent-Assent Form

Student Understanding of Alternative Energy Concepts is Enhanced by Hands-On Learning and Solving Real World Problems

I am currently enrolled as a graduate student in Michigan State University's Department of Science and Mathematics Education(DSME). The research for my thesis surrounds the use of hands-on projects and solving real world problems to facilitate students' understanding of alternative energy concepts. My research will focus on biofuels, wind energy and solar energy.

The data for my thesis will be generated from routine student work during the course of the unit. These pieces of data will include pre and post-tests, lab activities, quizzes, and surveys. The data will be used to determine the effectiveness of the unit only, and confidentiality is of the utmost concern. Student names will not be attached to any work presented in my thesis nor will any identities associated with images from class be revealed. Your child's privacy will be protected to the maximum extent allowable by law.

During the class the student will be asked to create biodiesel from ordinary household items. One of these chemicals is methanol. Methanol is used regularly in the classroom. Methanol can be dangerous if it is inhaled. I will personally add the methanol to each students' mixture. The mixtures will then be capped so students will never be exposed to the fumes. Once the reaction has taken place no methanol will be present and the mixture will no longer be harmful.

Participation in this study is completely voluntary. All students will be required to complete the work associated with the class. The students who participate in the study will have their work included in my research. Students not participating in the study will not be penalized. Their work will simply not be included in my research. If at any time during the course of the unit you request your student's work not be included in the study, your request will be honored.

If you are willing to have your student participate in the study, please complete the attached form and return it to me by ____________________, 2009. The forms will be kept in a sealed envelope in the principal's office until the study has been completed. If you have any questions about the project please contact me by email at zeluff@laingsburg.k12.mi.us or by phone at (517) 651-5034. You may also contact the program director, Dr. Merle Heidemann, at heidema2@msu.edu or (517)432-2152 ext. 107.

If you have any questions about the roles and rights of a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or email irb@msu.edu or standard mail at 202 Olds Hall, MSU, East Lansing, MI 48824.

I voluntarily agree to have ______________________________ participate in Mr. Zeluff's thesis research study. (Print Student Name)

Please check all that apply:

Parent/Guardian

_____ I give Mr. Zeluff permission to use images of my child through video and photography during his work on this thesis project. My student will not be identified in these images.

_____ I do not wish to have my student's image used at any time during this thesis project.

Student

_____ I give Mr. Zeluff permission to use images of myself through video and photography during his work on this thesis project. I realize I will not be identified in these images.

_____ I do not wish to have my image used at any time during this thesis project.

___________________________________ ________________

(Parent/Guardian signature) (Date)

I voluntarily agree to participate in this thesis project.

___________________________________ ________________

(Student signature) (Date)

Appendix M

Alternative Energy Pre Survey

For the following questions use the scale below:
5-always
4-often
3-sometimes
2-seldom
1-never

1. Labs help me understand science.

   5-always 4-often 3-sometimes 2-seldom 1-never

2. Solving problems helps my understanding of scientific concepts.

   5-always 4-often 3-sometimes 2-seldom 1-never

3. When I actively work on projects I understand concepts better.

   5-always 4-often 3-sometimes 2-seldom 1-never

4. Designing the procedure to the lab helps me understand the lab better.

   5-always 4-often 3-sometimes 2-seldom 1-never

5. Test and quiz questions are easier if I have done a lab about them.

   5-always 4-often 3-sometimes 2-seldom 1-never

6. I pay attention to science related issues in the news.

   5-always 4-often 3-sometimes 2-seldom 1-never

7. I pay attention to alternative energy related issues in the news

   5-always 4-often 3-sometimes 2-seldom 1-never

For the following questions use the scale below:

5-Strongly Agree
4-Agree
3-Somewhat Agree
2-Disagree
1-Strongly Disagree

8. I am interested in science.

   5-strongly agree   4-agree   3-somewhat agree   2-disagree   1-strongly disagree

9. I prefer doing labs to taking notes.

   5-strongly agree   4-agree   3-somewhat agree   2-disagree   1-strongly disagree

10. I would rather make the design up myself for a lab than have directions to follow.

   5-strongly agree   4-agree   3-somewhat agree   2-disagree   1-strongly disagree

11. I follow environmental issues in the news.

   5-strongly agree   4-agree   3-somewhat agree   2-disagree   1-strongly disagree

12. I am interested in news stories relating to alternative energy.

   5-strongly agree   4-agree   3-somewhat agree   2-disagree   1-strongly disagree

13. Alternative energy is an important topic.

   5-strongly agree   4-agree   3-somewhat agree   2-disagree   1-strongly disagree

Appendix M (cont'd)

Alternative Energy Post Survey

For the following questions use the scale below:
5-always
4-often
3-sometimes
2-seldom
1-never

1. Labs help me understand science.

   5-always 4-often 3-sometimes 2-seldom 1-never

2. Solving problems helps my understanding of scientific concepts.

   5-always 4-often 3-sometimes 2-seldom 1-never

3. When I actively work on projects I understand concepts better.

   5-always 4-often 3-sometimes 2-seldom 1-never

4. Designing the procedure to the lab helps me understand the lab better.

   5-always 4-often 3-sometimes 2-seldom 1-never

5. Test and quiz questions are easier if I have done a lab about them.

   5-always 4-often 3-sometimes 2-seldom 1-never

6. I pay attention to science related issues in the news.

   5-always 4-often 3-sometimes 2-seldom 1-never

7. I pay attention to alternative energy related issues in the news

   5-always 4-often 3-sometimes 2-seldom 1-never

For the following questions use the scale below:

5-Strongly Agree
4-Agree
3-Somewhat Agree
2-Disagree
1-Strongly Disagree

8. I am interested in science.

   5-strongly agree 4-agree 3-somewhat agree 2-disagree 1-strongly disagree

9. I prefer doing labs to taking notes.

   5-strongly agree 4-agree 3-somewhat agree 2-disagree 1-strongly disagree

10. I would rather make the design up myself for a lab than have directions to follow.

    5-strongly agree 4-agree 3-somewhat agree 2-disagree 1-strongly disagree

11. I follow environmental issues in the news.

    5-strongly agree 4-agree 3-somewhat agree 2-disagree 1-strongly disagree

12. I am interested in news stories relating to alternative energy.

    5-strongly agree 4-agree 3-somewhat agree 2-disagree 1-strongly disagree

13. Alternative energy is an important topic.

    5-strongly agree 4-agree 3-somewhat agree 2-disagree 1-strongly disagree

14. Which Lab or activity was the most helpful to you?

15. Did you prefer this science class to other science classes? Explain Why or Why Not.

16. Are you more likely, less likely, or just as likely to follow environmental issues since completing this unit? Explain.

17. Are you more likely, less likely, or just as likely to pay attention to issues involving alternative energy since completing this unit? Explain why or why not.

Appendix N

Biomass, Wind, and Solar Test

1. Electrical energy is produced directly from the sun in a branch of solar energy known as

a. Photovoltaics
c. Active Solar Heating
b. Passive Solar Heating
d. Photosynthesis

2. Wind energy involves mechanical energy, created by the spinning blades of a fan, being converted into

a. heat
c. electricity
b. fuel
d. transportation

3. The first major form of biomass used was

a. ethanol
c. wood
b. biodiesel
d. coal

4. Almost every form of energy is derived either directly or indirectly from

a. the sun
c. water
b. the earth
d. air

5. All of the following are considered forms of biomass except

a. wood
c. ethanol
b. yard waste
d. gasoline

6. All of the following are parts of a wind turbine except

a. rotor
c. blade
b. radiator
d. generator

7. All of the following are advantages to using solar energy except

a. very low pollution
c. unlimited supply
b. useful anytime
d. free resource

8. One major disadvantage of wind power is

a. limited resource
c. wind is not constant
b. high pollution
d. no place to build turbines

9. Name 2 advantages for using ethanol over gasoline in a vehicle. Name 2 advantages for using gasoline over ethanol in a vehicle.

10. Name 2 advantages to using solar energy at a power plant instead of coal. Name 2 advantages to using coal at a power plant instead of solar energy.

11. Give 2 reasons you might want to use a windmill to generate electricity at your house. Give 2 reasons you wouldn't want to use a windmill for electricity at your house.

12. What are the 3 main uses for alternative energy sources?

13. Label the parts of the wind turbine below.

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