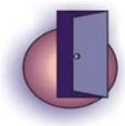
ECOLOGICALLY FRIENDLY CARS, WITHOUT EMISSION. SHOULD THEY BE COMPULSORY?



Introduction

The preservation of resources is becoming more and more important in a developing world. So looking for new sources of raw materials, as well as energy, is becoming of greater and greater interest. But at the same time, it is also important to reduce the emission of exhausts like carbon dioxide, e.g. to reduce the greenhouse effect. One possible solution to solve the emission problem may be a car powered by electricity using an electrochemical fuel cell based of hydrogen technology.

Educational Objectives:

Comment - All objectives have to be specified with respect to the age range, educational level and pre-knowledge of the learning group. The teacher will decide to what intensity the work is to be done, e.g. what types of fuel cells are to be investigated or which methods in teaching have to be chosen.). However, the science concepts to be acquired will relate to an age level and hence the script does not fit all age ranges.

Personal and social skills should be promoted by

1. Deciding, with justification, whether zero emission cars should be made compulsory.
2. Promoting communication abilities by students playing an active role in carrying out group work, discussions, role plays and describing positions to be taken including the critical arguments…
3. Cooperating as a member of a group by participating in group work.

Science content and process skills should be promoted by

4. Explaining that hydrogen will react with oxygen in air or by electron transfer in a fuel cell to produce water.
4. Explaining ways for the production of hydrogen (at least by the electrolysis of water). (Combine with 7 if this is really taught in this script)
5. Investigating different aspects of hydrogen production and the function of the hydrogen-oxygen-cell, so that the students show that they are able to carry out and evaluate different experimental works on this topic.

6. Gathering and evaluating information on the exhaust of fuel engines and electricity production, so that the students become able to give an estimation which kind of engine leads to less or no emissions.
7. Explaining that all engines give emissions and that the hotter the temperature, the more that the production of oxides of nitrogen become a problem

Science Concepts

1. Fuel Cell
2. Making Hydrogen

Students' Guide

Scenario

If the railway was the big transport development of the 19th century , then the motorcar must be the 20th century equivalent . So many cars were on the roads by the end of this century that concerns for the environment were increasing. Cars use the internal combustion engine in which fuel (hydrocarbons) are burned to form carbon dioxide and water. The increase of carbon dioxide in the atmosphere is a concern that can lead to global warming but the engine is not fully efficient , which means the hydrocarbons are not fully burned and some can escape into the atmosphere. Besides incomplete combustion leads to the formation of poisonous carbon monoxide and dirty, black smoke of carbon particles. Can we do better than use the internal combustion engine in cars?

Your Tasks

As a group

The activities which the students undertake are planned beforehand even if the exact content is unknown

1. From a consideration of the scenario, create questions that help your understanding of the advertisement and its claims

As an individual

2. Present these questions to another group of students and refine the questions.

As the group again

3. Undertake activities from those put forward by the teacher to answer the questions that your group sees of interest.
4. Prepare to communicate the finding of your group to other groups.
5. Present findings to the other groups

As a class

6. Discuss the findings in the light of the issue under consideration. Make justified decisions on ecologically friendly cars and the claims in advertisements that they are without emission. And consider whether they should they be compulsory.

Teacher's Guide

This module is intended to

(a) raise the problem of the internal combustion engine
(b) introduce the production of hydrogen
(c) the potential of using fuel cells.

Suggested Teaching Strategy

1. The teaching of the unit starts with an authentic impulse. In this case it is possible to use an authentic advertising or internet document (see students material) to intend the discussion.
2. So in the students material no recipe tasks are stated leading them through the whole process. It is intended to let the students ask their own questions, starting from their pre-experiences and pre-knowledge.
3. The guidance of the teacher on different aspects here is dependent on the learning group. From the material, it is expected that the students are stating several questions which have the potential to set up a frame for all following activities. It is expected that there are questions on the function of the «Hydrogen-Car», the properties and gathering of hydrogen and on the question whether it is true that there are really no emissions and whether it is a 'good' alternative.
4. A possible activity in this part is brainstorming.
5. More efficient, especially in involving all students, the use of the jigsaw method. Here the students are collecting their pre-knowledge and making up their questions in small groups of about 4 to 6. Then they present the ideas of their group in another setting of small groups where in each group only one member is of the original groups. Finally these questions are collected and edited to form a frame for following activities.
6. After setting up the frame, it seems helpful to understand the scientific background of the technology, the ways of producing hydrogen and the environmental consequences. Here a lot of different activities are available containing experimental work, doing a search on the internet or analyzing given information. This should include
   - reflecting on electron transfer for the reaction of hydrogen and oxygen and its potential in an electrochemical cell.
   - investigations on the function of the fuel cell. Here the work could start with letting the students plan a hydrogen fuel cell.
   - investigations on chemical or electrochemical ways to produce hydrogen. This may start with letting the students find out possible sources. On the one hand, water is a possible resource. Here the method of water electrolysis may be developed and investigated by the students. At higher levels, new tendencies of making hydrogen from methanol right in the car by a catalytic reaction could be investigated in an experimental way.
   - finding out ways to produce hydrogen. This means looking for the sources or raw materials and evaluate which of them are needed, which processes are done and which kind of emissions or pollution may be caused by this step. Here e.g. a

search on the internet or an evaluation of given information which may include data either in a table or graphical format are possible activities.

7. This phase should be organized as group work. If it is intended that all students are working on all aspects, «working on stations» approach may be a suitable method. [Here the teacher organizes in advance different stations to work on. These are based on different materials and activities (e.g. experiments) and each of them is dealing with a different aspect of the topic].
8. Then students start working on one of the stations of their choice and change to another after finishing. The stations need to be organized so that time need for completion of the task do not differ too much from station to station and that the sequence of working does not affect the results or understanding. It is not necessary that all materials have to be available for all groups, they can be offered only once. This more open form of working may also promote the ability of the students to organize their learning and take responsibility for it. They have to decide in which sequence they undertake their work and, if they are trained in open forms of working, they may be also allowed to decide about the time to spend on each of the stations. But also working out the different aspects in groups seems to be possible where each group becomes an expert group on a different part of the topic.
9. Later on, these groups communicate their results to the others by giving a presentation orally, or by means of a poster.
10. In the last part, the evaluation of the technology is discussed. Here it is important that the students become aware that the Hydrogen in the Hydrogen Car causes no emissions beside water. But the question whether the whole technology causes emissions has to be answered considering a broader view. It has to be mentioned that this kind of technology is only neutral to the environment, if the hydrogen itself is produced without emissions, e.g. by getting electricity from renewable energy sources like solar or wind energy use. Here it is possible to discuss that it is always a whole process that has to be characterized before valuing the economic and ecological background. Methods for products, or technologies like ecological balances, or life cycle analysis can be introduced and discussed with their chances and problems.
11. Students discussing different aspects and perspectives becomes important. This should include statements or views from different interest, or pressure groups, e.g. the producers of the car, environment protection organizations, crude oil industry or the government. It is also important to become aware that there are many aspects involved in this decision which are from science as well as from other fields like economy. This may give an insight that answering the question whether a new technology is 'better' than an old one cannot be easily or objectively answered in most cases. The individual has to make up his own mind about it as a consumer or elector in a democratic society. In a representative group, the discussion about other alternatives may be included, meaning e.g. the production of conventional fuel from renewable sources or a car concept directly based on solar technology.
12. This part is carried out in a method dependent on the learning group. For younger students, it seems a good idea to do this as a role play with prepared role cards. Students follow the roles of different pressure groups, companies or organizations and stand for the respective interests in a discussion round. For older students, a discussion with the whole group directly, starting with their own positions, seems to be more appropriate. Dependent on the abilities of the students this can be prepared by given materials, or an own search on viewpoints and arguments, maybe on the internet. In both cases, at the end, the students should state their own position and give

reasons for it. If this done in written format, it can contribute to the formative assessment of the educational objective (see below).

Achieving the Objectives

OBJECTIVE	**This is achieved by**
Deciding, with justification, whether zero emission cars should be made compulsory.	*participating in the whole class discussion and being able to justify the decision made*
Investigating different aspects of hydrogen production and the function of the hydrogen-oxygen-cell, so that the students show that they are able to carry out and evaluate different experimental works on this topic.	*undertaking the group work and recording the observations and the interpretations*
Gathering and evaluating information on the exhaust of fuel engines and electricity production, so that the students become able to give an estimation which kind of engine leads to less or no emissions.	*undertaking group work and recording information obtained*
Promoting communication abilities by students playing an active role in carrying out group work, discussions, role plays and describing positions to be taken including the critical arguments	*preparing to present information and findings to other students; participating in the group and whole class discussions*
Cooperating as a member of a group by participating in group work	*playing a positive role in devising questions and in carrying out the investigations*
Explaining that hydrogen will react with oxygen in air or by electron transfer in a fuel cell to produce water. Explaining ways for the production of hydrogen (at least by the electrolysis of water).	*preparing for the presentation of the group investigation results to the rest of the class*
Explaining that all engines give emissions and that the hotter the temperature, the more that the production of oxides of nitrogen become a problem	*preparing for the discussion on the claims of the advertisement*

Assessment

Social Values
The ability of a student to undertake a decision making exercise can be assessed by their participation in the decision making exercise on the advertisement

x The student was unable to put forward a decision based on the investigational findings and the discussion
√ The student was able to put forward a decision, but the justification of the decision was poor without the help of the teacher.
√√ The student was able to put forward a decision, and to well justify this with sound arguments

Process skills
The ability of the student to gather information for a variety of sources and to undertake an investigation can be determined by the teacher through the data obtained and the manner in which the student is involved in the investigations

x Not willing to obtain useful information and participate in the investigation
√ Able to gather useful information with the guidance of the teacher and undertake investigations as a member of a group
√√ Able to gather information from a wide variety of sources and to successfully undertake a number of investigations

Personal skills
x Not willing to cooperate with others and able to participate in group work
√ Able to play an active role in carrying out group work and in cooperating as a member of a group
√√ Able to play a leading role in group work and in helping others in the group to cooperate and communicate effectively.

Conceptual Skills
x Not able to explain the production and reactions of hydrogen, nor the working of a fuel cell.
√ Able to explain that hydrogen will react with oxygen to produce water. Able to explain ways for the production of hydrogen (at least by the electrolysis of water).
√√ Able to explain that hydrogen will react with oxygen in air, or by electron transfer in a fuel cell, to produce water. Able to explain ways for the production of hydrogen and recognise that an important source of hydrogen is the cracking of petroleum. Able to explain that all engines give emissions and that the hotter the temperature, the more the production of oxides of nitrogen becomes a problem.

Notes for the Teacher

The intended concepts can be taught on different levels. But it seems to be necessary that the students are able to understand elementary concepts of electricity as well as of chemical reactions. It seems useful that students have the ability to use (or is developed through this script) the concept of oxidation and reduction as an electron transfer process.

In the part acquiring the scientific background, activities need to be chosen which are suitable for the learning group (e. g. age range, school level). Here further aspects such as generating hydrogen from methanol, or the function of modern polymer-electrolyte-membrane(PEM)-cells can be added for higher grades.

The structure of the unit is given in the figure below and elaborated further with special impact on possible methods for student-oriented and student-activating activities.

Questions created by Students

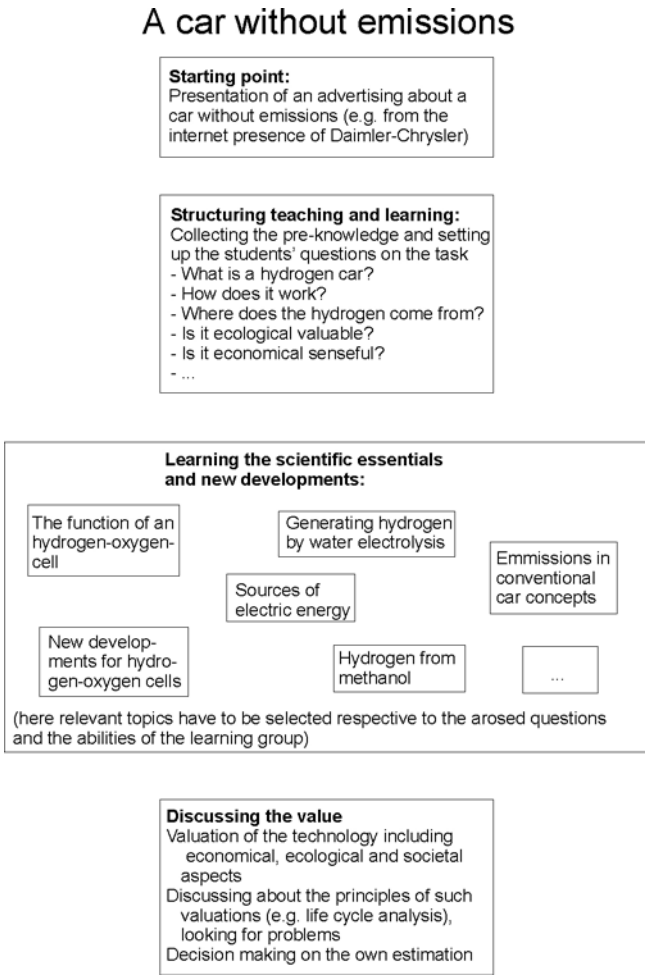
It is expected that students will develop questions on
- making hydrogen and its properties
- functioning of hydrogen cars
- emission from hydrogen as a fuel

The teacher may need to guide student groups where the students do not have the necessary vision themselves...

Rationale for the discussions

Such developments are intensely discussed in society and the discussion is driven by different interests, companies and pressure groups. The public opinion is very much influenced also by advertising materials. To compete in such a discussion, as an active member of a democratic society, it is necessary to become competent in understanding the scientific and technological essentials. But it is also necessary to become critical on the societal discussion and the arguments used.

The main argument for a «Hydrogen-Car» is that there are no emissions. On a closer look it is been seen that this is right only when the hydrogen had been produced on the basis of a no emission



technology as well e.g. solar or wind energy sources, or when the burning of hydrogen is not associated with the subsidiary reaction of nitrogen plus oxygen giving oxides of nitrogen as happens at hot temperatures (ca. 3000 celsius). Also the use of methanol is discussed to produce hydrogen, but also this seems to be a solution only if it is not produced from natural gas.

Beside this a lot of arguments have to be discussed whether the hydrogen technology is a good alternative to reduce emissions, e.g. whether it is helpful just to put the emissions outside the cities. So following a socio-critical and problem-oriented approach, it is intended to follow this discussion and to give an insight to the way it goes. It is intended to make the students aware about how difficult such a decision is, how necessary a basic scientific knowledge is and how easy the individual can be misled if there is only less, or intentional information available.

Assessment of Personal and social objectives

For the assessment of the personal and social objectives it is helpful to use different kinds of assessment approaches which follows a more qualitative perspective. A written (and maybe anonymous) report done by the students about their individual decision and point of view can be requested by the teacher. It can be judged whether the students are arguing by using facts and opinions correctly and doing it in an understandable and logical way. This can be evaluated also whether there is a critical view in it by looking whether there are arguments from both sides discussed.

A second way of assessing the personal development can be by letting the students reflect on their learning. This can be done by asking what, in their estimation, had been the main things they have had learned, or what the main objectives of this teaching might have been. It can be seen whether student only mentioning tasks from the scientific content point of view, or whether they give answers containing personal development, social awareness, communicative and process skills. Mentioning these aspects means to become aware of them. Becoming aware in this field is the first, and maybe the most important thing, in reaching further.

Supplementary information

Information about the fuel cell technology and actual developments are available at e.g. *www.daimlerchrysler.com* (→'Corporate Information'→ ‚Research and Technology ' (02/09/02))

Respective information on different aspects and viewpoints of pressure groups are available the internet and can be easily searched by sites like www.google.com, e.g. (02/09/02):

Producer of hydrogen technology cars	*www.daimlerchrysler.com* (→'Corporate Information'→ ‚Research and Technology ')
Overview on producers of fuel cell technology	*www.ttcorp.com/fccg/fc_othr.htm*
Crude oil Industry	*www.shell.com* (→'Issues and dilemmas' → 'Alternative energy'→ 'Hydrogen fuel cells')
Environment protection groups	*www.greenpeace.org.au/climate/archive/nonewoil/phasing_out.html*
Governmental organisations	*www.umweltbundesamt.de* (choose english version and search for 'fuel cells')
Overview on reports in media (Reuters)	*www.planetark.org/index.cfm* (→ 'fuel cells')

Experimental work

Electric energy from hydrogen and oxygen: Easy cells for the use of hydrogen can be investigated just by using two electrodes washed around by the two gases.

Modern fuel cells using a more advanced technology on the base of a polymer electrolyte membrane (PEM). Experimental kits and respective descriptions also to investigate such technologies are now available in different countries (e.g. www.heliocentris.com/eng/prods/pr_kits.html or www.carolina.com).

Generating hydrogen: An easy way to generate hydrogen is a simple electrolysis of water in a Hoffmann-apparatus ?? (using test tubes inverted in a beaker with plastic coated wire leads - wire exposed for electrodes) . For more advanced studies in higher grades a discussion on alternatives may be of interest. In the student material, the use of methanol is mentioned. Hydrogen can be easily generated by catalytic cracking of methanol on a copper/magnetite catalyst. Respective experiments had been described e.g. by Huntemann, H. et al. (2001) Die Wasserstoff-/Luft-Brennstoffzelle mit Methanolspaltung zur Gewinnung des Wasserstoffs, *Chemie Konkret* 8, p. 15-21. See also Parchmann, I. et al. (1999) Durch die Zelle in die Zukunft?.
www.ni.schule.de/~lmgvar/faecher/ch/zelle/.

- The easiest fuel cell just using two electrodes in a liquid flushed around by the gases leads to very low electricity. This can be optimized in the meaning of scientific development process either by developing the idea of combining several cells as well as to improve the potential of each of the cells. Here on a higher level the comparison of different types of cells can be done as well as talking about newer developments in this technology, e.g. the role of the membrane in actual cells. Whether this is done by experimental investigations, on the base of given information or through a search on the internet has to be decided with respect to the learning group.
E.g. at *www.ni.schule.de/~lmgvar/faecher/ch/zelle/* a project is described in which students of a specialized course in grade 13 (age range 18-20) of a German grammar school investigated and compared different types of fuel cells on an experimental level.

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