TEAM PROJECT REPORT

Making Biodiesel for Research and Education: A Research Experience and Classroom Implementation Plan

Submitted To

The RET Site
For
"Sustainable Engineering for Urban Needs:
Research Experiences for Middle and High School Teachers"

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ABSTRACT

Ever since Rudolph Diesel invented the diesel engine in the 1890s, biodiesel fuel production has become a growing important renewable energy resource. Due to its clean, cost effective, and environmental benefits, biodiesel production has become increasingly important due to high demand all over the world. Research scientists are continuously looking for ways to produce biodiesel fuel more effectively and more cost efficiently. The fuel is often made from vegetable oil such as soybean oil in America. In this research, waste cooking oil was used to produce biodiesel fuel due to fact that this oil has a lower market value which will help to lower the cost of biodiesel production. It is also able to eliminate the use of soybean which is a valuable food source. The free fatty acids have to be neutralized with sodium hydroxide or potassium hydroxide depending upon the FFA content. In this report, experiments were conducted to determine the amount of biodiesel fuel produced using the same method but varying amounts of catalyst and to determine the amount of products produced from different waste cooking oil types. The results of this experiment showed that there was more product produced from the canola and the zoo when oils when a slight increase in catalyst was used.

GOAL AND OBJECTIVES

The main goals of this research was to produce biodiesel fuel from waste cooking oil as well as to determine which type of oil would produce the most biodiesel fuel. Another goal was to compare the amount of sodium hydroxide used for different oils. Optimal amount of sodium hydroxide to use for biodiesel production was based on FFA (Free Fatty Acids) content. The goal of this research project was to determine if slightly increased levels of sodium hydroxide used in transesterification would have an impact on how much product was produced. Another goal was to compare the amount of products produced between different types of waste cooking oils.

RESEARCH TASKS

Determine the FFA Content for Feedstock Oil: Waste cooking oil usually has a high free fatty acid content which must be determined and pre- treated to lower the free fatty acid content to a desirable level which is under one percent. In this research, sodium hydroxide solution, the titrate, and ethanol, the solvent was used for titrations. Two different oils were collected in the lab and tested through titration analysis for their FFA content. The oils collected were from the Cincinnati Zoo and the Center Court cafeteria on UC campus. The other oil used as a comparison was pure canola oil.

Amount of Sodium Hydroxide to Use as the Catalyst: Six flasks were obtained and 100 ml of feedstock oil was placed in each flask. A range of .1g to .6g of sodium hydroxide was placed in each flask along with 20 ml of methanol. In order to heat and stir the mixture at the same time, a hot plate with magnetic stirring functions was used. A magnetic stirring bar was placed in each flask for ten minutes at a constant temperature of 60^{o}C. The flasks were allowed to settle for twenty-four hours.

Lab Scale Biodiesel Production: In order to practice making biodiesel fuel, three batches were made from different amounts of feedstock oil. The zoo feedstock oils were titrated to determine the FFA content to see if the oils can be directly used in transesterification process. The results were found to be below 2% which indicates that it can directly undergo transesterification process. After measuring the amount of biodiesel and glycerol produced the biodiesel was placed in a plastic cone so that it could be washed several times in order to separate the impurities from the crude biodiesel.

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	Batch 1	**Batch 2**	**Batch 3**
Waste Cooking Oil (ml)	600	300	1000
NaOH (g)	2.1	1.05	3.5
Methanol (ml)	120	60	200

Making Biodiesel from Different Feedstock Oils: In this experiment, three types of feedstock oil were used to compare the FFA content and amount of products produced after transesterification. The three types of oil used for this comparison were collected from the Cincinnati Zoo, the University of Cincinnati, and canola oil. 100 ml of each of the oils was placed into a flask to undergo the transesterification procedure that was previously described in this report. The biodiesel fuel was then analyzed using an instrument called GC-MS.

METHODOLOGIES USED

Titration Procedure and Calculation of Free Fatty Acid:

1. An acid/base titration was performed in order to determine the volume of NaOH (sodium hydroxide) in µl needed to neutralize the amount of FFA (Free Fatty Acids) found in one particular batch of waste restaurant oil.

2. Under a fume hood, perform the titration as follows:

    a. 1 mL of oil requires 10 mL of ethyl alcohol (ethanol)
    b. 2 mL of oil will be used so 20 mL of ethanol will be needed
    c. Use the graduated cylinder and pour ethanol into a flask
    d. Set the blue topped micropipette (range 100-1000) to 1,000 µl since it = 1 mL and lock it in place with black lever. Distribute two 1,000 µl pumps of oil (so 2,000 µl) into the flask containing 20 mL of ethanol. Make sure to change the tips!
    e. Set pipette to 100 µl and add the indicator, phenolphthalein, into the flask containing the 20 mL ethanol and 2 mL of oil. Change tip!
    f. Keep pipette at 100 µl and add one 100 µl of NaOH (0.005 g/mL solution) at a time until the solution turns pink and stays the stable color for 30 seconds.

g. The information obtained from the titration process is used to calculate the percent free fatty acid content of feedstock oil.
h. Once the fatty acid content has been calculated, the correct amount of catalyst can be determined and the process of transesterification can begin.

Transesterfication Process: This process requires 100 mL feedstock oil, 20 mL methanol and 0.35g of sodium hydroxide, and following steps:

1. Heat 100 mL of oil to 60^{o}C
2. Stir with the magnetic hotplate while maintaining temp (cover)
3. Prepare the methanol and the catalyst to be added to the flask by mixing the two together and heating at 60^{o}C until the sodium hydroxide has dissolved into the methanol.
4. Add this solution to the heated oil and add magnetic stir bar
5. Cover top of flask with aluminum foil and let sit for twenty four hours.

Washing Biodiesel Fuel: The very dark brown liquid which has collected in the bottom of the flask is the glycerin produced. The lighter-colored brown liquid is the crude biodiesel which has separated. The crude biodiesel still contains alcohol, catalyst, and small amounts of glycerin still dissolved in it. The crude biodiesel will be washed with water 7-8 times with a 1:1 ratio of oil to water to remove these impurities and obtain “usable” biodiesel.

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TRAINING RECEIVED

The training that was involved in making biodiesel fuel from feedstock oil included many techniques. The first step the participants learned in this process was titration. The participants pipetted out 100 µl of sodium hydroxide in 100 µl increments, until the color of the mixture of the oil, phenolphthalein and ethanol, changed to a pink color and was stable for at least thirty seconds. The fatty acid content was calculated from the results of the titration to ensure that the proper amount of sodium hydroxide would be added for transesterification.

The participants learned the process of transesterification which is the actual making of biodiesel fuel. For high FFA (above 4%) content, the participants learned a pre- treatment method called acid esterification which is used to lower the FFA content to an acceptable level for the transesterification process. The RET participants were shown the appropriate method to remove impurities from the crude biodiesel fuel using a water washing technique.

RESEARCH FINDINGS

Titration Results **Table 1** shows average amount of sodium hydroxide needed for neutralization. The results shown in **Table 1** show that the zoo oil had the highest FFA content while the pure canola oil had the lowest. All of these values are below 3% which indicates a low FFA content and are considered to be in “good range”. The UC oil was not much above the .338 value of canola which indicates that the UC waste cooking oil quality is very good.

Table 12. Titration Results

Oil type	Canola	Zoo	uc
Trial 1 (µl)	75	325	200
Trial 2 (µl)	100	400	200
Average (µl)	87.5	362.5	200
FFA content (%)	0.338	1.4	0.772

The first research finding was to determine the optimal amount of sodium hydroxide that would produce the best biodiesel product. **Table 2** shows the amount of sodium hydroxide used for six batches of feedstock oil.

Table 2. Results for Small Batches of Oil

Batch	Amount of Oil (ml)	Amount of Methanol (ml)	Amount of NaOH (g)	Phenomenon
1	100	20	0.1	No production of biodiesel
2	100	20	0.2	Formed soap, no viable results
3	100	20	0.3	Very good separation
4	100	20	0.4	Very good separation
5	100	20	0.5	Less produced
6	100	20	0.6	No separation

The samples shown in **Figure 1** show the results for sodium hydroxide ranges obtained. The results showed that an amount between 0.3 g and 0.4 g produced the most fuel. The group decided to use 0.35 g on later batches of feedstock which proved to be most effective.

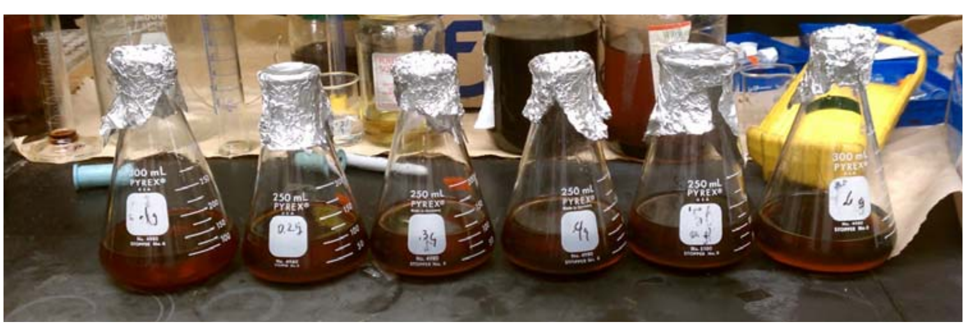

Figure 1. Sodium Hydroxide Samples Obtained

Table 3 and **Figure 2** below and below shows the results for the three larger batches of zoo feedstock oil which had an FFA content of under 2%.

Table 3. Results for Zoo Feedstock Oil

Production (ml)	Batch 1 (ml)	Batch 2 (ml)	Batch 3 (ml)
Biodiesel	620	305	1023
Glycerin	30	17	133

Batch 1 **Batch 2** **Batch 3**

Figure 2. Biodiesel Samples Obtained After Transesterification from Zoo Feedstock Oil

The amount of products produced from the three different oils is as follows:

Oil	**Biodiesel (ml)**	**Glycerol (ml)**
Zoo	103	12
UC	102	11
Canola	101	10

The results show a ten percent production of glycerol to biodiesel which is a typical finding for the transesterification. The final samples obtained after transesterification from the three oils are shown in **Figure 3**.

Figure 3. Final Samples Obtained from the Three Oils

Analysis of biodiesel was also conducted using gas chromatography - mass spectrometry. The Relative Percentage of ME components for the three kinds of biodiesel produced is presented in **Table 14** below. It can be seen that the three main components for the three types of biodiesel are C16:0, C18:2, and C18:1. The zoo and UC biodiesel are made from waste cooking oil and so contain a higher C8:0. The canola biodiesel had a lower C14:0 than the zoo and UC biodiesel.

Table 4. Relative Percentage of ME Components

ME	Relative Percentage		
	Canola Biodiesel	UC Biodiesel	Zoo Biodiesel
C8:0	0.65%	2.63%	3.08%
C10:0	0.62%	0.43%	0.57%
C12:0	0.31%	0.68%	0.41%
C14:0	0.81%	2.16%	3.30%
C16:2	0.42%	0.00%	0.23%
C16:1	2.53%	0.95%	2.56%
C16:0	21.31%	33.83%	30.33%
C18:3	4.97%	10.62%	1.61%
C18:2	36.41%	17.13%	33.92%
C18:1	29.79%	25.69%	20.35%
C18:0	1.97%	5.21%	3.55%
C20:0	0.21%	0.67%	0.11%

CLASSROOM IMPLEMENTATION PLAN

The lesson developed will be taught at a rural public high school that consists of about seven hundred students. The classes are called Chemistry in the Community but it is very similar to an environmental type of chemistry class where students relate the chemistry they are learning to their daily life. The class consists of juniors who are most likely not going to further their education after high school. The entire lesson will be taught over a course of four to five days with the majority of days consisting of students investigating how to produce biodiesel and performing lab experiments. This lesson will mimic the research that was performed over the summer by the RET participant. The students will acquire new lab techniques and gain knowledge on a multitude of science related topics. The first day of the lesson will consists of discussions of biodiesel fuel and students will be asked questions to determine if they already have any background knowledge about biodiesel fuel. The students will do titrations to determine the amount of free fatty acid content in several types of oils. Once the amount of FFA has been determined the students will make their own biodiesel fuel by using the transesterification process. After producing the fuel, students will wash the product and calculate the amount of biodiesel and glycerol produced. Students will then be informed on how to purify the crude biodiesel by using the washing technique. These students are typically the farming and more of the hands on learners so they will be very excited about making their own biodiesel fuel. It is believed that these students will welcome this investigative type of lab because they will be producing their own product and realize the environmental issues that can be helped by seeking alternative fuel methods.

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APPENDIX: LESSON PLANS

LESSON PLAN # 1

Lesson Name: Making Biodiesel Teacher Name: Phyllis Hutchinson _______________
Subject: _Chemistry_ Grade Level: _11_ Duration: 5 50min classes________

Lesson Plan

1. **Overview and Purpose**

   A Engineering

   Determine the most efficient way to make biodiesel fuel with low cost and environmentally safe.

   B Engineering Career

   Students will challenge each other to produce the most biodiesel fuel with the most effective measures.

   C Societal Impact

   Students will understand the advantages and disadvantages of biodiesel production for the environment.

2. **Education and Standards**

   - Investigate the effectiveness risk and efficiency of renewable and nonrenewable resources.
   - Using titration experiments to quantitatively study neutralization of reactions
   - Using stoichiometry to calculate the percentage of free fatty acid content in oil
   - Science Inquiry and Application
   - Use technology and mathematics to improve investigations and communications

3. **Goals**

   The students will be able to understand the process of making biodiesel fuel and the impact it has on society by describing the advantages and disadvantages of producing the fuel.

   Objective

   The students will be able to carry out a titration, calculate FFA in waste cooking oil, calculate the amount of catalyst needed for neutralization of the feedstock oil, and calculate the amount of crude biodiesel fuel from feedstock oil.

4. Misconceptions

a. students think that when a reaction happens the mass just disappears instead of actually realizing that the substances are changed to other substances

b. that all engines have to be modified to accommodate the biodiesel fuel

c. students that there is plenty of unlimited resources

5. Materials Needed

- Waste cooking oil
- Methanol
- Sodium hydroxide
- Indicator solution
- Hot plate/stirrer
- Flasks
- Graduated cylinders
- Collection funnel
- Scale

6. Instructional Strategies

Cooperative learning

Demonstration

7. Technology

Scales

8. Learner Participation

Day 1

- An intro to biodiesel fuel will be given. The movie produced over the summer will be shown and a discussion of biodiesel fuel will be included. Questions will be asked to the students about biodiesel fuel to determine the amount of knowledge they may already have about biodiesel fuel. The discussion will include advantages and disadvantages as well as general information on the production of biodiesel fuel.

Day 2

- The teacher will demonstrate the correct procedure for completing a titration using the waste cooking oil to determine the free fatty acid content. A 2ml sample of waste cooking oil will be placed in a flask and titrated with NaOH until the sample turns pink.

- A worksheet will be passed out with steps on how to calculate the amount of FFA in the sample. The students will fill in the blanks as the teacher guides the students through the calculations of FFA content in the sample. All papers will be collected at the end of the period.

Day 3

- Teacher will hand back papers that were done the previous day and calculation of FFA content will be reviewed
- Students will be divided into groups of 3
- Students will follow a written procedure to titrate a 2ml sample of waste cooking oil
- Students will then calculate the FFA content of their sample and teacher will circulate around the room to ensure proper procedure and correct calculations
- Teacher will collect the paper at the end of the period

Day 4

- Each group will receive 100ml of the waste cooking oil they had from the previous day
- The groups will calculate the amount of catalyst needed for transesterification process
- The groups will measure out the appropriate amount of methanol and catalyst
- Each group will combine waste cooking oil, methanol and sodium hydroxide for transesterification. A magnetic stir bar will be placed in the mixture and heated at the same time at 60^oC for ten minutes
- After ten minutes students will remove the mixture and not any changes
- The mixture will sit for twenty-four hours

Day 5

- Students will make observations and record the results of their experiment
- Students will separate out the biodiesel fuel from the glycerol by pouring it into a graduated cylinder

- The amount of biodiesel fuel and glycerol will be measured and recorded
- Results of the reaction will be discussed and students will compare their results to each other
- The teacher will demonstrate the proper procedure for washing biodiesel fuel
- Students will wash their biodiesel fuel

9. Evaluate (see attached worksheet)

Correct FFA content

Correct calculations for extra NaOH amount

Amount of Biodiesel Fuel produced

10. Essential Questions

a. What is transesterification?
b. What are the advantages of biodiesel fuel production?
c. .How is the free fatty acid content determined in waste cooking oil?
d. Why do we titrate the waste cooking oil.

11. Pre/Post Test Questions

a. What is biodiesel fuel?
b. What is transesterification?
c. List 3 advantages of biodiesel fuel?
d. How is the FFA content calculated?
e. Why is the mixture heated at a $60^{o}C$?
f. Why do the two layers separate?
g. What does a high or low FFA content mean as it relates to waste cooking oil?
h. What is the ratio of biodiesel fuel produced to glycerol produced?
i. g. Which waste cooking oil produced the most biodiesel fuel?
j. Can you think of any improvements for better results in the lab?

12. Reflection

All of the essentials in biodiesel fuel production can be taught in my classroom including the transesterification process. I anticipate the lesson to be very exciting for the students and I will incorporate this into the Chemistry in the Community class.

Chem Comm Name______________________________

Day 3

Calculation of FFA in waste cooking oil

1. Average amount of NaOH × Concentration of NaOH

2. Conversion of moles of NaOH to mass of NaOH (1 mole of NaOH = 40g of NaOH)

3. The ratio of NaOH and FFA is one to one in the reaction so the number of moles of NaOH is also the number of moles of FFA in the sample.

4. Convert moles of FFA to mass of FFA. (1 mole of FFA = 278 grams of FFA)

5. Use the density of waste cooking oil (.9g/ml) to determine the mass of waste cooking oil. Density =mass/volume

6. Mass of waste cooking oil is then used to calculate percentage of FFA in sample.

   Amount of FFA ÷ total amount of oil in sample × 100 = percent FFA

Day 4

Calculation of NaOH catalyst needed

Day 5

AFTER REACTION

TYPE OF OIL	BIODIESEL PRODUCED	GLYCEROL PRODUCED

LESSON PLAN # 2

1A. Lesson Name: ____Biodiesel___ Fellow or Teacher Name: _____ Lindsey Burkhart___
Subject: ____Biology__ Grade Level: __Sophomore__ Duration: _4 -50 Min Sessions____

1B. Analyze Learners:

Overview & Purpose (Engineering theme)

Students will learn how to produce useable biodiesel out of their cafeteria's waste cooking oil. This is important because it will prove to the students that the process is relatively simple and the resources are readily available. The students will have experience small scale yet genuine engineering experience.

- **A** – Engineering application
  - Once the process of producing the biodiesel has been perfected and the cost controlled, engineers can then focus on how to convert more engines to run off of biodiesel, thus greatly reducing carbon emissions.
- **C** – Engineering career connections
  - The students will apply their math and chemistry skills to convert an inedible waste product into a useful form of clean-burning fuel. This connects students to some of the associated careers in engineering such as working in a power plant, becoming a chemist, or a civil engineer.
- **S** – Societal impact
  - Lower carbon and sulfur emissions will greatly improve the Earth's air quality and consequently, the health of all of its inhabitants. Decreasing the amount of greenhouse gases in the atmosphere will help recover from the effects of global warming.

2. Education Standards Addressed (STEM)

National Standards for Engineering

- E. An ability to identify, formulate, and solve engineering problems
- H. The broad education necessary to understand the impact of engineering in global and social contexts

Ohio Standards for Science Inquiry and Application

- Identify questions and concepts that guide scientific investigations
- Communicate and support a scientific argument

3. Goals

Students will learn that it is relatively simple to produce biodiesel from used cooking oil that their school's cafeteria throws away. Students will be able to understand that there are barriers preventing the commercialized production of biodiesel, otherwise it would have already replaced petroleum since it is a cleaner burning fuel.

Objectives

1. Students will be able to describe in their own words how they made biodiesel from waste cooking oil in their classroom laboratory. (Comprehension)

2. Students will be able to compare and contrast the amount of air pollution that results from using biodiesel and petroleum in a combustion engine. (Analysis)

3. Students will be able to create and present a poster, movie, or a power point which suggests a solution to one of the problems currently preventing the commercialization of biodiesel in the U.S. (Synthesis).

4. Misconceptions about this topic:

1. Biodiesel is not worth producing because it requires farmers to use valuable land that should be used for growing food. We should not make biodiesel since it is made out of vegetables that we need to feed our population.

   This is the most common misconception about biodiesel. People often think that biodiesel can only be made out of corn or soybeans and so that the U.S. would be choosing cars over people. The truth is that biodiesel can be made from used cooking oil, which is plentiful and inedible. Most of this cooking oil can be acquired for free since it is a waste product of restaurants, one in which they must pay to dispose of.

   Source: Common Misconceptions about Biodiesel and Food

   http://laurelhurstoil.com/category/biodiesel-facts/

2. Using biodiesel in a diesel engine will ruin it.

   Actually, the opposite is true! Regular diesel is derived from petroleum, which contains contaminants that leave particulate matter behind when combusted. This particulate matter builds up in the engine and can impair its function. However, biodiesel is actually good for an engine since it contains far less contaminants than regular diesel fuel. Biodiesel also contains oxygen which allows for more complete combustion of the fuel.

   Source: Misconceptions about Biodiesel

   http://www.starttogogreen.com/alternate-energy/misconceptions-about-biodiesel

5**. Materials Needed for Students**

- Paper
- Pencil
- Poster-board
- Markers
- Internet access
- Printers
- Others

Materials Needed for Teacher

- Flasks
- Beakers
- Pipettes
- Feedstock Oil
- Graduated cylinder
- Hotplate with stirrer
- Digital scale
- NaOH
- Isopropyl Alcohol
- Methanol
- Water
- Separation Funnel
- Glass jars
- Thermometer
- Others

6. Select Instructional Strategies

- Direct Instruction- Procedure of producing the Biodiesel in form of a worksheet
- Hands on Lesson Activity- Convert waste cooking oil into Biodiesel
- Pair/Share – In pairs, create poster/movie/P-Point and present their ideas for a solution to the given problem
- Peer critique - Students will discuss which solution they feel is the best to solve the problem and why

7. Utilize Technology for Teachers and Students

- Smart Board (if available)
- Ipad (if available)
- Computer / Internet / Printers
- Document camera (if available)

- Digital Camera/ Recorder
- Graphing Calculators
- Other

8. Require Learner Participation

Activity

1. Begin class with a pre-test of the essential questions 5 levels of blooms (10 min)

2. What is global warming?

3. Explain how global warming is caused.

4. How could humans solve the problem of global warming?

5. Could you invent a new method of fighting global warming?

6. Predict what could happen to the Earth if the global temperature continues to rise at the current rate.

   - Next, have a question and answer session about the students' answers which will determine what their preconceived notions are about global warming as well as what they believe causes it. (10 min)

   - Then, the teacher shows the Simpson's Spoof Video of global warming. (4min)

   - The teacher leads into facts about melting ice caps and increasing global temperature, rising sea levels with use of pictures, power point slides, and current articles. (10 min)

   - The teacher checks for understanding while the students practice analyzing charts of exhaust emissions from biodiesel and petroleum. (10 min)

   - Teacher asks students: "Do humans have the ability to save the earth? YES!

   - And the answer is right here in your school cafeteria!" (1 min) Shows oil sample taken from the school cafeteria.

   - The teacher will perform a titration demonstration on the oil and explain its purpose to the students. (5 min)

   - Then, students will break into groups of 2-3 and each group will be given a sample (100ml) of cafeteria oil (5 min)

   - The students will perform the procedures outlined to produce their own biodiesel from their oil sample (30 min), (15 min)

TRANSESTERFICATION PROCESS

This process requires the following:

100mL feedstock oil

20mL methanol

0.35g of sodium hydroxide

1. .Heat 100mL of oil to 60^{o} C
2. Stir with the magnetic hotplate while maintaining temp (cover)
3. Prepare the methanol and the catalyst to be added to the flask by mixing the two together and heating at 60^{o}C until the sodium hydroxide has dissolved into the methanol.
4. Add this solution to the heated oil and add magnetic stir bar
5. Cover top of flask with aluminum foil and let sit for twenty-four hours (check results at beginning of next day)

WASHING BIODIESEL FUEL

The very dark brown liquid which has collected in the bottom of the flask is the glycerin produced. The lighter-colored brown liquid is the crude biodiesel which has separated. The crude biodiesel still contains alcohol, catalyst, and small amounts of glycerin still dissolved in it. The crude biodiesel will be washed with water 7-8 times with a 1:1 ratio of oil to water to remove these impurities and obtain "usable" biodiesel.

1. To separate the crude biodiesel layer (top light brown) from the glycerin layer (bottom dark brown) by using the funneling tube/cone by letting the glycerin layer flow out of the bottom by opening the valve. To separate completely, pour the remaining liquids into a graduated cylinder. Pipetting the biodiesel out of the cylinder is simple because of the density difference. The biodiesel will float to the top of the cylinder and the glycerin will fall to the bottom since it is so much dense. Observe how some of the impurities have coagulated and fallen to the bottom of the separation funnel while the biodiesel remains floating on the top. Open the valve and release the waste water but close the valve when the biodiesel draws near. Refill the funnel with more tap water, slowly invert, and replace into holder, and let settle overnight.

    - The following day, the biodiesel of all of the groups will be analyzed and the amounts of biodiesel and glycerin produced for each compared. There will be time allowed for questions which the students still have about making the biodiesel. (10 min)

    - The teacher will then explain details involving the students' final assessment for this lesson beginning with, "Students will learn that it is relatively simple to produce biodiesel from the used cooking oil which their school's cafeteria throws away. Students will be able to understand that there are barriers preventing the commercialized production of biodiesel, otherwise it would have already replaced petroleum as a cleaner burning fuel. Today's engineers have proven that converting inedible waste products into biodiesel is relatively simple. It is up to the engineers of tomorrow to find solutions to the problems associated with its commercialization."

- Students will be required to create a poster, movie, or power-point presentation which includes an introduction to the benefits of using biodiesel fuel, a brief segment describing in students' own words how they created biodiesel, one of the problems with its commercialization, and one idea of how the choses problem could be overcome. (10 min)
- The teacher will allow the students the remainder of the period to work on their final assessment and ask any more questions that they still have (this day should be a Friday).
- The following Monday, each group will present their final projects to the class explaining their chosen problem and their proposed solution. The students will also have to justify why their solution is valid and defend it if necessary.
- Teacher will display all groups' projects so that students can evaluate each other's ideas.

9. Evaluate (Assessment)

Class activities

Day 1

Present the Problem:

Give background info about global warming and greenhouse gases in the form of movie clip (Simpson's spoof video)

Also show graph for proof of global warming, *why it is necessary for us to reduce carbon emissions?*

Provide the graphs (students can interpret data) about the air pollution emitted from petroleum fuel.

Ask them the question – *what are some alternative fuel sources we could use to lower Carbon emissions?*

Probe the student's to say Biodiesel – then present the info on biodiesel emissions.

Have the students compare the graphs of petroleum and biodiesel and ask them which fuel is "better" for the environment

Check for understanding – Can the students interpret the results of the graph and make a valid conclusion?

10. **Essential Question #1:** How does burning Biodiesel fuel compare to burning petroleum fuel in the terms of air pollution?

Day 2

Do the titration as a teacher demonstration and think aloud as I it is being performed.. Explain why I am doing the titration; perform the calculation for the students while showing it on the smart board and giving it to the students so that they will have a recipe for making biodiesel for later to get a job.

10. **Essential Question #2:** Why is it necessary to perform a titration on the feedstock oil? To determine the FFA content in the oil is it low enough to perform one or two esterification processes on it to create the biodiesel.

Have the students add the appropriate amount of NaOH to the appropriate amount of methanol/ ethanol, heat oil to 60 degrees C and add catalyst solution to feedstock oil, stir and heat for 10 full minutes. Remove from heat, let sit overnight to allow for the crude biodiesel separating from the glycerin. (Students will follow the procedures from a print out of the procedure provided above as independently as possible).

Day 3 (Friday)

Separate the glycerin from the biodiesel with a pipette, allow each student to have a turn. Measure the volume of the biodiesel as well as the glycerin and record. Put the Biodiesel into a separation funnel and add water at a 1:1 ratio. Allow to sit overnight. For the remainder of the class period, check for understanding and explain what is expected for the assessment. This time can also be used as a work day with the teacher providing direction to the groups.

Students will participate in a genuine engineering experience by converting the waste cooking oil from their school's cafeteria into biodiesel. Students will also be required to interpret data found on charts and graphs and draw conclusions from this data. Students will also research the barriers preventing the commercialization of biodiesel in the United States and suggest a possible solution to this problem in true engineering form.

Day 4 (Monday)

Each group of students will present their final assessment which will be in the form of a poster, movie, or power-point presentation, and must have the requirements outlined above. Students will be evaluated on their ability to recognize the problem and formulate and defend a solution. (40 min)

11. **End the lesson by having the students answer the pre-test questions again with their newly acquired knowledge:** (10 min)

    1. What is global warming?

    2. Explain how global warming is caused.

    4. How could humans solve the problem of global warming?

    5. Could you invent a new method of fighting global warming?

    6. Predict what could happen to the Earth if the global temperature continues to rise at the current rate.

12. **Reflection**

Students enjoyed making the biodiesel, they were interested since it involved them and diesel fuel is something which most of the students are familiar with.

I learned that there needs to be something else for the students to do while they are waiting the ten minutes for the transesterification reaction to occur.

I would like to have more laboratory materials available so that the students could work independently if they wanted to.