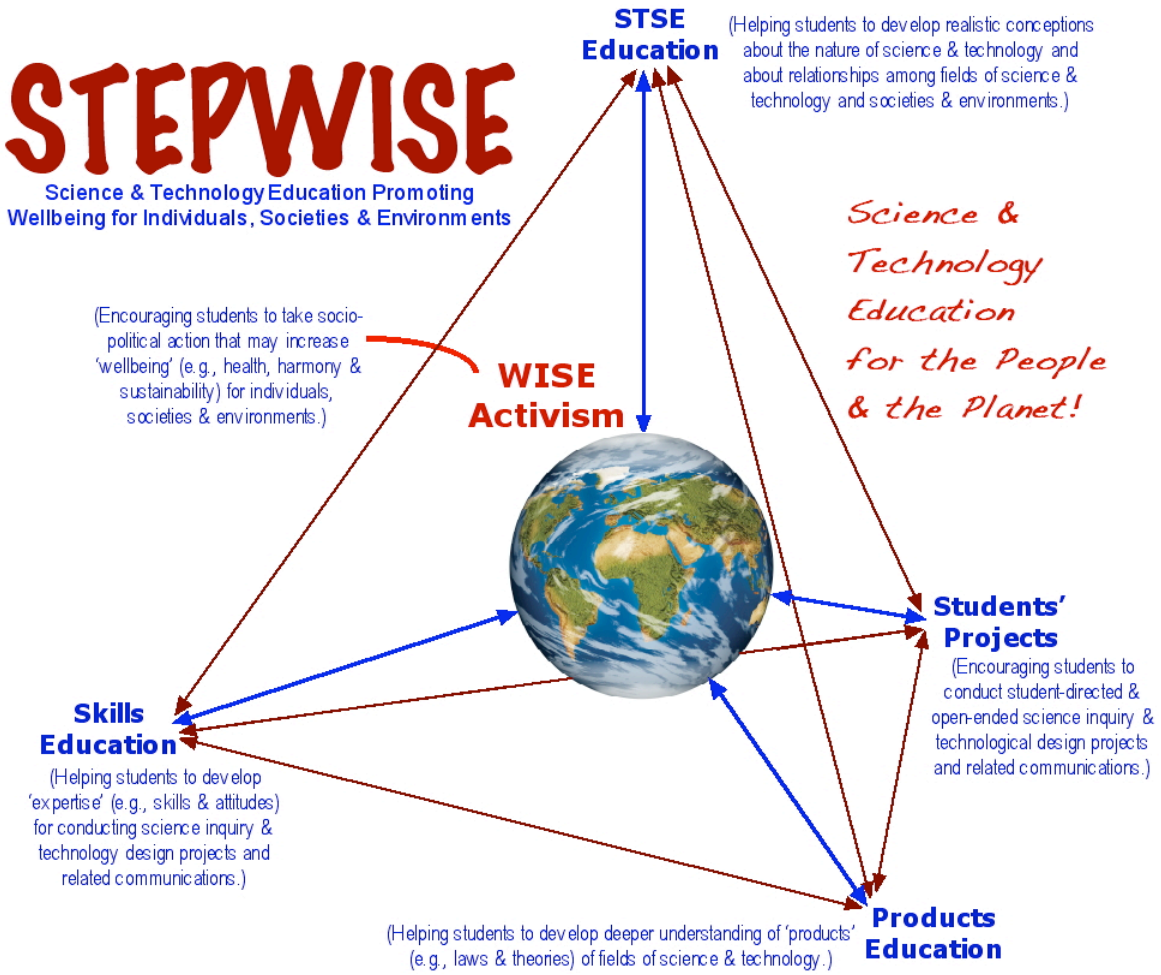
STEPWISE

http://www.stepwiser.ca

FUEL CELLS
Case Method

The case method provided here is based on the STEPWISE curriculum and instructional framework provided below. This and other case methods provide some basic information about a 'WISE' issue, such as possible problems relating to batteries. Teachers then provide instruction in each of the STEPWISE elements, and encourage students to conduct research to enhance their knowledge, skills and findings (in the case of Students' Projects) — related to the STEPWISE framework. Instruction and student work culminate in students' WISE Activism; i.e., action(s) to address the WISE issue.



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Case Method

HYDROGEN – THE FUEL OF THE FUTURE?

Introduction

A Fuel Cell is a lot like a typical battery that you would find in a car, cell phone, MP3 player, or laptop –they are both devices in which the energy of a chemical reaction is converted directly into electricity. However, this is where the similarity ends. Conventional batteries use a variety of chemicals like zinc, carbon, lithium, nickel, cadmium and lead to produce a flow of electrons and power their reactions, while a hydrogen fuel cell only uses the smallest atom there is, a hydrogen atom (atomic number 1), and even that has its electron stripped away. Instead of moving big molecules through thick gel-type 'goo' like most batteries, fuel cells move nothing but protons and electrons through tiny bubbles of gas. Another large distinction between a battery and a fuel cell is that a fuel cell does not run down or need re-charging, it operates as long as fuel (hydrogen) and an oxidant are supplied continuously from outside the cell. As most of you already know, water can undergo electrolysis to produce hydrogen gas and oxygen gas - well this electrolysis can work the other way as well. If you combine oxygen and hydrogen, you get that energy back (remember our 'exploding' water bottle demonstration!!). In a vehicle such as a space shuttle, hydrogen and oxygen are combined and burned. The huge release of chemical energy becomes the spectacular rush of hot expanding gases that force the shuttle skyward. The only by-product is pure water, which the crew uses as drinking water!! In a fuel cell, the idea is to combine hydrogen and oxygen slowly and in such a way that we capture the released chemical energy as electricity.

WISE Issue	Resources/Factors in Decision-making			WISE Action
	STSE Expertise	**Products Expertise**	**Activism Expertise**	**Possible Action Projects**
Impact of the use of fossil fuels in internal combustion engines on the Environment	**Environmental and health impacts associated with the use of internal combustion engines in cars and other forms of transportation**	**Function of the internal combustion engine** **Effects of pollutants in car exhaust** **Alternative technologies to the internal combustion engine such as hydrogen fuel cells**	**Assessing the benefits and hazards of a specific technology** **Developing and carrying out an action plan**	**Education campaign e.g. informational brochure or ad on hydrogen fuel cell technology in automobiles** **Community change campaign e.g. organizing a "car free day" in the school community** **Personal lifestyle change e.g. walking, using bicycles**

	NoST Expertise Opportunities to explore: the economic and cultural factors that can influence science and technology	Skills Expertise Expertise for: hypothesizing, experimenting, developing prudent conclusions	Project(s) Findings Results and conclusions from experimental studies on vehicular emissions	when possible

Prior Knowledge

Students should be able to:

- Recall the reaction equation for the combustion of a hydrocarbon
- Recall that fossil fuels are non-renewable and polluting
- Recall that hydrogen reacts with oxygen to produce water

Curriculum Expectations Addressed

This case is appropriate for the following grades and strands:

Grade	Course	Strand	Specific Expectations Addressed
7	Science and Technology	Earth and Space Systems: Heat in the Environment	HE1.01 describe causes and implications of global warming and analyze personal choices with respect to production of greenhouse gases. HE2.03 use the skills of scientific inquiry to investigate needs and problems related to heat in the environment, generate a list of possible solutions and compare the solutions (e.g. various types of windows and their effectiveness in reducing heat loss, alternative methods of heating homes and their environmental impacts).
11	SNC 3M	Thermal Energy and Heat	TEH1.1 analyse an issue and suggests improvements that involves a thermal energy transformation system, using the principles related to thermodynamics (e.g., home insulation, appliance efficiency, alternative fuels for vehicles, fuel cells).

			TEH1.2 assess and evaluate the societal and/or environmental impacts of a thermal energy transformation system (e.g., home insulation, appliance efficiency, alternative fuels for vehicles, fuel cells)

Fuel Cell Basics

A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte (most fuel cell technologies are named for the type of electrolyte they use). You can think of the electrodes as the bread in a sandwich and the electrolyte as the meat. Hydrogen is fed to the anode, and oxygen is fed to the cathode. Activated by a catalyst, hydrogen atoms separate into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they reunite with oxygen and the electrons to produce electricity, heat, and water (the only waste product). That's right – pure, drinkable water flowing from the tail pipe as an invisible gas; no carbon particulates, no nitrous oxides, no unburned gasoline, no carbon monoxide and this water can even be used to cool the engine. In addition, a typical car engine might be 28 percent efficient at converting the heat of burning gas into the mechanical work that moves it along. A fuel cell is about 50 percent efficient. So, we may be able to build vehicles that use half as much energy to get around and don't produce pollutants in the exhaust!

Stop and answer the following:

1. What is a fuel cell?
2. How do fuel cells compare to conventional batteries? Comment on their similarities and their differences.
3. What is the balanced chemical equation that can be used to describe the reaction that powers a fuel cell? What type of reaction is this?
4. What is an electrolyte?
5. What is a catalyst?
6. What are some of the benefits associated with fuel cells?

Since hydrogen fuel cells potentially only produce water as a byproduct of the electrolysis, they hold a great deal of promise as a low-pollution, energy-efficient alternative to traditional combustion engines found in most of today's cars. You may ask yourself, why aren't hydrogen fuel cells already being used on a wide-scale? Well, as it turns out there are a couple of issues that are preventing fuel cells from being adopted. The primary issue has to do with the 'fuel' itself. The oxygen the cells need is readily available in the air around us. However, hydrogen, the most plentiful gas in the universe, is not so readily available since it does not exist naturally on earth, and instead we must make it. One way that scientists are making hydrogen is by using fuel re-forming technology - this generally means that some sort of fossil fuel compound (natural gas, methane, propane) is transformed using energy to produce hydrogen. This technology takes a compound like natural gas (CH_4) and re-forms it with the oxygen from water (H_2O) to make hydrogen gas (H_2) and carbon dioxide (CO_2). This is not too bad, but it's not the best option because this process takes energy, and we were trying to avoid using fossil fuels such as gas and oil in the first place. On top of that, the main idea was to avoid pumping unnecessary CO_2 into the atmosphere. It is conceivable that the energy required to 're-form' hydrogen could be provided by nonpolluting and sustainable energy resources, such as wind or solar power, however there is still the issue of using fossil fuels and releasing carbon dioxide into the atmosphere. So, re-forming is probably not the best long-term approach to creating hydrogen for fuel cells.

Another promising fuel cell technology that appears to be the most adaptable to automobile use is PEM technology. This approach uses a proton exchange membrane (PEM) as the electrolyte and this membrane facilitates the chemical transfer of protons. Some fuel cells use

exchange membranes made of a special type of plastic impregnated with platinum, a very stable metal. Hydrogen is pumped in on one side of a thin membrane of this material, oxygen on the other. Protons are exchanged, and electricity flows out from the edges. $2H_2 + O_2 \rightarrow 2H_2O$. However, this approach is a bit tricky. For example, the pressures within the cells have to be just right. The surfaces where the gases meet have to be kept clean, and they can't be fragile.

Another issue associated with fuel cells is that there is no existing delivery system to get hydrogen to all the places people would need it to power their cars, houses, or companies. Today we can easily find a gas station if we need to re-fuel our vehicle but infrastructure and expertise to support hydrogen as a fuel source is not yet available. Then there is a question of what happens to all of the existing infrastructure and product that is used to support conventional engines and energy sources. In addition, hydrogen molecules are very small and they leak out of joints in pipes easily. Hydrogen is itself a greenhouse gas, as is the water vapor that forms in fuel-cell exhaust. Not to mention, it's very expensive to make hydrogen right now, but new technologies are being developed all the time. In fact, scientists have even discovered that some algae and bacteria give off hydrogen. British scientists fed Escherichia coli bacteria a diluted mix of waste caramel and nougat. The bacteria started eating the sugar and in the process produced hydrogen, using their own enzyme, called hydrogenase. The hydrogen produced by the bacteria was used to power a fuel cell, generating enough electricity to drive a small fan! So hopefully, the issue of expense will deteriorate as new technologies are developed.

Stop and answer the following:

7. What is fuel-reforming technology?
8. Write a word equation and skeletal equation for fuel reforming using natural gas. Be sure to balance this chemical equation.
9. With a partner brainstorm some of the issues or concerns associated with adopting hydrogen fuel cells as the 'fuel' of the future? (Be sure to include issues not listed in this case study)
10. It is obvious that finding a pure source of hydrogen is challenging. Propose one possible source of hydrogen that has not been discussed.
11. Some companies are already developing laptops that run on fuel cells. What other technologies that we use today could benefit from fuel cells?
12. Briefly research <u>one</u> of the following fuel cell technologies and identify the pros and the cons of the technology and the type of situation it would most likely be used:
    - Alkaline fuel Cells
    - Phosphoric Acid Fuel Cells
    - Solid Oxide Fuel Cells
    - Molten Carbonate Fuel Cells

The following websites can be used to help you with your research.

- http://www.eere.energy.gov/RE/hydrogen_fuel_cells.html
- http://www.howstuffworks.com/fuel-cell1.htm

Can we make fuel cells a reality?

Fuel cells hold a lot of promise as an energy-efficient, low-pollution alternative to traditional energy sources in a wide variety of applications. However, for hydrogen to become the fuel of the future, we probably need to make it from water, electrolyzing the water with renewable sources of electricity--sources like solar photovoltaic panels, wind turbines, or geothermal heat systems. Although electrolysis is expensive, water is abundant and renewable, and technological advances could make it a very attractive alternative especially if we can get the renewable electricity to make it. We should be able to improve fuel-cell systems the same way we have developed and improved modern gasoline engines over the last century. So, watch out for hydrogen fuel cells, they will likely play a big role in our near future.

Stop and answer the following:

13. How do hydrogen fuel cells compare to solar or wind energy as an alternative energy source?

14. Summarize the advantages and disadvantages of fuel cell technology (consider political, environmental, social, and cultural factors).
15. Would you buy a fuel cell-powered car even if it were much more expensive than a conventional one? What kind of information would you want to know if you were thinking of buying a fuel-cell powered car (eg. Is the car easy to refuel? Can it travel a good distance before refueling?)
16. Do you think hydrogen fuel cells are worth developing as an alternative energy source?

Teaching Notes
Beginning of the Lesson:

- Create a Class Consequence Map on the board – "What would happen if the world ran out of oil?" Hopefully students will identify development of new technology as a possible scientific consequence – this can be used as the spring board for introducing hydrogen fuel cells
- Create a KWL chart to determine what students know (K) and what they want to know about hydrogen fuel cells (W) – you can come back to what they learned about hydrogen fuel cells (L) at the end of the lesson
    - Ensure that students have a basic understanding of what a hydrogen fuel cell is (it is an alternative to things like combustion engines, uses hydrogen as a fuel source, and produces only water)
    - This may be a good place to demo electrolysis of water and discuss the water bottle demo we did with students previously
- Based on this knowledge provide the students with a scenario:
    - The government is awarding $10 million to develop the latest alternative energy technology – should this money go towards hydrogen fuel cells as an alternative to internal combustion engines in automobiles or should it be spent elsewhere?
    - Set up a 4 corners using chart paper in the classroom based on stakeholder perspective
        - Corner 1 – Oil and Gas Company
        - Corner 2 – Automotive Company
        - Corner 3 – Environmentalists
        - Corner 4 – Federal Government
    - Split students into these 4 corners and have them try to identify the stakeholder perspective (Students have limited knowledge at this point and may not be able to write a lot down – this is OK). Go around the class and have students provide some information on their perspective.
- Give students the case study to read and answer questions. Some questions would benefit from discussion in partners (At the individual teacher's discretion.)
- Re-visit 4 corners activity – students should have a better idea of how to represent their stakeholder perspective after reading the case study. Have students present their revised perspective and address the scenario: The government is awarding $10 million to develop the latest alternative energy technology – should this money go towards hydrogen fuel cells as an alternative to internal combustion engines in automobiles or should it be spent elsewhere?
    - First to the group (numbered head strategies: 1 present 2, 2 present to 3, . . .)
    - Potentially have the "best" perspective presented to the class (this will require cooperation among the students)
- Re-visit KWL chart

- Assessment: Individual answering of case study questions – not all of them have to be submitted. This can be discussed. This is meant to be a Making Connection mark.

Assessment Rubric

Criteria	Level 1	Level 2	Level 3	Level 4
Knowledge and Understanding	- demonstrates minimal understanding of the nature and use of fossil fuels in the internal combustion engine and the reaction of hydrogen and oxygen in a hydrogen fuel cell	- demonstrates some understanding of the nature and use of fossil fuels in the internal combustion engine and the reaction of hydrogen and oxygen in a hydrogen fuel cell	- demonstrates considerable understanding of the nature and use of fossil fuels in the internal combustion engine and the reaction of hydrogen and oxygen in a hydrogen fuel cell	- demonstrates a thorough understanding of the nature and use of fossil fuels in the internal combustion engine and the reaction of hydrogen and oxygen in a hydrogen fuel cell
Application	- connects knowledge of hydrogen fuel cell process with benefits to the environment with minimal effectiveness.	- connects knowledge of hydrogen fuel cell process with benefits to the environment with blood/conflict diamonds with some effectiveness.	- connects knowledge of hydrogen fuel cell process with benefits to the environment with blood/conflict diamonds with considerable effectiveness.	- connects knowledge of hydrogen fuel cell process with benefits to the environment with blood/conflict diamonds with a high level of effectiveness.
Communication	-communicates information with limited clarity - Information is communicated with minimal organization. -employs language skills with limited effectiveness.	- communicates information with some clarity - Information is communicated with some organization. -employs language skills with some effectiveness.	- communicates information with considerable clarity - Information is communicated with considerable organization. -employs language skills with considerable effectiveness	- communicates information with a high degree of clarity - Information is highly organized. -employs language skills with a high degree of effectiveness.

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