AC 2007-2288: EXPOSING HIGH SCHOOL STUDENTS TO THE ROLE OF ENGINEERING AND ADVANCED MATERIALS IN DEVELOPING ALTERNATIVE ENERGY SOURCES

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Exposing High School Students to the Role of Engineering and Advanced Materials in Developing Alternative Energy Sources

Introduction

There is an unprecedented need to foster a new awareness of and interest in engineering careers in the American workforce of tomorrow currently in the K-12 pipeline. The American College Testing organization reports that in the decade from 1992-2002, its surveys indicate a precipitous drop (from 9% to 6%) in US high school students interested in majoring in engineering. Additionally, there is the recurring problem of the lack of math and science preparedness among US students. Many programs have been started to address these problems. One of these is a growing movement towards teaming college faculty with K-12. The ASEE Engineering K-12 Center seeks to promote awareness and knowledge of engineering and technology as tools for advancing achievement in K-12 science and mathematics teaching and learning. As an active part of this effort, the College of Engineering at North Carolina A&T State University operates a summer camp-based Engineering Starters Program, with each camp lasting two weeks. It is well known that laboratories and demonstrations add information and interest to science and engineering courses [1]. Laboratory exercises provide a great opportunity to expose students to 'real materials' in an active learning environment. Such exercises also provide a mean to satisfy important learning objectives and the ability to conduct experiments, analyze and interpret data [2]. Our program centers on a series of interactive lectures in a lab setting, with relevant experiments immediately following. There are extensive pre-experiment discussions and comparison with actual results in post-experiment discussions. These are supplemented by lab tours of graduate and faculty research labs and interactions with those researchers, who also provide them with additional simple experiments to give them a feel of the scope and value of the research problem being investigated. Our paper discusses a specific module and an experiment to expose the students to electrical and electro-chemical engineering concepts and the challenges and opportunities of alternative energy sources such as fuel cells. In the summer of 2006, this camp was offered to a batch of about 25 high school students (9^{th} – 11^{th} grade) and about 25 middle school students (7^{th} – 8^{th} grade).

Introduction of Energy Concepts

The module begins with a detailed overview of the different sources of energy and their impact on the environment was discussed. Before the instructor presents, we ask the students about the chief sources of environmental pollution. High school students readily identify automobiles and chemical industries as major sources, showing their general awareness about the environment. The presentation discusses the major role of petroleum-based energies (gasoline and diesel, for instance) in transportation and the manufacturing and utility sectors. The gasoline energy cycle and its effect on the environment are illustrated with an easy-to-grasp slide (Fig. 1). The cycle explains the process of oil extraction from wells, followed by crude oil processing and finally distribution of the refined products (gasoline, diesel, natural gas, etc). The engineering operations behind these stages are explained to the students. Fig. 1 shows tailpipe emissions at the end of the gasoline cycle. The typical chemical analysis of tailpipe gases is presented, and their environmental impact is discussed.

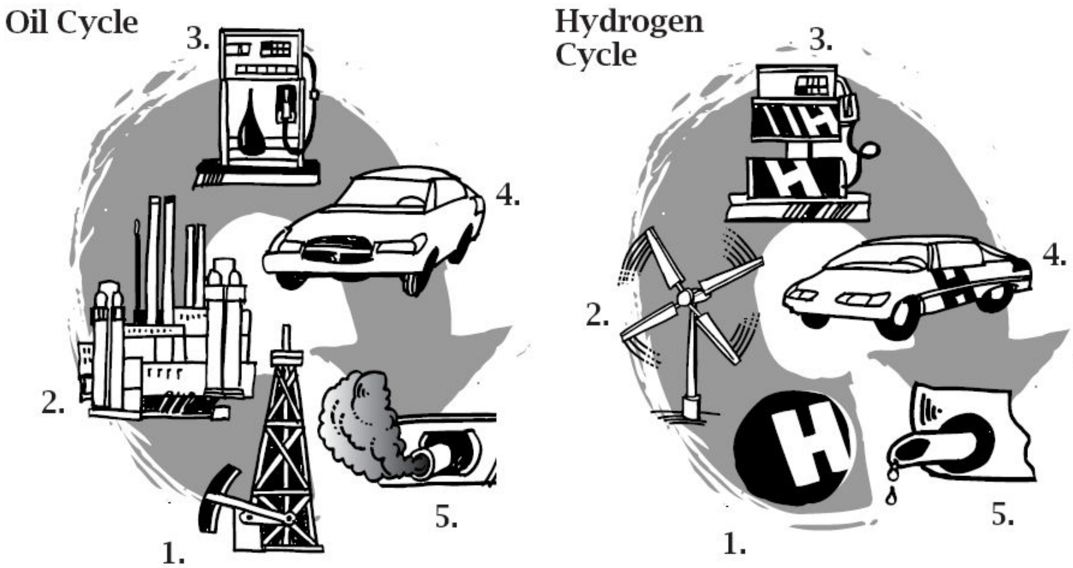


Figure 1. Comparison of gasoline and hydrogen cycle [3]

The presentation then moves on to ethanol-based energy sources. Major reasons for using ethanol-based gasoline are to reduce the nation’s dependence on foreign oil and also to help address global climate change. With corn being a prime source of ethanol, the country gets the dual benefit of boosting its agricultural sector while also increasing its energy security. The students are introduced to the concepts and nomenclature of ethanol-blended gasoline including the E15 and E85 grades, with the two digits indicating the percentage of ethanol in the blend (the remainder being gasoline).

Another alternative energy currently receiving a lot of research and development focus is the hydrogen-powered fuel cell, given its ability to generate clean energy. A pure hydrogen cycle is shown on the right side of Figure 1 – this cycle only emits water as exhaust. The methanol-based fuel cell cycle emits only water and carbon dioxide. Fuel cells generate power through the chemical reaction of oxygen with hydrogen (Figure 2). The chemical reaction in the cell is enabled by the function of the positive (anode)-electrolyte-negative (cathode). The fuel (hydrogen) is passes along the anode while the oxidant (air) passes along the cathode. The electrolyte is basically a selective membrane that separates the air and hydrogen streams, allowing the movement of oxygen ions but not allowing conduction of free electrons. When hydrogen reacts with oxygen at the anode, two electrons associated with the oxygen atom are replaced with hydrogen, producing water and electricity. These electrons are freely conducted through an external circuit back to the cathode, where they dissociate the incoming supply of O_2 molecules, thus sustaining the reaction [4]. Electricity is produced as the electrons move through the external circuit. The underlying principle is that the anode material should be electronically conductive so that it can carry the electron ions to the external circuit. This concept is explained in detail to the students to prepare them to perform and understand the motivation for the experiments being performed in our research labs.

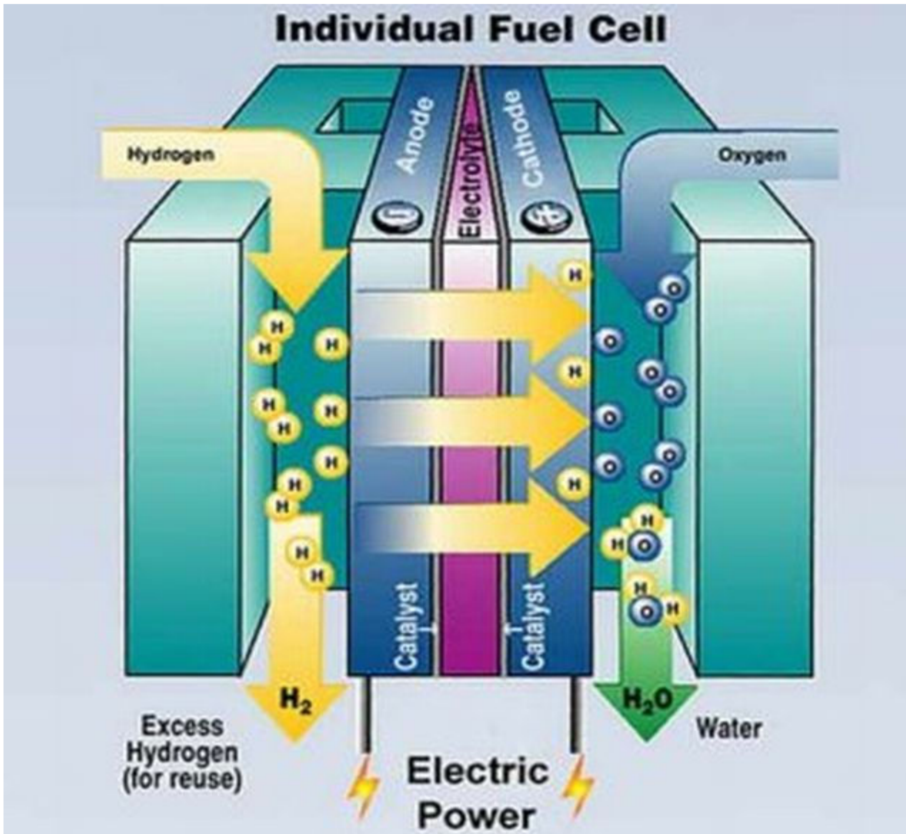
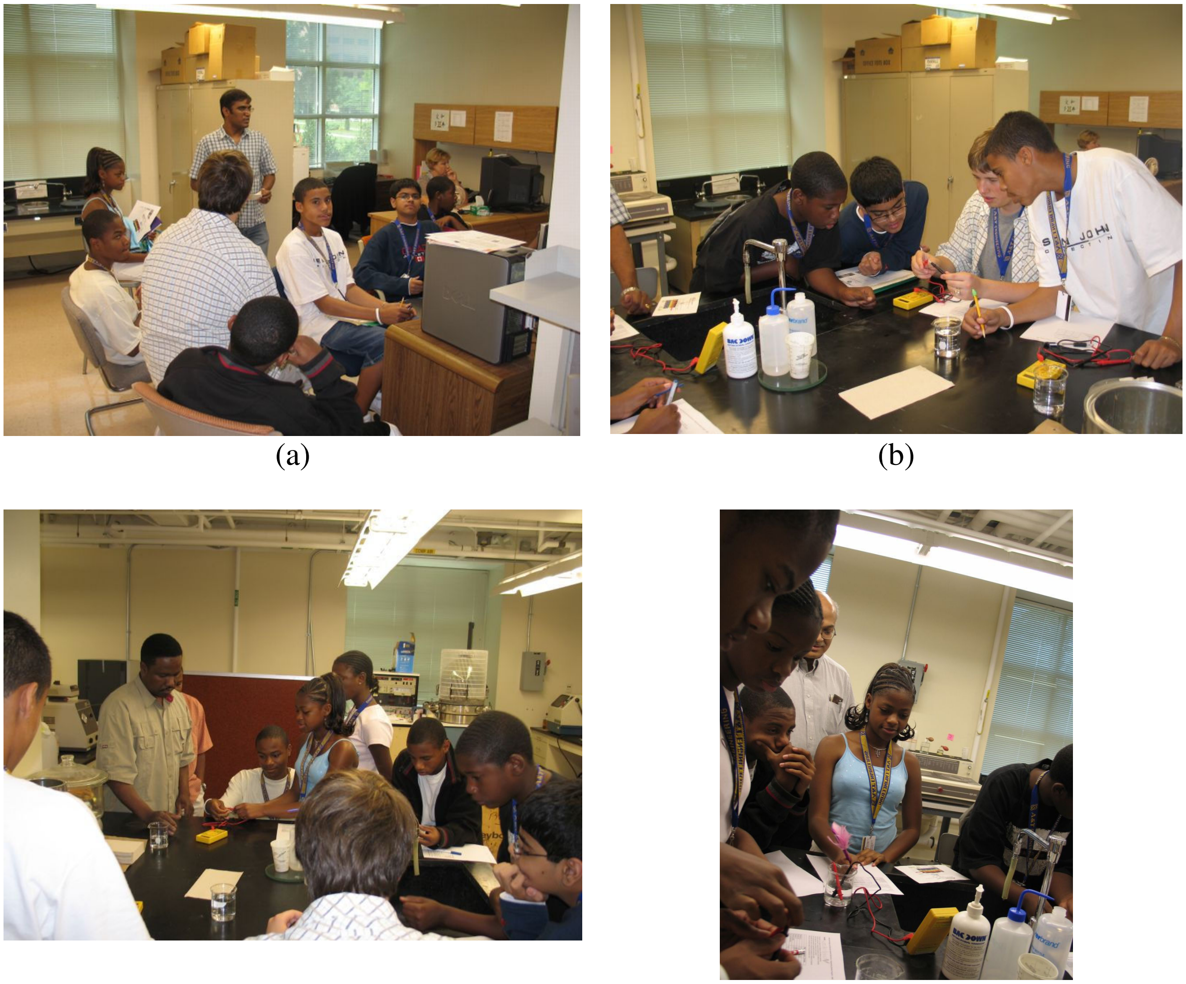


Figure 2. Working principle of a fuel cell

Lab Experiments

The objective is to demonstrate the concept of electrical resistivity and conductivity using different materials. The students are given a quick tutorial in the safe use of multimeters and their different modes of operation. They set the multimeter to ohm-meter mode to perform conductivity (in this case, resistance) measurements. For practice with the ohm-meter, students measure three different standard resistors. Most students are initially hesitant to hold the ends of the resistors firmly for fear of receiving an electric shock. The need for good metal-to-metal contact is emphasized and the safety aspect is clarified. The students start to get comfortable with and actually enjoy using the multimeter - a novel experience for many of them. Some of the more curious students ask for and receive supplementary information regarding the color-coding system for standard resistors. After gaining confidence in electrical resistance measurement, the students are given buttons of fuel cell anode material and its precursor ceramic material (produced from ongoing graduate and faculty research) to measure and compare the resistances of straight ceramics and the metallized ceramic anode material. After this, the students also measure and compare the resistance of water straight from the faucet with that of water with an Alka Seltzer table dropped in (Figure 3). Concepts of electronic and ionic conductivity are explained.



(a) (b)

(c) (d)

Figure 3. (a) Students listening to the presentation about energy concepts, (b) Students learning to use the multimeter, (c) Students do measurement on resistors and (d) Students do measurements on water plus Alka Seltzer solution.

The students' observations are tabulated as shown in Table 1. They then get a quick tutorial in plotting the data on a bar chart using MS-Excel (Figure 4). The results help them to understand the resistivity and the corresponding conductivity of the different samples. Most students are surprised to observe that the pure water is relatively resistive and less conductive. Their primary observation is the marked difference in resistivity values between the fuel cell anode material and the other materials.

Assessment of Activities

The students are (with IRB approval and consent procedures) administered a pre- and post-program survey on level of familiarity with and interest in science and engineering concepts. The post-survey also includes a free-response section for participant comments. The data following aggregates the response of a batch of about 24 high school participants from the summer of 2006, with filling of the both pre- and post-surveys being optional on the part of the students.

Table 1. Resistances measured by camp students for different materials

Material	Resistance (ohms)		
	Reading 1	Reading 2	Average
Resistor A	20	20	20
Resistor B	100	100	100
Resistor C	10000	10,000	10,000
Sintered pellet	1.00E+07	1.00E+07	1.00E+07
Fuel cell electrode	0.4	0.4	0.4
Water	1.00E+07	1.00E+07	1.00E+07
Water plus Alka Seltzer	80,000	80,000	80,000

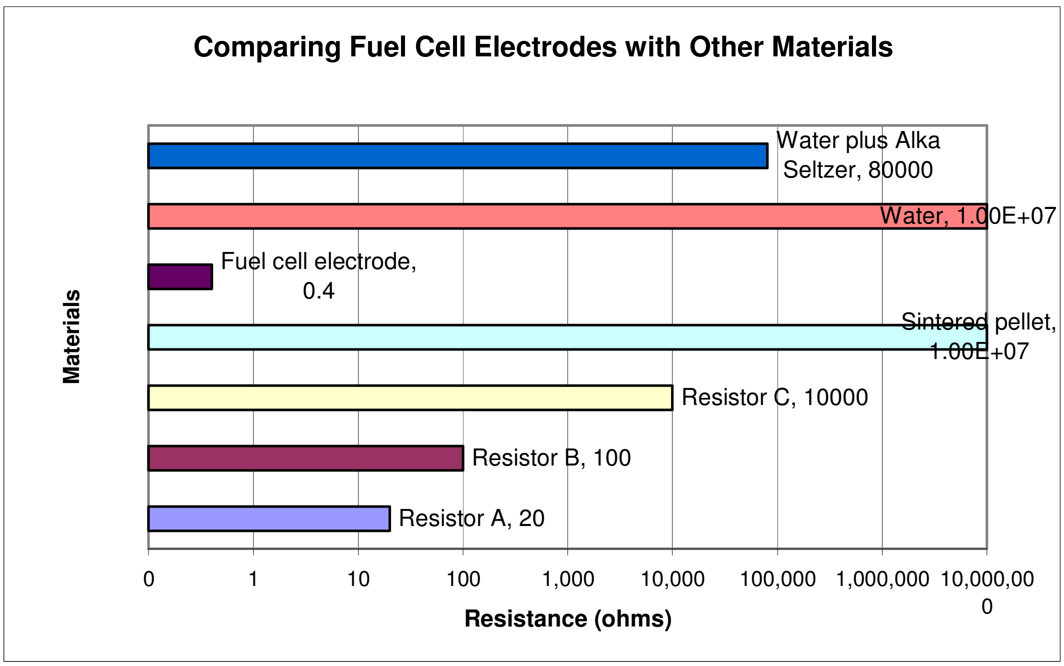


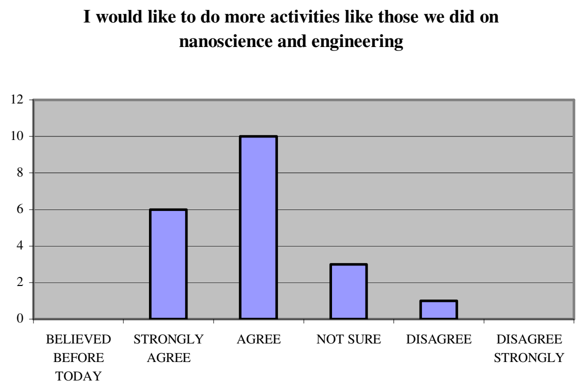
Figure 4. Electrical resistance values for different materials – sample student measurements

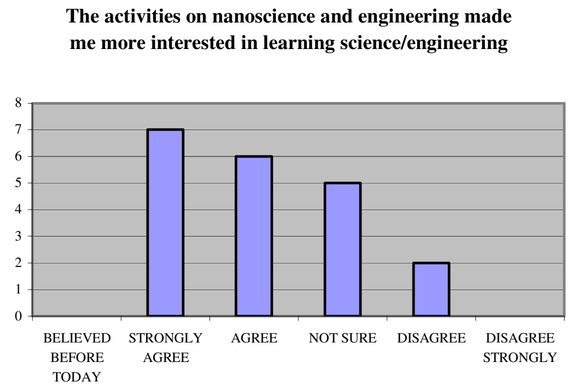
Table 2 Summer camp pre- and post-survey results

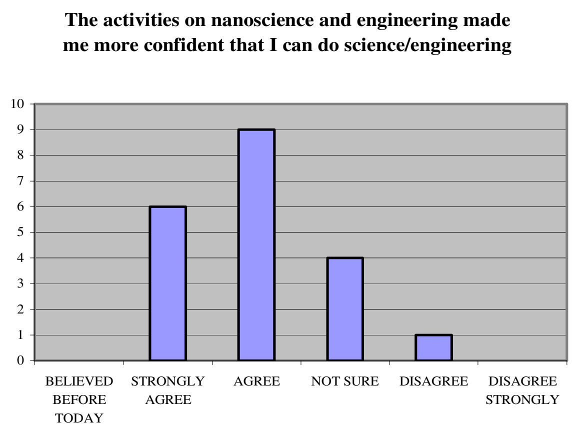
	Believed before today	Strongly agree	Agree	Not sure	Disagree	Disagree strongly
I would like to do more activities like those we did on nanoscience and engineering	0	6	10	3	1	0
I'd tell my friends to attend a camp like this so they could participate in activities like those we did on nanoscience and engineering	0	7	8	4	1	0
The activities on nonoscience and engineering made me more interested in learning science/engineering	0	7	6	5	2	0
The session on nanoscience and engineering was boring	0	0	1	3	11	5
I would like to attend a college or university to study nanoscience or engineering	4	5	0	6	5	0
The activities on nanoscience and engineering were too easy	0	0	3	7	10	0
The activities on nanoscience and engineering made me more confident that I can do science/engineering	0	6	9	4	1	0
Doing the activities on nanoscience and engineering made me think that working in a science laboratory would not be an interesting way to earn a living	1	1	2	6	7	3

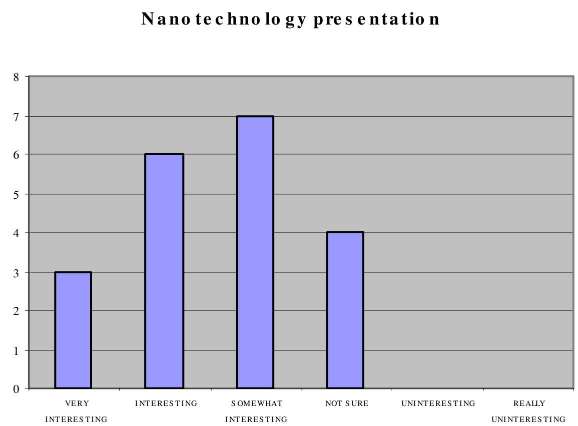
	Very Interesting	Interesting	Somewhat interesting	Not sure	Uninteresting	Really uninteresting
Nanotechnology presentation	3	6	7	4	0	0

	Always clear	Mostly clear	Somewhat clear	Not sure	Mostly unclear	Never clear
The teachers' explanations	6	11	2	1	0	0









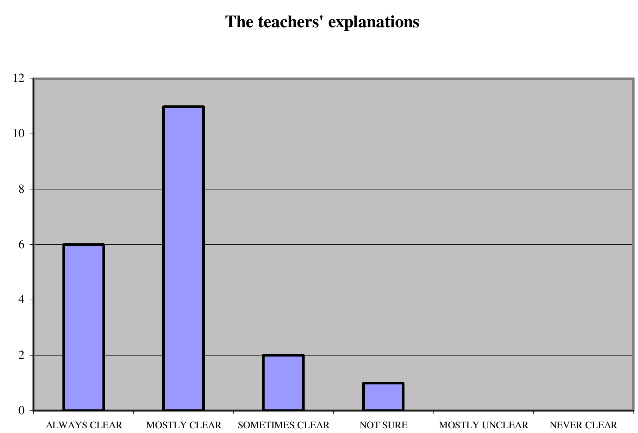


Figure 5 Student post-survey responses: sample charts

Selected Student Comments

"I really enjoyed doing experiments with resistors"

"There are many ways to incorporate nanoscience into jobs and many different ways to create electricity"

"I thought that nanoscience was cool and still is. I think that materials engineering is very interesting"

Conclusions

As an integral part of the Engineering Starters Program, our module on alternate energy sources gives the students an appreciation of the different energy sources and their underlying engineering concepts, challenges and opportunities. It enables them to understand the role of the engineers in developing a cleaner environment. At the end of the day, the excitement of active learning experiences piques the natural curiosity of these bright and talented youngsters and encourages them to investigate a higher education option they may not have otherwise considered.

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