Biofuels: An Alternative to Fossil Fuel

Stuart Surrey
Girls High School

Index:

Overview:

The most perplexing international problem concerning the fate of our planet is the issue of global warming. There are a number of complex factors governing the resolution of this extremely important environmental challenge. The decrease in world-wide fossil fuel reserves coupled with an increase in carbon dioxide emissions from the combustion of hydrocarbons makes it imperative that alternative energy resources be developed and utilized. This curriculum unit is designed for a traditional high school biology class and will focus on the feasibility of using various plants as a replacement for fossil fuel. The proposed unit will cover an examination of renewable versus non-renewable resources, factors affecting global warming, and the chemistry behind the combustion of fuel. It is envisioned that this unit will coincide with the implementation of unit ten: "Ecology", of the School District of Philadelphia's standardized curriculum for biology as outlined in the Planning and Scheduling Timeline for Science 2009-2010: Biology (1). There are a number of behavioral objectives embedded within this unit. Students will examine the interaction between the biotic and abiotic components within an ecosystem, analyze the effects of abiotic factors on the environment, and evaluate of the consequences of interrupting natural cycles. As designed, this curriculum unit could very easily be adapted to any environmental science, chemistry, and/or physical science class.

Rationale:

At no other time in history has there been such an urgent need for international cooperation in solving an environmental problem of global proportions as there exists today. We have progressed from a period of merely debating the probability that climatic changes might occur to participating in multinational conferences dealing with immediate measures that will reduce its causes and effects. The debatable issue of whether or not climatic changes are a normal cyclical event, due anthropogenic (man-made) causes, or a combination of both represents only part of an even more complex issue that being non-renewable versus renewable energy resources. Fossil fuel (oil, coal, and natural gas) is a non-renewable energy resource that comprises the majority of energy currently used around the world. Whether tapped or untapped, these reserves are in limited supply and will be depleted by the end of the twenty-first century. Therefore, it is imperative that alternative, renewable energy resources be developed and utilized. Wind, solar and geothermal energy will all be important for generating power. However, alternative sources must also be developed to replace oil in the production of petroleum based products such as plastics. One area of interest is in the research and development of biofuels.

Switching from fossil fuels to biofuels could lead to energy independence for the United States, but it does not address the issue of climatic changes. In developing an enlightened, long range energy policy one must address the following concerns: development of renewable energy resources, and the reduction of greenhouse gas emissions. With such a universal policy in place, it might be possible to control the environmental impact of the Earth's changing climate. Before proceeding any further, it would be noteworthy to clearly differentiate the greenhouse effect from global warming. Whereas the greenhouse effect involves the natural warming of the Earth's surface by a number of naturally occurring greenhouse gases, global warming is generally attributed to the anthropogenic production and/or emission of additional greenhouse gases. As a result, global warming is also referred to as an enhanced greenhouse effect. The mechanism behind the greenhouse effect and global warming is the same. Greenhouse gases in the troposphere, which is the atmospheric layer closest to the Earth's surface, absorb infrared radiation emitted from the surface of the Earth and radiate it back to the Earth as infrared radiation of a longer wavelength (2).

The Chemistry of Greenhouse Gases

Although air pollution significantly affects global warming, not all air pollutants are greenhouse gases. Only those pollutants in the atmosphere that will absorb infrared radiation and radiate it back to the Earth's surface are true greenhouse gases. These gases include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons. It is clear that the two greatest sources of global warming are due to water vapor and carbon dioxide (3, 4).

Even though water vapor is the most abundant greenhouse gas in the atmosphere, its beneficial effects in controlling Earth's average surface temperature should not be overlooked. Without the greenhouse effect, Earth's average surface temperature would be approximately 246 K or -17 °F. Due in large part to the hydrologic cycle, the average surface temperature of the Earth is calculated to be 287 K or 57 °F (5). In spite of its affect on Earth's average surface temperature, water vapor in the atmosphere is not considered to be a major factor in global warming for several reasons. First of all, the mean lifetime of water vapor in the atmosphere is only ten days (6). Another reason seems to be an insignificant anthropogenic effect on water vapor concentrations (7).

The anthropogenic production of carbon dioxide is believed to account for approximately 43 percent of all global warming and its number one contributing factor (8). According to the National Oceanic and Atmospheric Administration (NOAA), atmospheric carbon dioxide concentrations have increased thirty percent over what they were prior to the industrial revolution (9). During the same period, the average surface temperature of the Earth increased by 1.33 °F (10). Compounding the problem is the mean lifetime of carbon dioxide in the troposphere which is estimated to be from 50 to 120 years (11). Carbon dioxide is generated from the following two sources: the combustion of fossil fuels and deforestation. Fossil fuels such as coal, oil, and natural gas together account for 86.5 percent of the energy produced globally. Oil alone accounts for 36.5 percent of the energy produced on Earth making it the greatest energy resource (12). Crude oil is primarily a mixture of hydrocarbons. The separation of this mixture into usable products by fractional distillation is based on the boiling points of the constituent compounds. In this process, crude oil will produce the following fractions: gas containing C_1 to C_4 compounds, gasoline containing C_5 to C_{12} compounds, kerosene containing C_{12} to C_{16} containing compounds, heating oil containing C_{15} to C_{18} compounds, lubricating oil containing compounds in excess C_{17}, and an asphalt/paraffin residue which contains compounds of C_{20} or greater (13).

The complete combustion of any hydrocarbon produces the same two products, carbon dioxide and water. As a result, the major difference between the combustion of any two hydrocarbons is the amount of energy produced. This can be calculated from the standard enthalpy of formation for each hydrocarbon. The change in enthalpy for a given reaction can be determined from the following equation:

$$\Delta H^\circ_{reaction} = \Sigma n_p \Delta H^\circ_f (products) - \Sigma n_r \Delta H^\circ_f (reactants)$$

$\Delta H^\circ_{reaction}$ = change in enthalpy for the reaction
n_p , n_r = number of moles of products and reactants respectively
ΔH°_f = standard enthalpy of formation

Using the above equation to determine the change in enthalpy for the combustion methanol and octane, the following thermochemical reactions can be obtained.

Methanol: $2CH_3OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 4H_2O + 22\ kJ$
Octane: $2C_8H_{18(l)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(l)} + 47.8\ kJ/g$

From the above equations, it is clear that the enthalpy of combustion for octane is slightly more than twice as much as that for methanol on a gram to gram basis (14).

Methane, another major greenhouse gas, is believed to contribute close to 27 percent of all global warming (15). It is generated from both natural and anthropogenic sources including: animal waste, biomass burning, combustion of fossil fuels, landfills, livestock, sewage, wetlands, and from the production of rice (16, 17). In addition to methane's ability to absorb infrared radiation as a greenhouse gas, the complete combustion of methane leads to the same two greenhouse gases as any other hydrocarbon, carbon dioxide and water vapor. The thermochemical equation for which is given as:

$$CH_{4\,(g)} + 2\ O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{\,(g)} + 50\ kJ/g$$

Even though the mean lifetime of methane in the atmosphere is 12 to 18 years which is considerably less than that for carbon dioxide, it has a global warming potential (GWP) approximately 23 times greater than that of carbon dioxide (18). The GWP is a measure of the extent to which a particular greenhouse gas will contribute to global warming. Calculation of the GWP is dependent upon the absorption of infrared radiation, the spectral location of the absorbing wavelengths, and the mean atmospheric wavelengths (19).

Chlorofluorocarbons (CFCs) are a class of organic compounds principally used as refrigerants and propellants in aerosol sprays. Included in this class are Freon-11, trichlorofluoromethane, and Freon-12, dichlorodifluoromethane. Not only are the CFCs considered to be greenhouse gases, but they are also responsible for the depletion of the ozone layer which comprises the upper layer of the stratosphere. The chemical decomposition of ozone by CFCs can be summarized as shown by the following equations:

$$CCl_2F_{2\,(g)} + \text{energy} \rightarrow CClF_{2\,(g)} + Cl_{\,(g)}$$

$$Cl_{\,(g)} + O_{3\,(g)} \rightarrow ClO_{\,(g)} + O_{2\,(g)}$$

$$O_{\,(g)} + ClO_{\,(g)} \rightarrow Cl_{\,(g)} + O_{2\,(g)}$$

From the above reactions, one can observe how the production of chlorine atoms serves as a catalyst in the further breakdown of ozone into chlorine monoxide and oxygen. The average length of time that CFCs remain in the troposphere ranges from 11 to 20 years however they can remain in the ozone containing stratosphere from between 65 to 110 years. The GWP for CFCs ranges from 900 up to 8 300 (20). Due in large part to the 1987 Montreal Protocol, CFC production in the United States has been banned since 1995 (21). Expected projections suggest, however, that it will not be much before the year 2100 that the ozone layer could return to its 1950 level, if all of the international agreements are kept (22).

Another significant greenhouse gas is nitrous oxide which accounts for close to 4 percent of global warming (23). The major sources of anthropogenic nitrous oxide emissions include: biomass burning, deforestation, fossil fuels, and microbial activity on fertilizers (24). In spite of its relatively minor contribution to global warming, its mean lifetime in the atmosphere has been estimated to be between 114 to 120 years with a GWP of 296 (25). Taking these factors into consideration, controlling nitrous oxide emissions becomes as formidable as any of the other greenhouse gases.

Chemistry of Oil

In light of the dwindling fossil fuel reserves, renewable alternatives must be developed to replace crude oil both as an energy source and for the manufacturing of petrochemical products. The oils derived from plants seem to be at the forefront as the potential replacement for at least the synthesis of petrochemical products. Chemically, oils and fats belong to a class of organic compounds known as lipids. They are hydrophobic compounds and as such are non-polar. The major difference between fats and oil is that fats are solid at room temperature whereas oils are liquid under the same conditions. This difference in physical state is attributed to the degree of hydrogenation present. Saturated fatty acids lead to lipids that are solid whereas polyunsaturated fatty acids lead to lipids that are liquids at room temperature.

Fats and oils are triglycerides which are composed of the same two general constituents, glycerol and fatty acids as shown below:

CH_2OH
|
$CHOH$
|
CH_2OH

Glycerol

$CH_3(CH_2)_nCOOH$

Fatty acid

Glycerol is an alcohol composed of three carbon atoms each containing an alcoholic –OH group. In contrast, fatty acids tend to be long chain monocarboxylic acids. Fatty acids can either be saturated or unsaturated with respect to the number of hydrogen atoms bonded to each carbon atom in the fatty acid chain. A fatty acid which contains no double bonds between adjacent carbon atoms is referred to as a saturated fatty acid. Conversely, those fatty acids which contain at least one double bond are referred to as unsaturated fatty acids. The terms *cis*- and *trans*- fatty acids refer to the orientation of the hydrogen atoms around the carbon-carbon double bond. Hydrogen atoms occurring on the same side of the double bond result in the *cis*- configuration. If the hydrogen atoms occur on opposite sides of the double bond, then the *trans*- configuration is the result.

```
cis- configuration            trans- configuration
    H   H                          H
    |   |                          |
  - C = C -                      - C = C -
                                       |
                                       H
```

Conformational changes in the fatty acid result when the unsaturation is of the *cis*- configuration. The resultant conformation change is a bending of the hydrocarbon chain at the site of the double bond. The greater the number of *cis*- double bonds, the greater is the degree of bending or distortion. No such conformational change results from the *trans*- configuration. The double bonds in polyunsaturated fatty acids with *cis*- configurations usually occur at intervals of three carbon atoms as illustrated below:

$$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$$

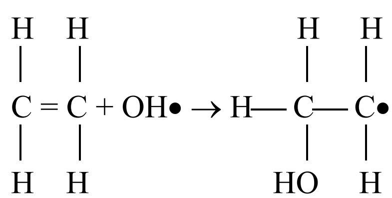
α-Linolenic acid

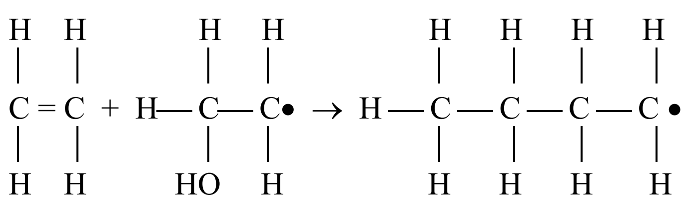
The biosynthesis of a triglyceride initially involves the removal of the hydrogen atom from each of the three alcoholic groups in the glycerol molecule along with the removal of three hydroxyl groups from each fatty acid. This dehydration reaction followed by the esterifcation of each fatty acid to the glycerol molecule produces a triglyceride. The esterified fatty acids can either be the same as in the case of triolein, tripalmitin, or tristearin in which oleic aid, palmitic acid, and stearic acid are the respective fatty acids in each triglyceride. In most cases, however, oils are mixtures of a variety of triglycerides (26).

Chemistry of Plastics and Polymers

The derivation of the term plastic comes from a Greek word that refers to materials that can be molded into shape. This group of materials can be further classified as either thermoplastics or thermosetting polymers also referred to as thermosets. When subjected to sufficient heat, thermoplastics will become pliable and/or melt. In contrast, thermoset materials will not melt after being molded into shape. They will either crack or become charred when exposed to extreme heat. Thermoplastics include a long list of such common everyday materials as: polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polytetrafluoroethylene. Materials classified as thermosets include among others, polyester fiberglass, vulcanized rubber, epoxy resins and polyimides. Due to molecular cross-linking, thermosets tend to be stronger than thermoplastics. Regardless of whether they are thermoplastic or thermoset, they have a number of things in common. Plastics are synthetic organic molecules generally having molecular weights in excess of 20 000 consisting of long chains, or polymers, of individual units known as monomers (27, 28, 29).

The synthesis of plastics generally involves one of three basic types of chemical reactions which include: polyaddition, condensation, or cross-linking (30, 31). Polymerization by addition reactions involve chemically joining multiple monomers together ultimately forming the polymer. Everyday plastics manufactured by means of polyaddition reactions include: polyethylene, polypropylene, polystyrene, polyvinyl chloride, polyvinylidene commonly known as Saran Wrap, polytetrafluoroethylene or Teflon, polyacrylonitrile, polyvinyl acetate, and polymethyl methacrylate. As shown below, the synthesis of polyethylene begins with a molecule of ethylene and a free radical such as a hydroxyl group.





The reaction continues until two radical groups join together with the resulting formation of the polymer, polyethylene. The overall general equation for addition polymerization reactions shows the monomer and the repeating unit within brackets as illustrated below for polyethylene.

$$nCH_2{=}\ CH_2 \rightarrow —[CH_2CH_2]_n—$$

In the case of condensation reactions, the polymer is formed by chemically combining two identical monomers or two different monomers. In either case, a small molecule such as water is formed in the process. For example, in the synthesis of nylon 6 two monomers of 6-aminohexanoic acid is chemically combined with the liberation of water as depicted in the following reaction:

```
      O       H               O       H            O      H   O      H
      Π       |               Π       |            Π      |   Π      |
HO — C(CH2)5N— H  +  HO — C(CH2)5N— H  →  —[C(CH2)5N— C(CH2)5N]n—
```

6-aminohexanoic acid + n H_2O

In the formation of another nylon product two different monomers, 1,6-hexanediamine and adipic acid are used in the manufacturing of nylon 66 and water.

```
     H      H                O      O             H      H   O      H
     |      |                Π      Π             |      |   Π      Π
n H—N(CH2)6N—H  +  n HO—C(CH2)4C—OH  →  —[N(CH2)6N—C(CH2)4C]n—
```

1,6-hexanediamine adipic acid + 2n H_2O

In the formation of nylon, whether it is nylon 6, nylon 66, or some other nylon product, the chemical bond between the two monomers is a peptide bond. This is the same bond that is formed between any two amino acids in the formation of a polypeptide chain during protein synthesis. Although water is a product in many condensation polymerization reactions, the resulting chemical bond between the two monomer subunits is not always a peptide bond. For instance, in the case of Dacron, ethylene glycol reacts with *p*-terephthalic acid to produce a polyester and water as the byproduct. The bond formed between ethylene glycol and *p*-terephthalic acid is an ester, as shown below, not a peptide.

```
      O
      Π
R−O−C−R1
```

R−O represents the formula for the ethylene glycol moiety

```
O
Π
C−R1
```

$C-R_1$ represents the formula for the *p*-terephthalic acid moiety

In the third major type of polymerization reaction, cross-linking between adjacent chains occurs as the result of the formation of covalent bonds formed between the adjacent chains. One of the desirable properties of cross-linked polymers is their added strength and/or rigidity. These materials which cannot be melted and reformed are classified as thermosets. In contrast, cross-linkages are not present in thermoplastics. The earliest example of a thermoset plastic, Bakelite, was developed by Dr. Leo Baekeland in

1907. It is a polymer of phenol and formaldehyde in which the $-CH_2-$ groups from formaldehyde are cross-linked to the benzene ring of phenol at either the 2- or 4-position. Current uses of Bakelite include the manufacturing of billiard balls, chess, checkers and other game pieces (32, 33).

Bioplastics

The idea of producing plastics from plants is not new. In 1941, Henry Ford built an automobile with plastic side panels constructed from soybeans (34). Considering the future of fossil fuel reserves and the demand for petrochemical products there has been a renewed interest in the production of plastics from a variety of renewable sources. In 1992, plant molecular geneticists at Michigan State University discovered and cloned a gene responsible for the enzymatic synthesis of polyunsaturated fatty acids. Interest in this gene led others from the DuPont and Monsanto companies to isolate an additional eight genes that control the polyunsaturation of plant oils in *Arabidopsis*. These genes were later inserted into such crops as soybean, canola, and flax in order to increase the production of saturated oils. Additional research has shown that with genetic engineering plants can produce the polyester, polyhydroxybutyrate, which is used in the manufacturing of biodegradable plastic (35).

In August of 2000, Dr. Bernard Tao from Purdue University suggested the need for plant oils, especially from corn and soybean, as renewable sources in the production of petrochemical products including plastics (36). Several years later, it was reported in Scientific American that researchers at Pacific Northwest National Laboratory had developed a catalytic process for converting glucose and other sugars into hydroxymethylfurfural, a compound that could be used in the production of plastics as well as a number of other products. Among the advantages of this process are the use of renewable biomass such as cornstalks and the use of much lower temperatures. Whereas refining crude oil requires temperatures around 600 °C, this process would require temperatures of about 100 °C (37).

To date, the number of crops suggested as sources for the production of bioplastics continues to increase. Australian researchers plan on manufacturing bioplastics from such plants as safflower (38). A major Chicago company has started manufacturing bioplastics from soybean (39). Other companies using soybean to produce polyurethane foams, resins, binders, sealants, and automotive body parts include: Urethane Soy Systems Company, BioBased Systems, Ford Motor Company, Ashland Specialty Chemical Company, John Deere, Case New Holland, and Green Products Inc. (40). Canadian researchers have produced polyurethane sheets from canola oil (41). Meanwhile, German researchers at the University of Konstanz have developed a process of making the polyester, polydodecyloate, from castor oil (42).

Objectives:

This curriculum unit was designed with the specific intent of teaching a traditional high school biology class the role of alternative energy sources as a means of reducing greenhouse gas emissions, controlling global warming, and replacing fossil fuel with plants in the production of petrochemical products such as plastic. It is intended to coincide with the ecology unit of the School District of Philadelphia's standardized curriculum for biology as outlined in the Planning and Scheduling Timeline for Science 2009-2010: Biology (43). As envisioned, the unit will last for approximately two weeks. The resources and activities utilized throughout the unit are intended to help stimulate creative thought, encourage students to examine the use of renewable resources in replacing fossil fuel, and help students gain an understanding of the consequences of global warming.

The unit will target a number of Pennsylvania Academic Standards for Science and Technology including, but not limited to: 3.3.10 B "Describe and explain the chemical and structural basis of living organisms", 4.3.10 C "Explain biological diversity as an indicator of a healthy environment", 4.6.10 A "Explain the biotic and abiotic components of an ecosystem and their interaction", 4.6. 10 B "Explain how cycles affect the balance in an ecosystem", 4.6.10 C "Analyze how ecosystems change over time" , 4.7.10 A "Explain the significance of diversity in ecosystems", 4.7.10 C "Identify and explain why adaptations can lead to specialization", 4.8.10 A "Analyze how society's needs relate to the sustainability of natural resources", 4.8.10 B "Analyze the relationship between the use of natural resources and sustaining our society", 4.8.10 C "Analyze how human activities may cause a change in an ecosystem", and 4.8.10 D "Explain how the concept of supply and demand affects the environment" (44).

Strategies:

In an ongoing effort to improve student achievement throughout the district, the School District of Philadelphia adopted an initiative for all high schools. The six step plan includes the following teaching strategies. With the first strategy, students are expected to preview content specific vocabulary on a daily basis. They are also expected to be able to preview, analyze, and connect material presented in textbooks. The remaining strategies include: reciprocal teaching, the ability to summarize material, the use of comprehension connectors or graphic organizers, and the ability to take notes. Parts of this unit will also necessitate the use of cooperative learning strategies which has been a successful pedagogical strategy for many years. The benefits of which have been shown to increase scholastic achievement, improve social skills, as well as team self-esteem. In order for cooperative learning to be an effective teaching strategy, deliberate care must be used in evaluating its ideal classroom design. There are six basic factors that one needs to consider in establishing and maintaining an effective cooperative learning environment. These factors include: team organization, cooperative management, the will to cooperate, the skill to cooperate, basic practices, and structuring the cooperative lesson. A synopsis of each will be presented in the presented in the following paragraphs (45).

From past experiences, team organization tends to be most effective when there is academic heterogeneity among the students rather than random selection. Academic heterogeneity allows for the establishment of teams or groups each of which contains students with high, average, and below average scholastic ability. Administering an entrance test the first week of school is extremely useful in this regard. Groups consisting of no more than four students have been ideal for a variety of reasons. Lateness and absences are real concerns for most of the high schools within the School District of Philadelphia. With four students in a group, individual groups can still function even when half of the students in any one group are absent. From the standpoint of classroom management, teacher determined learning groups tend to eliminate or diminish behavioral problems associated with those groups which were determined by the students.

Classroom management is essential to an effective cooperative learning environment. This can be accomplished through: cooperative management, the will to cooperate, and the skill to cooperate. It is imperative that students understand the guidelines for acceptable classroom behavior. For example, teachers must establish consistency in dealing with unacceptable noise level within the classroom. The will to cooperate is developed over time and is based on positive social interactions and pride within the group. The skill to cooperate is based on the ability of the students to assume specific roles within the group, listen to, and work with each other.

The basic practices inherent to cooperative learning include a number of behavioral skills which include: simultaneous interaction, positive interdependence, and individual accountability. Within a cooperative learning environment, the students are encouraged to interact with members within the group. This freedom is usually not permissible within a traditional classroom setting. Positive interdependence comes from the achievement of individual students within the group and from the entire group as a whole. Individual accountability can be addressed with the aid of a variety of assessments. For instance, students can be given individual grades for a project, or they can be made aware of their part of a group grade.

Effective classroom management depends, in large part, upon the structure of the lesson. Not only does it involve the arrangement of the students within the group, but it is also dependent upon the manner in which individual lessons are designed and presented. These structures, designs, or activities are meant to improve such areas as team building, information sharing, thinking skills, communication skills, and content mastery. A brief list of classroom structures and lesson designs include: brainstorming, jigsaw, numbered heads together, rally table, round robin, roundtable, student teams achievement division

(STAD), team projects, and think pair share. A detailed review of each activity can be found in Cooperative Learning (46).

By improving their note taking skills, students should be able to utilize, practice, and/or engage in summarizing, comprehension connectors, and structured note taking. For those reasons, I intend to teach my students the highly successful method of note taking that was developed by Walter Pauk, an English professor at Cornell University in the 1950's. The Cornell Method, as it is referred to, involves writing a key word, phrase, or concept on the left hand side of a sheet of paper. In a column, on the right hand side of the sheet of paper, relevant material about the concept is written in short sentences or phrases. Finally, at the bottom of the page, the material listed is then summarized into a short paragraph. This widely used method enables students to improve their skills in summarizing material presented in both lecture and written form (47).

In order to address and improve reading comprehension, my students will participate in reciprocal teaching techniques. This is another cooperative learning activity which is designed to encompass four skills: summarizing, questioning, clarifying, and predicting. Each student within the group will be responsible for reading a specific section within their textbook or assigned reading material, summarizing that material, and reporting out to the rest of his or her group. This pedagogical strategy has been reported to be successful in both small groups as well as in large classroom settings (48).

Classroom Activities:

Activity 1: Calculating the Rate of Photosynthesis and Respiration

This introductory activity is intended to align with state standard 3.3.10 B and demonstrate the importance of photosynthesis in controlling atmospheric carbon dioxide levels. It was taken from Vernier's Biology with Calculators (49). In this hands on laboratory experiment, the students will be able to calculate both the rate of photosynthesis and respiration using a TI-84 Plus calculator, a Vernier oxygen gas sensor and an EasyLink interface. The students will graph their results, calculate the slopes of each graph and compare these rates between two different plants: spinach and elodea. Additionally, this activity will enable the students to gain experience in data collection, processing, and graphical analysis.

Activity 2: Determining the Percent of Oil in Nuts

The basis for this activity was obtained from an experiment entitled "Solubility and the Percent Oil in Peanuts" (50). Using acetone to extract the oil from a variety of nuts, the students will be able to examine the oil content in some common nuts. The type and amount of saturated and unsaturated fatty acids in nuts varies considerably. For example, the Brazil nut contains more than twice the amount of saturated fatty acids compared to the peanut, but in terms of polyunsaturated fatty acids they are equivalent (51). In this experiment, the students will compare the percentage of oil in each type of nut as well as between the different types of nuts. In addition, the students will research the differences in saturated and unsaturated fatty acids between the nuts.

Activity 3: Creating Plastics from Plants

In this problem-based learning activity, the class will be divided into groups of four. Each group represents the board of directors of a local plastics manufacturing company. In light of the dwindling world-wide oil reserves and the global warming crisis, the board of directors will examine the feasibility of producing a "greener" plastic. The production of this product will be environmentally friendly and utilize renewable resources. Each board will be required to address the following questions: 1. "Which plant would be best for replacing our current raw material, crude oil?", 2. "In what way does the composition of the plant oil differ from the crude oil?", 3. "How will the plastic be produced from the plant?", and 4. "What is the environmental impact posed by the use of this particular plant in the manufacturing of plastics?" Each board will create a power point presentation consisting of at least fifteen slides with one additional slide for references.

Problem-based scenarios, such as this one, allow students to work collaboratively thereby enabling them to develop their social skills. Furthermore, the state standards addressed in this activity include: 4.8.10 A, 4.8.10 B, and 4.8.10 C.

Annotated Bibliography/ Resources:

Cited References

1. The School District of Philadelphia. Planning and Scheduling Timeline for Science: 2009-2010 Biology. 2009.
   The School District of Philadelphia outlines the sequence of units to be covered, the time allocated for each unit, and the resources to be used in the implementation of the unit.

2. Brown, Theodore L., Lemay, H. Eugene, Bursten, Bruce E., and Burdge, Julia R. Chemistry: The Central Science ninth edition. Upper Saddle River, NJ: Prentice Hall, 702-733.
   This textbook which has been used in the upper level chemistry classes explains the chemistry of greenhouse gases, global warming, and polymerization reactions.

3. National Oceanic and Atmospheric Administration National Climatic Data Center. "Greenhouse Gases Frequently asked Questions." Retrieved April, 2010 from http://www.ncdc.noaa.gov./oa/climate/gases.html
   This article gives a clear and concise overview of the individual greenhouse gases.

4. Al Gore. Our Choice: A Plan to Solve the Climate Crisis. Emmaus, PA: Rodale, 2009, 32-48.
This is an excellent resource on global warming and the use of alternative energy.

5. Freedman, Roger A, and Kaufmann III, William J. Universe. 7th edition, New York: W. H. Freeman and Company, 2005, 188-189.
This is an excellent textbook and resource on Earth's atmosphere and the universe.

6. "Water Vapor." Retrieved April, 2010 from http://wapedia.mobi/en/Water_vapor
This is a rather technical article on the role of water vapor as a greenhouse gas and not very useful for most students.

7. "Greenhouse Gas." Retrieved April, 2010 from http://en.wikipedia.org/wiki/Greenhouse_gas
This is a nice overview on the topic of greenhouse gases with many useful links to other reference sources

8. Al Gore. Our Choice: A Plan to Solve the Climate Crisis. Emmaus, PA: Rodale, 2009, 32-48.
This is an excellent resource on global warming and the use of alternative energy.

9. National Oceanic and Atmospheric Administration National Climatic Data Center. "Greenhouse Gases Frequently asked Questions." Retrieved April, 2010 from http://www.ncdc.noaa.gov./oa/climate/gases.html
The National Oceanic and Atmospheric Administration National Climatic Data Center answers a number of very common questions concerning the causes and effects of global warming

10. "Global Warming." Retrieved May, 2010 from http://en.wikipedia.org/wiki/Global_warming
This is an excellent article on the topic of global warming with many references.

11. Miller, G. Tyler. Living in the Environment. 13th edition, Pacific Grove, CA: Brooks/Cole-Thomson, 2004, 449.
In this textbook, Tyler Miller thoroughly covers the topic of climate change. It would be useful for the more advanced students.

12. Al Gore. Our Choice: A Plan to Solve the Climate Crisis. Emmaus, PA: Rodale, 2009, 57.
This is an excellent resource on global warming and the use of alternative energy.

13. Hill, John H. and Kolb, Doris K. Chemistry for Changing Times. 9th edition, Upper

Saddle River, NJ: Prentice Hall, 2001, 384-385.
In this section of the textbook, the refining process for crude oil and the various fractions obtained from fractional distillation are explained

14. Zumdahl, Steven S. and Zumdahl, Susan A. Chemistry. 6th edition, Boston: Houghton, Mifflin Co., 2003, 263-269.
This advanced high school chemistry textbook explains the chemistry behind the present sources of energy. I would not recommend it to students who have not previously taken a chemistry course.

15. Al Gore. Our Choice: A Plan to Solve the Climate Crisis. Emmaus, PA: Rodale, 2009, 47.
This is an excellent resource on global warming and the use of alternative energy.

16. Gore 39.
This is an excellent resource on global warming and the use of alternative energy.

17. Arms, Karen. Environmental Science. Austin: Holt, Rinehart and Winston, 2006, 341.
This textbook covers global warming at the basic level and is the textbook currently used in our environmental science classes.

18. Miller, G. Tyler. Living in the Environment. 13th edition, Pacific Grove, CA: Brooks/Cole-Thomson, 2004, 449.
In this textbook, Tyler Miller thoroughly covers the topic of climate change. It would be useful for the more advanced students.

19. "Global Warming Potential." Retrieved May, 2010 from http://en.wikipedia.org/wiki/Global_warming_potential
In this brief article calculation of global warming potential is discussed and the values for a number of greenhouse gases are reported.

20. Miller, G. Tyler. Living in the Environment. 13th edition, Pacific Grove, CA: Brooks/Cole-Thomson, 2004, 449.
In this textbook, Tyler Miller thoroughly covers the topic of climate change. It would be useful for the more advanced students.

21. American Chemical Society. Chemistry in the Community. 4th edition, New York: W. H. Freeman and Company, 2002, 332.
This chemistry textbook has a useful section on the chemistry of the atmosphere. I think it would make a good resource to any environmental science class,

22. Miller, G. Tyler. Living in the Environment. 13th edition, Pacific Grove, CA: Brooks/Cole-Thomson, 2004, 479.

In this textbook, Tyler Miller thoroughly covers the topic of climate change. It would be useful for the more advanced students.

23. Al Gore. Our Choice: A Plan to Solve the Climate Crisis. Emmaus, PA: Rodale, 2009, 47.
This is an excellent resource on global warming and the use of alternative energy.

24. Arms, Karen. Environmental Science. Austin: Holt, Rinehart and Winston, 2006, 341.
This textbook covers global warming at the basic level and is the textbook currently used in our environmental science classes.

25. Miller, G. Tyler. Living in the Environment thirteenth edition. Pacific Grove, CA: Brooks/Cole-Thomson, 2004, 449.
In this textbook, Tyler Miller thoroughly covers the topic of climate change. It would be useful for the more advanced students.

26. Alsberg, Carl L. and Taylor, Alonzo E. "The Fats and Oils: A General View." Retrieved May, 2010 from http://www.journeytoforever.org/biofuel_library/fatsoils/fatsoils2.html
The authors give an excellent overview of the chemistry of fats and oils.

27. "Plastic." Retrieved May, 2010 from http://en.wikipedia.org/wiki/Plastic
This is a good introduction into the area of plastics covering its history, types, environmental concerns and uses.

28. "Thermoplastic." Retrieved May, 2010 from http://plastics.inwiki.org/Thermoplastic
This is a very brief article on the nature of thermoplastics with a list of examples.

29. "Thermosetting polymer." Retrieved May, 2010 from http://en.wikipedia.org/wiki/Thermosetting_polymer
In this short article thermosetting plastics are discussed and examples are given.

30. Hill, John H. and Kolb, Doris K. Chemistry for Changing Times. 9th edition, Upper Saddle River, NJ: Prentice Hall, 2001, 267-293.
This section of the textbook outlines the chemistry of the different polymerization reactions leading to thermoplastics and thermosetting polymers.

31. Zumdahl, Steven S. and Zumdahl, Susan A. Chemistry. 6th edition, Boston: Houghton, Mifflin Co., 2003 1064-1073.
These pages of the textbook cover the chemistry of polymerization reactions.

32. "Bakelite." Retrieved May, 2010 from http://en.wikipedia.org/wiki/Bakelite
This short article on Bakelite covers its history, properties, and uses.

33. “Plastics.” Retrieved May, 2010 from
http://www.chemistryexplained.com/Pl-Pr/Plastics.html
This is an excellent short article on the history of plastics.

34. “Soybean Car.” Retrieved June, 2010 from
http://www.thehenryford.org/research/soybeancar.aspx
This article interesting little article discusses the reasons why Henry Ford built a car in 1941 with plastic side panels made from soybeans.

35. “Making Plastics (and Other Fine Things) from Plants.” Retrieved June, 2010 from
http://www.nsf.gov/bio/pubs/reports/arabid/arab-pl.htm
This article on bioplastics discusses how genetic research with the plant *Arabidopsis* has lead to interest in producing genetically engineered plants that are capable of producing plastic.

36. “Plant Oils Will Replace Petroleum in Coming Years.” Retrieved May, 2010 from
http://news.uns.purdue.edu/html4ever/0007.Tao.biofuels.html
In this news release, Dr. Tao discusses the reasons for why he believes plant oils hold the key to replacing petroleum in the near future.

37. Biello, David. “Turning Plants into Plastic – And Replacing Oil in the Process.” Scientific American. Retrieved May, 2010 from
http://www.scientificamerican.com/article.cfm?id=turning-plants-to-plastic- replacing-oil
The author briefly discusses the work of researchers at the Pacific Northwest National Laboratory in turning sugars into plastics.

38. “Boost for ‘Green Plastics’ from Plants.” Retrieved May, 2010 from
http://www.sciencedaily.com/releases/2008/04/080429085916.htm
This article discusses the feasibility of Australian researchers turning such crops as safflower into plastics.

39. “Cargill Breaks Ground for Soy-Plastics Plant in Chicago” Retrieved June, 2010 from
http://www.ens-newswire.com/ens/jul2008/2008-07-09-091.html
This article which was reported by the Environmental News Service discusses plans for a major Chicago company to produce plastics made from soybeans.

40. “Soy Plastics: Versatile and Cost Effective.” Retrieved June, 2010 from
http://www.soynewuses.org/Plastics/Default.aspx
The article written by the United Soybean Board discusses the use of soybeans in producing polyurethanes and plastic composites.

41. “Polyurethane Sheets from Canola Oil.” Retrieved June, 2010 from

http://www.sciencedaily.com/releases/2007/07/070702151141.htm
This new release reports the work of Canadian researchers in producing polyurethane sheets from canola oil.

42. "Plastic Made from Castor Oil." Retrieved June, 2010 from http://www.rsc.org/Publishing/ChemScience/Volume/2009/10/Plastic_Castor_Oil.asp
In this very short article, German researchers briefly discuss their process for producing polyesters from castor oil.

43. The School District of Philadelphia. Planning and Scheduling Timeline for Science: 2009-2010 Biology. 2009.
The School District of Philadelphia outlines the sequence of units to be covered, the time allocated for each unit, and the resources to be used in the implementation of the unit.

44. Pennsylvania Department of Education. Pennsylvania Teacher's Desk Reference: A Critical Thinking Guide, Jacksonville, FL: Educational Tools, Inc, 2006.
This reference guide details Pennsylvania's academic standards for science and technology for grades 9-12. It also addresses the assessment anchors and teaching strategies for each academic standard.

45. Kagan, Spencer. Cooperative Learning. San Juan Capistrano, CA: Kagan Cooperative Learning, 1992, 4:1-4:9.
Spencer Kagan's book on cooperative learning is an excellent resource for developing and sustaining a cooperative learning environment.

46. Kagan 7:1-8:2, 10:1-10:17
Spencer Kagan's book on cooperative learning is an excellent resource for developing and sustaining a cooperative learning environment.

47. "Cornell Notes." Retrieved April, 2007 from http://en.wikipedia.org/wiki/Cornell_Notes
This article briefly explains the Cornell Method of note taking as developed by Walter Pauk.

48. North Carolina Regional Educational Laboratory. "Reciprocal Teaching." Retrieved April, 2007 from http://www.ncrel.org/sdrs/areas/issues/students/atrisk/at6lk.38.htm
The benefits of reciprocal teaching are discussed as well as the steps involved.

49. Holman, Scott and Masterman, David. Biology with Calculators. 2nd edition, Beaverton, OR: Vernier Software and Technology, 2000, 31A-1.
The laboratory activity outlined in this lab book allows students to engage in an

inquiry based experiment using an oxygen gas sensor interfaced with a Texas Instruments calculator.

50. "Peanut Oil Experiment." Retrieved May, 2010 from http://www.woodrow.org/teachers/ci/1988/peanutlab.html
In this laboratory exercise, students will be able to calculate the percent of oil found in peanuts.

51. "Table of Fatty Acids in Nuts." Retrieved May, 2010 from http://www.thepaleodiet.com/nutritional_tools/nuts_table.html
This is a very useful table where the types and amounts of fatty acids are listed for a number of different nuts.

Teacher Resources:

Gore, Al. Our Choice: A Plan to Solve the Climate Crisis. Emmaus, PA: Rodale, Inc, 2009.
This is an excellent resource on global warming and the use of alternative energy.

Zumdahl, Steven S. and Zumdahl, Susan A. Chemistry. 6th edition, Boston: Houghton, Mifflin Co., 2003.
This advanced high school chemistry textbook provides valuable background information concerning the chemistry of greenhouse gases, global warming, and polymerization reactions.

Student Resources:

Johnson, George and Raven, Peter. Biology. Austin: Holt, Rinehart, and Winston, 2004.
This is the recommended textbook for the School District of Philadelphia's standardized curriculum for biology.

Standards:

All of the standardized curricula for the School District of Philadelphia are in alignment with the Pennsylvania Department of Education's academic standards for science and technology. The specific standards that will be addressed in this unit were taken directly from the Pennsylvania Teacher's desk Reference and Critical Thinking Guide and include the following:

3.3.10 B. Describe and explain the chemical and structural basis of living organisms.

- Describe the relationship between the structure of organic molecules and the function they serve in living organisms.

- Explain cell functions and processes in terms of chemical reactions and energy changes.

4.3.10 C. Explain biological diversity as an indicator of a healthy environment.

- Analyze the effects of species extinction on the health of an ecosystem.

4.6.10 A. Explain the biotic and abiotic components of an ecosystem and their interaction.

- Compare and contrast the interactions of biotic and abiotic components in an ecosystem.
- Analyze the effects of abiotic factors on specific ecosystems.
- Describe how the availability of resources affects organisms in an ecosystem.
- Identify a specific environmental impact and predict what change may take place to affect homeostasis.

4.6.10 B. Explain how cycles affect the balance in an ecosystem.

- Explain the consequences of interrupting natural cycles.

4.6.10 C. Analyze how ecosystems change over time.

- Analyze consequences of interrupting natural cycles.

4.7.10 A. Explain the significance of diversity in ecosystems.

- Explain the role that specific organisms have in their ecosystem.
- Identify a species and explain what effects its increase or decline might have on the ecosystem.

4.7.10 C. Identify and explain why adaptations can lead to specialization.

- Explain factors that could lead to a species' increase or decrease.

4.8.10 A. Analyze how society's needs relate to the sustainability of natural resources.

- Compare and contrast the use of natural resources and the environmental conditions in several countries.
- Describe how uses of natural resources impact sustainability.

4.8.10 B. Analyze the relationship between the use of natural resources and sustaining our society.

- Explain the role of natural resources in sustaining society.
- Analyze the effects of a natural resource's availability on a community or region.

4.8.10 C. Analyze how human activities may cause a change in an ecosystem.

- Analyze and evaluate changes in the environment that are the result of human activities.

- Compare and contrast the environmental effects of different industrial strategies (e.g. energy generation, transportation, logging, mining, agriculture).

4.8.10 D. Explain how the concept of supply and demand affects the environment.
- Identify natural resources for which societal demands have been increasing.
- Describe the relationship between population density and resource use and management.