PROFILES

Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science

Should Vegetable Oils be used as a Fuel ?

A grade 10-12 science (chemistry) material on making and testing Biodiesel as a Fuel

Abstract

This module explores the ethical dilemma in using edible substances as fuels. In this aspect the problem did not arise because vegetable oils were too viscous to be used in standard engines. But by a process of exchanging the ester components the oils are mad in a substance resembling diesel and have less polluting properties. This module explores the making of biodiesel and its suitability as a fuel before trying to decide whether it is appropriate in this day and age of high costs of diesel to use vegetable oils as a source of fuels.

Sections included		
1.	Student activities	Describes the scenario in more detail and the tasks the students should perform.
2.	Teaching guide	Suggests a teaching approach.
3.	Assessment	Gives suggested formative assessment strategies.
4.	Teacher notes	Gives background information and student worksheet on making biodiesel.

Acknowledgement

This module has been adapted from that developed under the PARSEL project (**www.parsel.eu**) as part of an EC FP6 funded project (SAS6-CT-2006-042922-PARSEL) on Popularity and Relevance of Science Education for scientific Literacy

Project funded within the EC FP7 Programme: 5.2.2.1 – SiS-2010-2.2.1
Grant Agreement No.:266589
Supporting and coordinating actions on innovative methods in science education: teacher training on inquiry based teaching methods on a large scale in Europe

Overall Objectives/Competencies: The students are expected to:

- ability to put forward socio-scientific reasons on the merits and demerits of using vegetable oils as fuels and formulate a justified decision;
- able to follow procedures to prepare bio-diesel experimentally using a commonly available vegetable oil;
- able to plan and devising procedures for testing the suitability of the bio-diesel created; carry out and interpret experiments to determine the suitability of bio-diesel as a fuel;
- explain the manner in which diesel and biodiesel are able to act as fuels in an internal combustion engine, suggest how the suitability of a fuel can be determine and suggest parameters for deciding on the 'best' bio-diesel;
- cooperate in a team member in carrying out the experimental procedures, devising tests for determining the suitability of the bio-diesel created and in discussing the merits and demerits of using vegetable oils as fuels;
- communicate orally by putting forward justified reasons for the decision of whether bio-diesel should be used as a fuel;
- understanding the formation and hydrolysis of esters and be able to contrast this with the trans-esterification of esters.

Curriculum content: Esters (consolidation), esterification (consolidation), biodiesel, non-aqueous catalyst, calorific value of fuels.

Kind of activity: Following an experimental procedure, preparing biodiesel; developing separation techniques, planning and carry out investigations on calorific value, participating in a debate on whether vegetable oils should be used as fuels.

Anticipated time: 5 lessons

This unique teaching-learning material is intended to guide the teacher towards promoting students' scientific literacy by recognising learning in 4 domains – intellectual development, the process and nature of science, personal development and social development.

Its uniqueness extends to an approach to science lessons which is designed to follow a 3 stage model. For this the approach is intentionally from society to science and attempts to specifically meet student learning needs.

This uniqueness is specifically exhibited by:

1. a motivational, society-related and issue-based title (supported in the student guide by a motivational, socio-scientific, real life scenario);
2. forming a bridge from the scenario to the scientific learning to be undertaken;
3. student-centred emphasis on scientific problem solving, encompassing the learning of a range of educational and scientific goals;
4. utilising the new science by including in socio-scientific decision making to relate the science acquired to societal needs for responsible citizenship.

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Should Vegetable Oils be used as a Fuel ?

Student Activities

Read the following scenario and then undertake the activities suggested below:

Scenario

(A story type scenario – other scenarios may be more appropriate)

Old Fred lives in the city of Los Angeles in the USA. He suffers from bronchitis and finds it difficult to breathe. His doctors advise him to move away from Los Angeles to somewhere where the air is more fresh and contains much less hydrocarbon and sulphur emissions. Alas old Fred cannot afford to move, but instead plans to interest diesel vehicle manufacturers in a cleaner fuel. Fuels based on vegetable oils produce much less hydrocarbon emissions and practically no sulphur emissions. Although, direct use of the oil itself is possible only with modification to existing diesel engines, old Fred suggests vegetable oils can be changed to biodiesel and biodiesel requires little modification to existing vehicle engines. Unfortunately biodiesel, made from vegetable oil, is based on foodstuffs such as corn. It can take away food from hungry mouths!!

Your Tasks

You are asked to embark on a project to develop and test an alternative fuel to diesel made from crude petroleum. In particular you are asked to consider a fuel from vegetable oils, especially its preparation and suitability.

In addition, you are asked to discuss the use of vegetable oils as alternative fuels for vehicles?

Student Activities

1. Noting vegetable oils are esters and you are familiar with them when learning about the saponification process to make soap, discuss ways to modify vegetable oils to make a diesel fuel suitable for existing diesel engines.
2. In a group, following instructions given by the teacher and appreciating the catalyst needs to be in a non-aqueous environment, make biodiesel using the vegetable oil supplied.

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3. Separate out the biodiesel from the more viscous reactant using a separating funnel. (Take care because if the two liquids are shaking together they will form an emulsion which will take a long time to separate).
4. Test the biodiesel using simple tests. You are expected to suggest these tests and the equipment needed and to undertake the tests. In a group complete the tests, once the teacher has approved your procedure.
5. Write an individual report on the making of biodiesel, its separation and the testing of the product for suitability as a fuel.
6. Discuss whether it is acceptable to use biodiesel in vehicles.

Factors to consider:

a) *Are these viable alternatives (perhaps by being converted to a better product?)?*
They are viable if vegetable oils are easily obtained, are cheap and are usable in a diesel engine directly, or with simple or cheap modifications - modifications to the diesel engine itself, or the conversion of vegetable oils to products usable in diesel engines.
If so, which vegetable oil is 'best' ?

b) *Are bio-diesels economically and commercially suitable for use as fuels ?*
They are suitable if they are of sufficient calorific value and have properties that make them stable and safe for storage, and for the public and the environment when used.

c) *Would it be ethical ?*
Vegetable oils are a source of food for both humans and animals. To use vegetable oils for fuel, land needs to be set aside for this purpose. This land is thus not available for growing foodstuffs. If land is plentiful, setting aside some land is not a problem, but when the land needed to generate fuel is at a premium, it becomes a question of ethics.

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Should Vegetable Oil be used as a Fuel?

Teaching Guide

This project relates to biodiesel and the process of transesterification. Neither are usual topics within a science (chemistry) curriculum. However an understanding of the process and the development of the skills in making the actual product are secondary to the educational skills of devising procedures (by the students) to measure ease of burning, viscosity, suitability of flame and calorific value. The project can also be used to consolidate learning on esters and esterification.

In total it is suggested this module will occupy 5 lessons in order to meet the education objectives put forward. The suggested breakdown is given below, noting that reaction time and separation time are lengthy and neither can be completed within a 45 minute lesson.

Learning Outcomes by Lesson

At the end of lessons 1, students are expected to be able to:

- Discuss why vegetable oils are a good fuel, but not usable as is.
- Made preparations for making bio-diesel

At the end of lesson 2, students are expected to be able to:

- Undertake the preparation of a biodiesel.
- Devise a procedure for separating out the product; operate a separating funnel.
- Devise tests to determine the suitability of biodiesel as a fuel.

At the end of lesson 3, students are expected to be able to:

- Separated out the bio-diesel
- Shown understanding of the process of trans-esterification and a comparison with tri-hydric esters

At the end of lessons 4, students are expected to be able to:

- Carry out the tests on samples of the biodiesel
- Explain the testing of the suitability of bio-diesel for use as a fuel

At the end of lessons 5, students are expected to be able to:

- Cooperate as a member of a team in a debate on the use of bio-diesel
- Put forward a justified socio-scientific decision on whether vegetable oils should be used as a fuel

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Suggested Teaching Strategy

1. To prepare a number of samples of biodiesel by one student or one group of students is obviously a time consuming process. It is recommended for this project that different groups of students work with different vegetable oils and results are compared between groups.
2. To prepare biodiesel, students utilize the instructions given in the handout. Students should test various vegetable oils. The amount of chemicals can be scaled down if necessary.
3. The initial lesson is suggested as a group discussion on what is biodiesel and can it be used as a fuel. This enables students to become familiar with the term biodiesel and its origins, differing from those of diesel made from petroleum. In this manner the teacher is able to determine the students prior knowledge in this area and their initial attitudes towards the issues being put forward.
4. Another important goal for the first lesson is to recognize that although vegetable oils burn, they are not suitable for use in the standard diesel engine because of the high viscosity. Hence there is a need to reduce viscosity, one way being to make a new substance of lower viscosity. This sets the process for the next lesson which is to make biodiesel by reduction of viscosity and one fairly simply process for this is to replace the ester groups.
5. The second lesson can begin with setting up the experimental process based on experimental procedures supplied. Once the experiment is underway, students can be asked to write a possible procedure for the separation of the biodiesel and be introduced to the use of a separation funnel. Time permitting students can also begin initial thinking on how to test the biodiesel for suitability for use.
6. The third lesson is related to the separation of the biodiesel which is a time consuming process but one requiring little student attention once it is set up. The extra time can be used to prepare for the testing of the biodiesel in the next lesson, both in terms of the conceptual understanding of suitability and in how the experimentation can be conducted.
7. Having prepared a sample of biodiesel, students are then challenged in the 4th lesson to test the biodiesel and compare it with diesel. The tests suggested are -

a) Determining Flammability,
Intended here is a simple test of how easy it is to burn the product. Putting a match to a little of the sample on a watch glass is perhaps the simplest manner in which this test can be performed.

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If this does not lead to a noticeable difference between the various biodiesels or between a biodiesel and ordinary diesel, then more sophisticated tests can be devised.

[Industrially the temperature at which a biodiesel burns after ignition by an electric spark is obtained. Also measured is the flash point - the temperature at which the fuel self ignites. THESE TESTS ARE NOT SUGGESTED.]

b) Suitability of flame.

Is it possible to burn biodiesel, or ordinary diesel in the standard spirit burner? If so, the 'sootiness' of the flame can be compared. A sooty flame indicates incomplete combustion and gives a measure of whether the fuel will be efficient and whether it leads to greater pollution of the atmosphere.

c) Viscosity (Quantity of product nay be a problem to perform this test)

Again the emphasis is on a simple test such as the time it takes a weight (ball bearing) to fall through the biodiesel for a given length.

A test tube is not really long enough but a length of wide bore glass tubing is good. Should this not be available, a 1 litre plastic bottle can be used but the quantity of oil needed is obviously much greater. Other substitutes can be used to show that something like a ball bearing will take different times to fall through the liquid is dependent on the viscosity.

d) Calorific value

The emphasis is on simple apparatus and, if necessary, students can devise ways to minimise heat losses by draughts, etc.

The suggestion is to burn a known quantity of fuel in a spirit burner and to use this to heat a small tin can containing a known quantity of water. The quantity of fuel needed to raise the temperature of the water by a standard temperature rise ($5^{o}C$) is determined and used as a measure of the calorific value. (Whether students undertake the actual calculation depend on the level if the students).

8. Students are expected to create a record of their experimental work from the preparing of biodiesel, its separation and its testing for suitability as a fuel.

9. The final lesson is a return to the debate on the issue of whether biodiesel should be used as a fuel, considered from a variety of perspectives. The lesson focuses on the use of argumentation skills and the correct scientific conceptualisation of biodiesel (especially with respect to it being a ‘clean’ fuel), but the lesson is expected to include input from ethical considerations (the use of foodstuff for producing the fuel), economic (cost of biodiesel), environmental considerations (use of land, etc) and other considerations.

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SUGGESTED TEACHING- LEARNING OUTLINE

STAGE	TEACHING - LEARNING APPROACH	TEACHING - LEARNING OUTLINE
1. Setting the scene	Material presented through a real life title and scenario. (1 lesson)	1. Appreciate that vegetable oils burn and cause less pollution as they are esters (containing O). 2. Realisation that vegetable oils are too viscous to use in a diesel engine as is. 3. Aware that the vegetable oil can be made less viscous by exchange of the ester groups.
2. Inquiry-based Problem Solving	Teacher guided, Student-centred material includes Problem Solving, Nature of Science and Conceptual Science Learning (and consolidation of the conceptual learning through adequate feedback - assessment). (3 lessons)	1. Making biodiesel by a trans-esterification process in a non-aqueous solvent. 2. Separation of the biodiesel by making use of a separating funnel. 3. Devise tests, which include flammability, colour of flame, calorific value and viscosity, to determine the suitability of biodiesel as a fuel. 4. Carry out tests and record outcomes
3. Socio-Scientific Decision Making	Teacher guided, Student centred material includes reasoned socio-scientific decision making (and consolidation of the conceptual learning through adequate feedback – assessment). (1 lesson)	1. Knowing the suitability of biodiesel as a fuel and taking note of the economic availability of biodiesel and the ethical question of whether edible vegetable oils should be used as a source of fuel, discuss the issue of whether vegetable oils should be used as a fuel.

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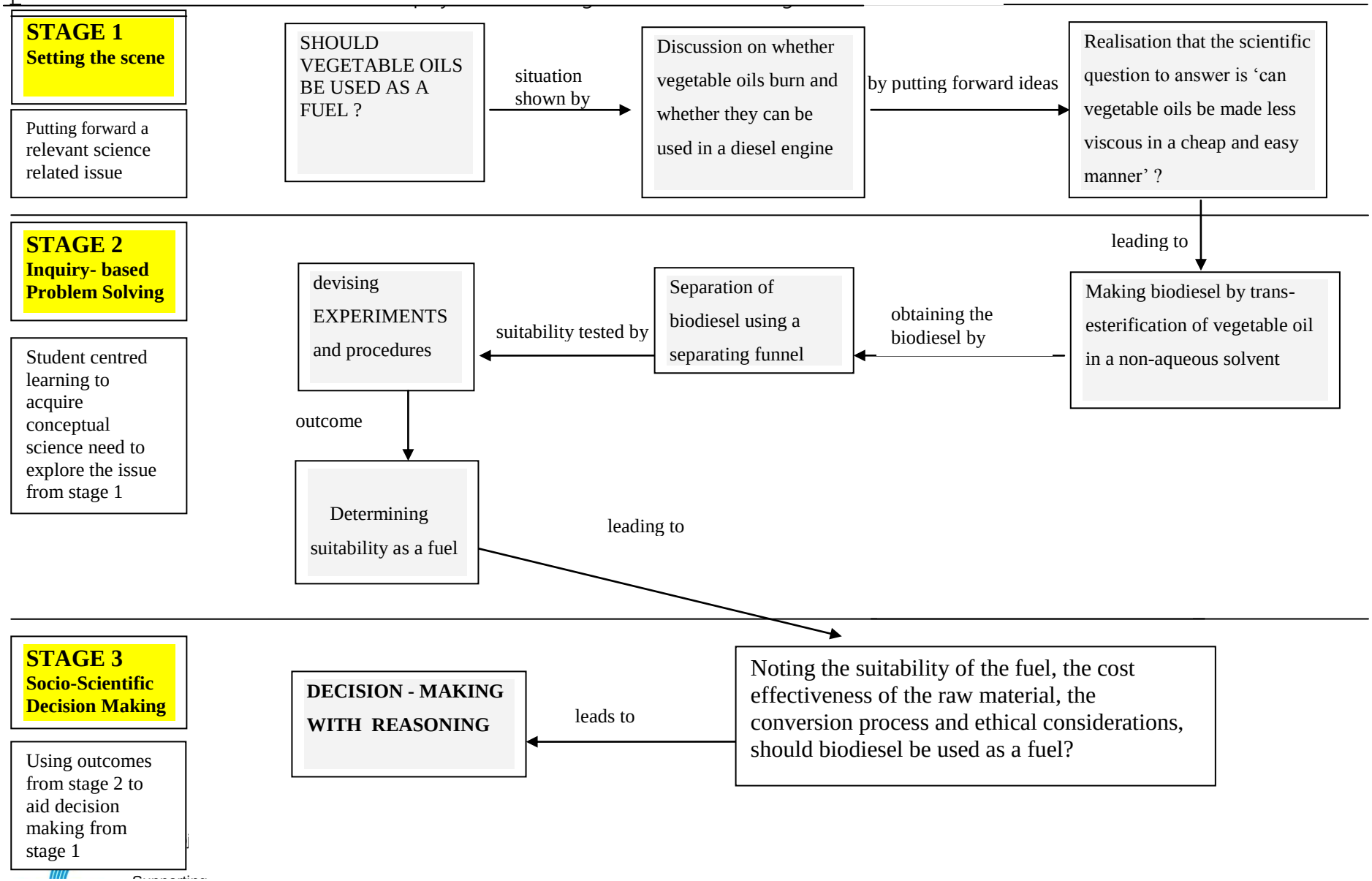
Suggested Teaching Flowchart



Achieving the competencies

* *to be able to make biodiesel;*

  This objective is achieved by students following the instructions given in the handout and preparing a sample of biodiesel.

* *to devise procedures for testing the biodiesel;*

  This challenging objective is achieved by students being called upon to devise their own tests for flammability, suitability of flame, viscosity and calorific value.

* *to suggest parameters for deciding on the 'best' biodiesel*;

  This is achieved by students putting forward their ideas on which biodiesel is best after they have tested a number of biodiesel fuels.

* *ability to discuss the merits and demerits of using vegetable oils as fuels*

  Students achieve this objective by undertaking a written discussion on the merits and demerits

* *to cooperate as part of a team*;

  In undertaking the production and testing of biodiesel fuels, it is expected that different groups of students will test different vegetable oils and that within groups, students will cooperate as a team in the production of the biodiesel and then its subsequent testing.

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Should Vegetable Oil be used as a Fuel?

Suggested Assessment Criteria

This module provides much opportunity for student assessment without the need for setting aside a separate time for this. Thus formative assessment methods are advocated. These are illustrated in three different approaches

- Assessment by skill
- |Assessment by lesson
- Assessment by teacher strategy

(The teachers is expected to choose only one method and then only those parts considered viable by the teacher. The suggested criteria are thus intended to be exhaustive not operational).

Part A Assessment based on Skill Acquired

Award of social value grade

x not able to put forward justified reason as to whether vegetable oil should be used as a fuel. Not able to cooperate well within the group;

√ able to put forward merits and demerits of using vegetable oils as fuels and formulate a decision; able to cooperate as a member of a team;

√√ able to put forward socio-scientific merits and demerits for using vegetable oils as fuels and formulate a justified decision; cooperate as a team member and showing leadership skills in the carrying out the experimental procedures, devising tests for determining the suitability of the bio-diesel created and in discussing the merits and demerits of using vegetable oils as fuels.

Award of a science method grade

x not able to prepare bio-diesel without much guidance;

√ able to prepare bio-diesel successfully and put forward plans and carry them out for testing the suitability of the bio-diesel with help from the teacher;

√√ able to prepare bio-diesel successfully and put forward plans and carry them out for testing the suitability of the bio-diesel.

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Award of a science concept grade

- x not able to understand the functioning of diesel in an internal combustion engine and poor understanding of esters and their function;
- √ able to explain the functioning of ordinary diesel as a fuel, suggest how to determine the suitability of fuels, understands the formation and hydrolysis of esters;
- √√ able to explain the functioning of biodiesel and ordinary diesel as fuels, suggest how to determine the suitability of fuels and the best biodiesel, understand the formation and hydrolysis of esters and the transesterification process.

Award of a personal skill grade

- x poor report on biodiesel and little interest shown in the experimentation;
- √ willing to participate as a member of the group and produce a sound report;
- √√ willing to participate and help others and produces a complete and accurate report.

Part B Assessment by Lesson

Lesson 1

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Discussion on whether biodiesel compared to vegetable oil as a fuel	Contributes to the discussion	
		Illustrates leadership skills in guiding others in the discussion	
		Shows tolerance of the views of others	
2	During preparations for making biodiesel	Contributes to the preparation procedures	
		Understands the process	
		Understands the need for a non-aqueous catalyst	

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Lesson 2

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Performing the experiment to make biodiesel	Is able to follow instructions	
		Performs the experiment	
		Uses the equipment/chemicals safely	
		Behaves in a safe manner	
		Maintains an orderly and clean work table.	
2	Devising tests for separation and suitability	Puts forward positive ideas for separating out the biodiesel	
		Cooperates as a member of a group in devising tests to determine the suitability of the fuel	
		Illustrates leadership skills in guiding the group.	
		Shows tolerance of the views of others	

Lesson 3

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Performing the experiment to separate out biodiesel	Able to separate the liquids	
		Able to limit the formation of an em	
		Maintains an orderly and clean wo	
2	Compare with trans-esterification	Provides appropriate written respo the meaning of trans-esterification	

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Lessons 4

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Conducts tests on suitability of biodiesel as a fuel	Contributes to the group work in carrying out the tests	
2	Record observations	Makes and records observations	
3	Interpret from data collected and makes inferences	Intreprets form the observations	
4	Questions to the group on the experimental work	Able to explain the work of the group	
		Understands the science involved in the work of the group	
		Willing to support the responses given by others in the group	
5	Questions to individuals in the group	Able to explain the action taken by each member of the group	
		Understands the objective of the work	
		Exhibits appropriate non-verbal behaviour	

Lessons 5

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Participation in the debate on whether biodiesel should be used as fuel	Contributes to the group discussion to make justified decisions.	
		Illustrates leadership skills in guiding the discussions to involve all members of the group	
		Shows tolerance towards opinions of others	
2	Put forward socio-scientific reasoning	Illustrates reasoning skills in discussions and arriving at a decision	
		Gives a justified socio-scientific decision	

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Part C Assessment by Teacher Strategy

Assessment Tool based on the Teacher's Observations

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Functioning in the group during experimentation or discussion	Contributes to the group discussion during the planning phase, experimental phase and decision making.	
		Cooperates with others in a group and fully participates in the work of the group.	
		Illustrates leadership skills – guiding the group by thinking creatively and helping those needing assistance (cognitive or psychomotor); summarising outcomes.	
		Shows tolerance with, and gives encouragement to, the group members.	
2	Performing the investigation or experiment	Understands the objectives of the investigation/experimental work and knows which tests and measurements to perform.	
		Performs the investigation/experiment according to the instructions/plan created.	
		Uses lab tools and the measurement equipment in a safe and appropriate manner.	
		Behaves in a safe manner with respect to him/herself and to others.	
		Maintains an orderly and clean work table.	
3	Presenting the investigation or experiment orally	Presents the activity in a clear and practical manner with justified decisions.	
		Presents by illustrating knowledge and understanding of the subject.	
		Uses precise and appropriate scientific terms and language.	
		Presents with clarity and confidence using an audible voice.	

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Assessment Tool based on Marking of Written Material

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Writes a plan or report of an investigation	Puts forward an appropriate research/ scientific question and/or knows the purpose of the investigation/experiment	
		Creates an appropriate experimental plan for testing the suitability of biodiesel as a fuel.	
		Develops an appropriate procedure (including apparatus and safety procedures required) and indicates variables to control	
2	Record experimental data collected	Makes and Records observations/data collected appropriately (in terms of numbers of observations deemed acceptable/accuracy recorded/errors given)	
3	Interpret or calculate from data collected and making conclusions	Interprets data collected in a justifiable manner including the use of appropriate graphs, tables and symbols	
		Draws appropriate conclusions related to the suitability of biodiesel as a fuel.	
4	Answers questions	Provides correct written answers to questions given orally or in written format	
		Provides answers in sufficient detail especially when called upon to give an opinion or decision	
5	Scientific or socio-scientific reasoning	Gives a justified socio-scientific decision to an issue or concern, correctly highlighting the scientific component	

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Assessment Tool based on the Teacher's Oral Questioning

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	**Questions to individuals in a Whole Class setting**	Answers questions at an appropriate cognitive level using appropriate scientific language	
		Shows interest and a willingness to answer	
		Willing and able to challenge/support answers by others, as appropriate	
2	**Questions to the group**	Able to explain the work of the group and the actions undertaken by each member	
		Understands and can explain the science involved using appropriate language	
		Willing to support other members in the group in giving answers when required	
		Thinks in a creative manner, exhibits vision and can make justified decisions	
3	**Questions to individuals in the group**	Able to explain the work of the group and actions taken by each member	
		Understands the purpose of the work and shows knowledge and understanding of the subject using appropriate scientific language	
		Can exhibit non-verbal activity (demonstrate) in response to the teacher's questions, as appropriate	

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Should Vegetable Oils be used as a Fuel?

Teacher Notes

1. Vegetable oils

One property of vegetable oils is that they burn.
But vegetable oils, without modification, are not considered suitable as fuels for diesel engines.

A suggestion is to break down the oil in some way to create smaller molecules that will be less viscous but still flammable. If these molecules are similar in size to the hydrocarbons used in diesel, then it will be possible to utilise them in standard diesel engines. *Explain this statement*.

2. Breaking Down Vegetable Oils

We are familiar with breaking down vegetable oils using an acid or an alkali.
But by reacting the oil with an aqueous substance, we have a problem of extracting the flammable part. How great a problem is this ? Do you have a simple solution to extracting a flammable product (If the solution is not simple, the cost of extraction will stop the process from being viable)?

One cheap and simple method of breaking down vegetable oils is known as transesterification. This means making one ester from another. Vegetable oils are triglycerides (they are based on the alcohol, glycerol, which has three OH groups). It is possible by transesterification to base the ester on methanol or ethanol and thus create simpler molecules. Three simpler ester molecules are formed from the original triglyceride.

$$R_3X + 3MeOH \longrightarrow 3ROH + Me_3X$$

3. Factors affecting the best vegetable oil

The best vegetable oil can depend on many factors such as cost, appearance, calorific value, viscosity, stability, ease of burning, smell, or not being used for another purpose. Very often the weighting placed on the various factors is a societal choice and hence the best vegetable oil can vary from country to country. Best is thus very difficult to define. The manner in which best is interpreted is left for you to determine.

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4. Viability of the vegetable oil

   The use of vegetable oils is viable if vegetable oils are easily obtained, are cheap and are usable in a diesel engine directly, or with simple or cheap modifications - modifications to the diesel engine itself, or the conversion of vegetable oils to products usable in diesel engines directly).

5. Main use of vegetable oils

   Vegetable oils are a source of food for both humans and animals. To use vegetable oils for fuel, land needs to be set aside for this purpose. This land is thus not available for growing foodstuffs. If land is plentiful, setting aside some land is not a problem, but when the land needed to generate fuel is at a premium, it becomes a question of ethics.

Testing biodiesel for flammability

Pour a little biodiesel into the top of a beer bottle (or other suitable small container). Try to light the biodiesel using a burning taper, or wooden splint. Note the ease with which it burns.

Test the suitability of the flame
With the biodiesel burning, check the colour of the flame. The more the flame is blue rather than yellow, the better. The flame should not be sooty.

Testing the viscosity of biodiesel

Depending on the quantity of biodiesel available, pour the biodiesel into a narrow glass tube. Seal both ends of the tube but allow a small air bubble to remain inside. Take the time for the air bubble to go from one end of the tube to the other, when the tube is held vertical and then inverted. Compare with other liquids.

Testing the calorific value

Pour a small but know mass of biodiesel into a spirit burner making sure the wick is in the liquid. Place the burner under a small tin can holding a known quantity of water and with the temperature being indicated by means of a thermometer. Light the burner and determine the time taken and the mass of biodiesel used in heating the water a known temperature rise ($1^{o}C$).

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Student Handout

Follow the trans-esterification process described below and carefully collect the washed and dried product. This product can be called biodiesel.
Then devise a procedure for comparing flammability, viscosity, suitability of flame and calorific value with that of diesel.
Also suggest which vegetable oil gives the best biodiesel (don't forget to indicate the parameters chosen to determine the meaning you have attached to best).

Preparation of Biodiesel

100 cm^3 Vegetable Oil
15 cm^3 95% Ethanol
1 cm^3 9 mol dm^{-3} aq. Potassium Hydroxide Solution

1. Pour the vegetable oil and ethanol into a 250 cm^3 beaker.
2. Slowly add the potassium hydroxide solution from a 1 cm^3 plastic syringe or a small dropping pipette, over about 1 minute.
3. Stir continuously for a further 2-3 minutes and then stir occasionally (5-10 seconds every 2-3 minutes) for 2-3 hours or until 2 layers are formed on settling. Do not stir too vigorously as this may lead to emulsification.
4. Pour into a separating funnel and allow to settle for 1 hour.
5. Run off the lower layer. This layer contains most of the glycerol which is released during the reaction. The lower layer is discarded.
6. Add 10 cm^3 of distilled water to the crude product and mix well (shaking is not advisable since an emulsion can form which will take a long time to separate). Leave to stand for 1 hour.
7. Run off and discard the lower layer (This washing procedure can be repeated if the product is not clear).
8. Add 0.5g anhydrous sodium sulphate. Stir for about 15 minutes.
9. Allow the sodium sulphate to settle.
10. Decant the biodiesel into a sample bottle.

Devise your own procedure for the following.

Test the product for:

a) flammability, b) viscosity,
c) calorific value and d) suitability of flame.

Compare the biodiesels so as to determine which is considered the ‘best’ biodiesel. Compare if necessary with ordinary diesel.

Project funded within the EC FP7 Programme: 5.2.2.1 – SiS-2010-2.2.1
Grant Agreement No.:266589
Supporting and coordinating actions on innovative methods in science education: teacher training on inquiry based teaching methods on a large scale in Europe