PROFILES

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

Is Home-made Soap Appropriate and Viable in Today's World?

A grade 10-11 science (chemistry) module on the preparation and cleaning action of soap

Abstract

This set of activities introduces soap as a common chemical substance which is familiar to students. It examines the making of soap and guides students to put forward and explanation for the cleaning action of soap. The activity reinforces the meaning of the saponification process and compares this in terms of reversibility of the process with the hydrolysis of fats and oils in the body.

Sections included		
1.	Student activities (for students)	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 experimental details and additional information for teachers

Developer: Jack Holbrook
Institute: University of Tartu
Country: Estonia

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 Competencies: The students are expected to:learn to be able to

- Recognise factors that affect the choice of soap to buy.
- Put forward and carry out procedures for making home-made soap.
- Put forward and carry out a procedure for testing the cleansing ability of soaps.
- Cooperate and meaningfully communicate orally as member of a group in planning, carrying out the preparation and interpreting the testing of soap so as to undertake this in an effective manner.
- Explain saponification, emulsifying power and the action of soap as a cleansing agent.
- Explain how the energy stored in fats can be transported around the body by changing fats into water soluble substances.
- Decide, with justification, how to determine whether home-made soap is appropriate and viable.

Curriculum content: Soap as a chemical substance; Saponification (consolidation of concept); making soap; cleaning action of soap; reversible reaction.

Kind of activity: Group discussions; planning experiments, conducting experiments (to make soap) and carrying out self –devised tests (related to soap). Putting forward justified decisions (related to viability/suitability of home-made soap).

Anticipated time: 6 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

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

Is Home-made Soap Appropriate and Viable in Today's World?

Student Activities

Scenario

There are many brands of soap on the supermarket shelves. Yet there is a growing interest in making home-made soap, especially for festive occasions when many people are looking for suitable gifts for relative and friends.

But how to make home-made soap and how do you decide whether buying home-made soap is safe, suitable for use and is a viable proposition? And is it important that such soap also be able to clean well? Should such soaps have a pleasant smell, look good and have a good feel on the hands? Is price a factor in determining what might be the most appropriate commercial soap? And does this mean home-made soaps are only viable to sell on festive occasions?

Your Tasks

Part 1. Hold a group discussion on the value and advantages of home-made soap, including how home-made soap is made by considering the following questions. Be prepared to share your comments with the rest of the class.

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

Part 2 Undertake a library search on (a) How soap is made? What are the essential ingredients? (b) How are soaps useful for the body? (c) Why is soap is a valuable substance. Record your findings in a report.

Part 3 Put forward a procedure for making soap in the laboratory. Use the guiding questions below to help you in this task. After discussion with the teacher, carry out the preparation of soap using your plan, or the teacher's modification of the experimental approach. Separate out your soap and obtain a solid sample which can be used in subsequent tests.

Guiding questions

1. What is the main ingredient that is used as the base?
2. Is the main ingredient soluble in water?
3. The main chemical reaction to make the soap 'breaks down' the main ingredient. What substance can be used to do this?
4. What suggestions do you have to speed up the reaction?

Part 4 Making comparisons - testing the soap you made and commercial soaps

Undertake the following:

1. Discuss, as a group, home-made soap and its appropriateness. Reflect on whether commercial soaps are better? And on what does 'better' mean?
2. After weighing samples of the soap (as given), soak them in water for 1 hour. Do not move them during this time. After one hour remove them and allow the soaps to dry for 1 day. Reweigh the bar. Calculate the loss in mass.
3. Design further experiments to compare the different soaps based on: (a) pH, (b) feel on the hands (be careful with the home-made soap and only carry this out if the pH is very similar to that of commercial soap), (c) cleaning ability with cloth, (d) lathering ability.
4. Answer the following questions in writing.
   a. What useful comparative information can you get from the test in 2 above?
   b. Do you think perfume is added to soap? Is this likely to be a factor in determining the appropriateness of the soap in tests 2 and 3?
   c. Imagine you are a counsellor working for the consumer society. What factors, based on tests 2 and 3, would you suggest were important when choosing which soap to buy?
   d In test 3c, I will clean (type of cloth to clean) .....
   In this, I will compare .....
   (For this comparison, I will control the following ..... .)

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

e. Did you think you can find any soap that is black in colour? (Very unlikely) Can you suggest a reason for this?
f. The chemical reaction to make soap is known as saponification. Explain the meaning of the term saponification and indicate how the product differs from the initial main ingredient.
g. Soap has the ability to form links with oils and fats. Is soap soluble in water (check results of test 2)? How do you suggest soap acts in the way it does (it cleans)?

Part 5 Comparing the home-made soap with commercial soap and determining the appropriateness and viability of homemade soap

I suggest the best soap is .....
I based my choice on the following …….....
I feel that home-made soap is appropriate to use if
…….....
I feel home-made soap is not good because
…….....

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

Is Home-made Soap Appropriate and Viable in Today's World?

Teacher Guide

This project enables students to learn about

a) why the body needs fats and oils and how it convert them to transport needed substances around the body
b) the preparation of soap
c) the functions of soap
d) procedures for testing the cleansing ability of soaps.
e) controlling variables to arrive at a valid conclusion about the cleaning ability of soaps
f) how home-made soap compares to commercially available soaps.

Learning Outcomes by Lesson

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

- aware that soap can be easily made at home
- aware that soap making is a very old process
- put forward an opinion with suitable supporting arguments whether there are advantages in making and using home-made soap
- suggest approaches to the making of soap in the school laboratory

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

- recognise the body needs substances that can be insoluble in water (fats, oils), but can be soluble for mobility by changing into an ionic, water-soluble format (hydrolysis)
- recognise that the hydrolysis process is reversible
- explain the reversible process using water as the reactant with (a) single esters and (b) fats/oils
- recognise the structure of fats/oils as complex trihydric substances

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

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

- explain that although soap making involves hydrolysis of fats, the process is not reversible
- explain why the soap making process is not reversible
- explain soap making symbolically
- put forward a practical plan to make home-made soap
- make soap based on a suitable procedure

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

- separate out the soap from the lye
- explain substances that are suitable for colouring and adding perfume to soap
- develop a plan for testing the suitability and cleaning ability of a range of soaps
- carry out an experiment to compare the solubility of soaps.

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

- carry out a set of tests to determine the cleansing ability of soaps
- compare the actions of different soaps
- explain the manner in which soaps act as cleansing agents
- argue whether industrially made soaps are more appropriate for cleaning

At the end of lessons 6, students are expected to be able to:

- determine whether home-made soaps have advantages and disadvantages;
- decide as a group whether home-made soap is appropriate and viable.
- Be able to make a presentation to the rest of the class on the suitability of home-made soap.

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

Suggested Teaching Strategy

1. This project is intiated by drawing on the students prior knowledge about home-made soap and from what soap is actually made. It allows students to discuss whether home-made soap has any advantages in the eyes of the public.
2. This can lead to the questions why some soaps are more effective than others, or why we now use detergents rather than soaps to clean clothes. It leads to a consideration of what soap is or how it is made.
3. Students determine from a library search the need for fats in the body as energy stores and the need to move this energy around the body. This leads to the need to change fats into water soluble substances and hence the concept of hydrolysis whereby fats and esters are changed to acids and alcohols, both more polar than the fats and capable of dissolving in aqueous solutions.
4. Finding out through the library search can also include the fact that the hydrolysis of fats is a reversible process and hence esterification re-occurs between the acids and alcohols. By removal of the acid however in the hydrolysis process means that the reaction is no longer reversible. This can come about by using an alkali instead of water for the hydrolysis process. Students need to understand that this is the essence of soap making.
5. Students, in groups, are now ready to plan how to make soap for themselves using an oil (rather than a fat for convenience) and making use of an alkali such as sodium hydroxide (a substance with which they are already familiar and can write the formula in a molecular and/or ionic manner)
6. The soap making process will take time as the hydrolysis (saponification) process is slow and involves much stirring to bring the non-polar and polar substances together. The reaction needs heat and it is appropriate to allow the mixture to simmer rather than boil. Great care needs to be taken not to spill the mixture of get any on the skin as the mixture is very hot and the alkali is corrosive to both skin and clothes.
7. To compare commercial soaps and the home-made soaps, the teacher may ask students themselves to bring in samples of soap. If this is the case, the teachers should instruct students to ensure that the soap is clearly marked so that the brand name is clearly visible.
8. The experiments to determine the solubility of the soap need some planning on the part of the teacher. As it is not important the experiment is undertaken for exactly 1 hour, probably the best procedure here is to initiate this experiment at the beginning of the lesson and to remove the soap at the end of the lesson. The soap then dries until the students again meet in class which may be 1 day or longer.
9. During the rest of the lesson, students can design a further experiment and careful explain what they hope this experiment will contribute to a comparison of different

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

soaps. Students can also be guided to discuss the questions given for this part of the project. But most important of all, students can develop their ideas on how they might study the cleaning power of the soaps in the main part of the project which will follow in the next lesson. The teacher can collect these at the end of the lesson

10. The teacher will be able to study the suggestions of the students for their project and prepare the required apparatus for this. Largely this will mean making available 'dirty' samples of cloth that can be compared easily using the facilities available in the laboratory.
11. After comparing the suitability (especially pH) and the cleaning action of the homemade soap, the students are now in a position to initiate a group discussion on the appropriateness and viability of using home-made soap in today's world. Is it simply a gimmick for festive occasions or does home-made soap have real advantages that need to be considered further. Students need to be able to put forward convincing arguments in support of their position and to reach a group consensus. This can be recorded by all students to give a written record,
12. The topic can conclude by students, based on their written records, presenting to the rest of the class their understanding of the saponification process, the cleansing action of soap and their case for determining whether home-made soap is appropriate and viable.

Achieving the Competencies

1. Put forward reasons for deciding on whether home-made soap is appropriate and viable.
   This is an integral component of the project and the teacher will be able to determine how far this is being achieved by seeing the written records of students.
2. Recognising factors that affect the choice of soap and the appropriateness and viable of home-made soap.
   This aspect is achieved by undertaking a group discussion. It should be further consolidated by the reasoning given by the students for their particular stance.
3. Put forward and carry out a procedure for making soap.
   The teacher will determine the students' ability to achieve this objective by marking written record of their suggested procedures and then observing and guiding their actions during the following practical session.
4 Put forward and carry out a procedure for testing the cleaning ability of soaps.
   The teacher will determine the students' ability to achieve this objective by marking written record of their suggested procedures and findings and then observing and guiding their actions during the following practical session.

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

5. Ability of students to work as a member of a group
   This is achieved by students working as a group. Special attention to cooperation can be placed in the designing of the testing experiments where the results across groups will most probably be required.
6. Understand saponification and the manner in which soap is able to clean.

Is Home-made Soap Appropriate and Viable in Today's World ?

Different Assessment methods (and possible criteria for each) are put forward for the teacher to consider. Only part A or part B or part C is likely to be used (and even then only to the extent the teacher feels it is viable).

Suggested Assessment of Student Learning.

The suggested method of assessment in each cases is formative i.e. takes placed during the learning. This means that the marking needs to be kept simple and a 3-point scheme is suggested (any 3 point marking scheme can be used). It is left to the teacher to divide whether marks are given to individual students, or whether some or all occasions marks are given for the work of the group as a whole, thus encouraging teamwork and student-student assistance where additional understanding is required.

Part A Assessment based on Skills

This guide to assessment strategies is put forward from different perspectives. In part A the assessment is based on the skill to be developed in the student. Part B is based on the assessment strategies to use in each lesson, whereas part C illustrates the assessment by the 3 different approaches which a teacher may use for formative assessment – observation, by oral communication, or by marking of written work. Summative assessment strategies are not shown, but these could relate to viva type oral communication and/or to the marking of written tests/examination questions.

Award of social value grade (learning outcomes 1 and 2)

Teachers listens to the debate on whether home-made soap is appropriate and viable

x Not able to take part meaningfully in the discussion and suggest a justifiable decision

√ Actually takes part in the discussion but is not able to justify any meaningful decision to be taken on whether home-made soap is appropriate and viable

√√ Is able to play a major role in the discussion and in making meaningful and justified decisions related to home-made soap

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

Award scientific method grade (learning outcomes 3 and 4)

Teacher observes the students and notes the observations recorded

x Carries out the experiments, but the observations are either not accurate or inappropriate

√ Able to carry out the experiments in an careful and safe manner and make meaningful observations and obtains a good product in the case of home-made soap

√√ Able to carry out the experiments, obtains a good yield in the case of home-made soap and undertakes sufficient repeat observations to make the comparison experiments meaningful and reliable

Award of a personal skill grade (learning outcome 5)

Teacher observes the students and notes the observations recorded

x Carries out the experiment, but without enthusiasm and the observations are either not accurate or inappropriate

√ Able to carry out the experiment in a component and safe manner and make and record meaningful observations

√√ Able to carry out the experiment in an efficient and safe manner, taking sufficient repeat observations to make the experiment meaningful and reliable. Able to record the experimentation and discussions on whether home-made soap is appropriate and viable in a suitable manner.

Award of a cognitive skill grade (learning outcome 6)

Teacher reads the student reports

x Not able to explain the saponification process and the cleansing action of soap.

√ Able to explain saponification and how this differs from hydrolysis. Able to explain the cleansing action of soap. Able to compare the cleansing action of soap and indicate the appropriateness and viability of home-made soap in a written record.

√√ Able to explain saponification and how this differs from hydrolysis using suitable models and equations. Able to explain the cleansing action of soap in a diagrammatical as well as written format. Able to compare the cleansing action of soap and indicate the appropriateness and viability of home-made soap in a written record with strong justification.

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

Part B Assessment by Lesson

Lesson 1

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Socio or socio-scientific reasoning	Puts forward ideas on whether making soap at home is appropriate and viable	
2	Developing Experimental procedure	Suggests ideas related to ways to make soap	
3	Willingness to respond to questions	Willing to attempt to provide answers to the purpose of soap and historical aspects related to soap making	

Lesson 2

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Seek information	Able to gather information from suitable sources on the reason fro fats in the body and the type of substances they represent.	
		Able to seek information on the process of hydrolysis and how this can be applied to the reaction of water with (a) esters and (b) fats	
		Able to gather information on reversible reactions and the structure of fats/oils	
2	Answers questions	Provides correct verbal or written answers to questions on fats in the body and how they can be made soluble through hydrolysis	

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

Lesson 3

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Writes a plan for a procedure to make soap	Develops an appropriate procedure to make soap starting from an oil and sodium hydroxide	
2	Carries out the experimental procedure	Undertake experiments on the preparation of soap when the teacher approves the plan or provides specific instructions	
3	Answers questions	Provides correct written answers to questions given orally or in written format to question explaining saponification and why the process is not reversible	

Lesson 4

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Writes a plan to compare soaps	Develops an appropriate procedure to compare soaps	
2	Collect experimental data collected	Separates out the home-made soap in a suitable manner	
		Undertake experiments on the solubility of soaps and record observations	
3	Interpret or calculate from data collected and making conclusions	Correctly carries out calculations on the solubility of soaps	
		Draws appropriate conclusions	
4	Answers questions	Provides correct written answers to questions given orally or in written format related to which substances are suitable to use to colour soap and to add a smell	
5	Cooperate as a group	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; summarising outcomes.	

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

Lesson 5

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Record experimental data collected	Carries out tests on the cleansing action of soaps and records observations/data collected appropriately (in terms of numbers of observations deemed acceptable/accuracy recorded/errors given)	
2	Interpret or calculate from data collected and making conclusions	Interprets data collected on the solubility of soaps in a justifiable manner	
		Draws appropriate conclusions	
3	Answers questions	Provides correct written answers to questions given orally or in written format on whether industrial soaps are more appropriate	
		Provides answers in sufficient detail especially on ph factors and other differences between home-made soap and commercial soap when called upon to give an opinion or decision	

Lesson 6

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Answers questions	Able to explain the manner in which soaps act as cleansing agents	
		Able to explain whether home-made soap has any advantages and disadvantage over commercial soap	
2	Scientific or socio-scientific reasoning	Gives a justified decision on whether home-made soap is appropriate and viable	

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

Part C Assessment by Teacher Strategy

Assessment Tool based on the Teacher's 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 investigation or experimental plan to the level of detail required by the teacher	
		Puts forward an appropriate prediction	
		Develops an appropriate procedure (including apparatus/chemicals required and safety procedures required)	
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 make conclusions	Interprets data collected in a justifiable manner	
		Draws appropriate conclusions	
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 decision on the 'best' choice of soap	

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

Student Assessment Tool based on the Teacher's Observations

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Performing the experiment (at the pre-inquiry and inquiry phases)	Performs the experiment according to the instructions/plan created.	
		Maintains an orderly and clean work table.	
		Understands the objectives of the experimental work and knows which tests and measurements to perform.	
		Uses lab tools and the measurement equipment in a safe and appropriate manner.	
		Behaves in a safe manner with respect to him or herself and to others.	
2	Functioning in the group during experimentation or discussion	Contributes to the group discussion during the theoretical inquiry phases (raises questions and hypotheses, designs the experiment, draws conclusions, makes justified decisions) .	
		Shows tolerance with, and gives encouragement to, the group members.	
		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.	
3	Presenting the 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.	

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

Is Home-made Soap Appropriate and Viable in Today's World ?

Teacher Notes

For these lessons it is assumed that students are already familiar with the saponification reaction and the type of substances which form the raw materials for making soaps. These lessons reinforce this learning and relate the reactions to the properties of actual soap in the marketplace. It illustrates that it is difficult to make a decision on which soap is best and factors such as price and advertising may well play a greater role in enabling society to choose than does the cleansing properties of the soap itself.

The lessons thus cover the cost of the soap, the solubility of the soap if left to stand in water for some time and allow students to introduce other factors that may have influence such as packaging, size of the soap bar and colour.

The actual testing of the cleansing properties reinforces the need for a control if comparisons are to be meaningful. Students are required to suggest suitable experiments, give appropriate apparatus for this (based on their experiences if prior working in the school laboratory) and, importantly, how the control experiment will be set up in each case.

Expected experiments are:

1. pH of the soap bar (a measurement and control is the fixed amount of soap, fixed quantity of water used and that the water must come from the same source i.e. all tap water, or all distilled (deionised – if water is truly pH = 7) water. This experiment is probably not meaningful without the use of a pH meter as the differences are likely to be small.
2. Ability to remove stains from a piece of cloth (controls are – same cloth, same size of cloth, same type of stain, same intensity of stain, same temperature, same water, same quantity of water, same type of container for undertaking the experiment, same additional aids e.g. stirring, same length of time for experiment, same post-experiment check)
3. Variations in these factors may affect the cleansing ability of the soap and hence experiments could vary one variable at a time using different soaps and then checks made on the effectiveness of the various soaps under each condition.

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

4. Ability to lather (controls here are same quantity of soap, same water, same quantity of water, same time, same additional aids such as shaking, same type of container, same instrument for measuring depth of lather.

Experimental details for the saponification of fats

The breakdown of sunflower oil by sodium hydroxide

APPARATUS

Each pupil or pair of pupils will need:
Page from *Laboratory Investigations* (experiment 21.5)
Teat pipette
Two beakers, 250cm^3
Tripod and gauze
Bunsen burner and asbestos square
Glass rod
Filter flask, funnel, filter papers, and filter pump (if possible)
Spatula
Sunflower oil
5M sodium hydroxide solution
Common salt

PROCEDURE

1. Place about 10 cm^3 of sunflower oil in a 250 cm^3 beaker, with about 50 cm^3 of 5M sodium hydroxide solution. (The pupils should be warned not to get this on their skins or on the bench.) Warm the beaker and stir the contents with a glass rod until it is boiling. Boil it gently for 10-15 minutes, stirring throughout.

Add about 50 cm^3 of distilled water and spatula measures of salt (sodium chloride) to saturate the solution; boil gently and stir for 3-5 minutes. Let the mixture cool, stir to break up any large pieces of solid and filter this off. Wash the solid residue in the funnel with a little distilled water and then allow the product to dry.

Shake a small quantity of the solid with water in a test-tube, when it should lather, showing the formation of soap.
(colouring matter and perfume can be added and the solid put in a press to form a solid bar of soap)

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

What is soap ?

Soap is a cleansing agent made from fats and oils with alkali.

Ingredients

Oils and fats for soap are esters of fatty acids which react with alkalis such as sodium hydroxide to form glycerol and the sodium salt of the fatty acid. The fatty acids required for soap making can come from animal fats, grease, fish oils, and vegetable oils. The hardness, lathering qualities, and transparency of soap vary according to the combinations of fats and alkalis used as ingredients. An experienced soap crafter uses many combinations of oils.

How does soap clean?

Most soaps remove grease and dirt because they (or some of their components if we consider the colouring and perfumes added) are surfactants (surface-active agents). Surfactants have a molecular structure that acts as a link between water and the dirt particles. This loosens the particles from the underlying fibres, or surfaces to be cleaned. One end of the soap molecule is hydrophilic (attracted to water), and the other is hydrophobic (attracted to substances that are not water soluble). This peculiar structure allows soap to adhere to substances that are otherwise insoluble in water. The dirt is then washed away with the soap.

A Scientific Explanation

Water molecules consist of 2 hydrogen atoms and an oxygen atom. The oxygen atom is linked to the two hydrogen atoms at a bond angle of about 104 degrees. Oxygen is far more electronegative than hydrogen and so it tends to have a higher electron density. Consequently the water molecule is *polar - it has a* positive charge at one end of the molecule (the hydrogen end) and a negative charge at the other (the oxygen end).

The positive end of one water molecule will be strongly attracted to the negative end of another water molecule. When an ionic compound, like sodium chloride, dissolves in water, the oxygen (negative) end of the water is attracted to the cations (positive ions) while the hydrogen (positive) end of the water is attracted to the anions (negative ions). The solubility of a substance in water is largely determined by the relative strength of the attraction of water to the substance compared to the strength of the attraction between water molecules.

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

In contrast to oxygen, carbon has almost the same electronegativity as hydrogen and the carbon-hydrogen bond is *non-polar*. For example, the octane molecule (a component of gasoline) consists of 8 carbon atoms in a chain, with 2 hydrogen atoms attached to the interior carbons and 3 hydrogen atoms on the end carbons. Since the electron density is evenly spread, the molecule is electrically neutral along its entire length.

The simplest way to understand solubility is to remember the rule "like dissolves like," that is polar and ionic substances are soluble in polar and ionic substances while non-polar substances are soluble in non-polar substances. Thus salt dissolves in water, but not in gasoline. Oil dissolves in gasoline, but not water.

Living cells and polar/non-polar substances

Living cells need both polar and non-polar substances. The cell uses non-polar substances, fats and oils, to make up the cell membrane which separates the interior of the cell from the exterior. If the cell membrane were soluble in water, it would dissolve away and soon there would be nothing to divide the cell from the non-cell. But in order to get to the cell in the first place, all the parts of the cell must be water soluble because that's how materials are transported from place to place. What nature needs is a non-polar material that can be dissolved, moved around, and then made non-polar again. This material is known as a *lipid (fat)*, or *triglyceride*.

A lipid is an ester and basically consists of two parts - a fatty acid and a trihydric (3 OH groups) alcohol called glycerol. Both the fatty acid by itself and the glycerol by itself are water soluble, because of the polar oxygen atoms on the ends of these molecules. In a lipid, three fatty acids are bonded to the three oxygen atoms (3OH groups) on the glycerol. Although the oxygen atoms are still there, they are now buried inside the molecule and the lipid is essentially non-polar. The lipid is therefore insoluble in water.

A fatty acid (saturated) has the formula $C_nH_{2n+1}COOH$. The chemistry is dominated by the properties of the COOH group. Because this group is polar, fatty acids tend to be soluble in water. Octanoic acid, $C_8H_{17}COOH$, is just one of a very large number of fatty acids. In fact, most fatty acids are longer than octanoic acid. Two very common components of lipids are palmitic acid ($C_{15}H_{31}COOH$) and stearic acid ($C_{17}H_{35}COOH$). Solid lipids are generally called *fats*. Another class of fatty acids are the *unsaturated* fatty acids, with less than 2n+1 hydrogens for every n carbons. Oleic acid, for example, has formula $C_{17}H_{33}COOH$ and linoleic acid has formula $C_{17}H_{31}COOH$.

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

Saturated fats contain saturated fatty acids and are solids at room temperature. Lard, and butter are examples of saturated fats. Soap made from these fats tends also to be solid at room temperature. Unsaturated fats contain unsaturated fatty acids and are liquids at room temperature. Generally these are called *oils and* examples include corn oil and safflower oil. These oils produce liquid soap. While unsaturated fats are generally more healthy than saturated fats, a liquid is often not very convenient. Thus margarine, which is made from unsaturated plant oils (e.g. corn oil) is hydrogenated to change it from an unsaturated oil to produce a saturated (solid) fat.

To make soap, the trihydric ester (fat) is hydrolysed (broken down) into its fatty acid and glycerol constituents. The fatty acid has a long hydrocarbon tail which is soluble in fats, and a polar oxygen end which is soluble in water. Thus a fatty acid in solution acts as a soap by dissolving fats in one end of the molecule and water in the other. When a strong base, such as lye, is used to hydrolyse (saponify) the fat, the fatty acid is then present as a large cation, which is polar at one end and non-polar at the other. Just as sodium chloride and sodium carbonate which are soluble in water, sodium octanoate, the sodium salt of octanoic acid is also soluble in water.

Saponification

Saponification is the term applied to the hydrolysis of fats using a strong alkali like lye. If we take a fat derived from palm oil (containing palmitic acid) and hydrolyse it using sodium hydroxide, the reaction is

$[C_{15}H_{31}CO]_3[C_3H_5O_3](s) + 3\ NaOH(aq)$ -----> $3\ C_{15}H_{31}COONa(aq) + C_3H_5(OH)_3(aq)$

fat(s) + 3 lye(aq) -----> 3 sodium palmitate(aq) + glycerol(aq)

While this reaction may appear intimidating because of the long formulas, it is, in fact, quite simple. It could be written generally as

$[RCO]_3[C_3H_5O_3](s) + 3\ NaOH(aq)$ -----> $3\ RCOONa(aq) + CH_2OH.CHOH.CH_2OH(aq)$

where "R" is some long carbon hydrogen chain.

If you look on a list of ingredients on a soap, you will find things like "sodium stearate," or "sodium palmitate". This is simply specifying the particular fatty acids present in the soap.

When fat is introduced to a soap solution, the non-polar tail of the fatty acids dissolves in the non-polar fat, leaving the water-soluble oxygen end at the surface of the fat globule. With enough soap, these fat globules become covered with a water-soluble coating and disperse throughout the solution, as in the last figure. They are not truly dissolved since individual fat molecules are not dispersed in the solution. Rather, the fat is *emulsified*.

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