IX.1 Hydrogen Technology and Energy Curriculum (HyTEC)

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- Schatz Energy Research Center, Humboldt State University, Arcata, CA

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Objectives

- Develop, field test, revise, publish, and disseminate three curriculum modules and integrate hydrogen and fuel cells into existing Lawrence Hall of Science (LHS) high school materials.
- Develop and implement a professional development plan for teachers who will use the materials.
- Develop a model for collaboration among school districts, informal science centers, university scientists, local transportation agencies, and other leaders in the field.
- Disseminate the materials to a broad national audience.
- Evaluate the quality and effectiveness of the curriculum materials and professional development strategies.

Technical Barriers

This project addresses the following technical barriers from the Education section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Mixed Messages

(C) Disconnect Between Hydrogen Information and Dissemination Networks

(D) Lack of Educated Trainers and Training Opportunities

(E) Regional Differences

Contribution to Achievement of DOE Education Milestones

This project will contribute to achievement of the following DOE education milestones from the Education section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 29:** Develop modules for high schools. (4Q, 2007)
- **Milestone 30:** Launch high school teacher professional development. (4Q, 2008 through 3Q, 2011)

Accomplishments

- Further revised draft module, with activities correlated to national and state standards and including topics commonly taught in chemistry and environmental science classrooms.
- Improved the design of the kit materials and produced three new sets of student fuel cells and electrolyzers for classroom use.
- Prepared and piloted pre-test and post-test instruments for the curriculum module.
- Developed an educational hydrogen fuel cell simulation that integrates into the curriculum.
- Piloted the video and fuel cell simulation along with the revised curriculum in Berkeley, CA.
- A Stack-in-a-Box® has been produced for use by the Lawrence Hall of Science and in San Francisco Bay area classrooms.

Introduction

This project is producing a curriculum module about hydrogen and fuel cells for high school students. In order to ensure that it will fit into typical high school classrooms, the module addresses topics teachers usually teach and correlates to the National Science Education Standards and/or state and local standards. This project will also investigate students' progress toward the intended learning goals. A group of experienced science

curriculum developers, teacher professional developers, leaders in the field of hydrogen and fuel cell technology and its application to transportation, and the publishers of instructional materials are collaborating to develop commercial educational modules that will fit into high school courses such as physical science, chemistry, environmental science, and physics.

In the past year, work has focused on revising and piloting the curriculum in additional classrooms. This has included piloting the video developed last year and piloting a new online hydrogen fuel cell simulation developed this year.

Approach

The module has been developed through a close collaboration among the partners. LHS and the Schatz Energy Research Center (SERC) work closely with each other and with teacher associates to develop and revise module activities and kit components. Activities were piloted by both SERC and LHS staff in California classrooms. Pilot classrooms to date have included several chemistry classes, one advanced placement chemistry class, and one environmental science class. They also included diverse student populations from three significantly different communities in California. The classes were observed by the regular classroom teachers and project staff from LHS or SERC. The observers provided feedback on the activities. In the most recent pilot, students' classroom work and a pre-test/post-test assessment were also used to gather information on student learning.

The module uses an issue-oriented approach to teaching concepts related to chemistry and energy topics. This approach demonstrates to students the relevance of their science education to their lives and the role of scientists and engineers in solving practical problems. The module begins with an introduction to hydrogen fuel cells for transportation and a comparison of their advantages and disadvantages compared to other options for running a car or bus. Students then learn about hydrogen and fuel cells and return to the advantages of fuel cells and the challenges for the future in a culminating activity.

Results

During the 2006–2007 school year, the project completed a second round of revision and local trial testing of the materials. A set of improved student electrolyzers (shown in Figure 1) and a revised draft of the module were prepared and used in pilot tests in six chemistry classrooms (taught by two different teachers) in Berkeley, California. The pilot module included activities on the following topics: energy and transportation, water electrolysis and the production of hydrogen, using hydrogen fuel cells to lift a weight

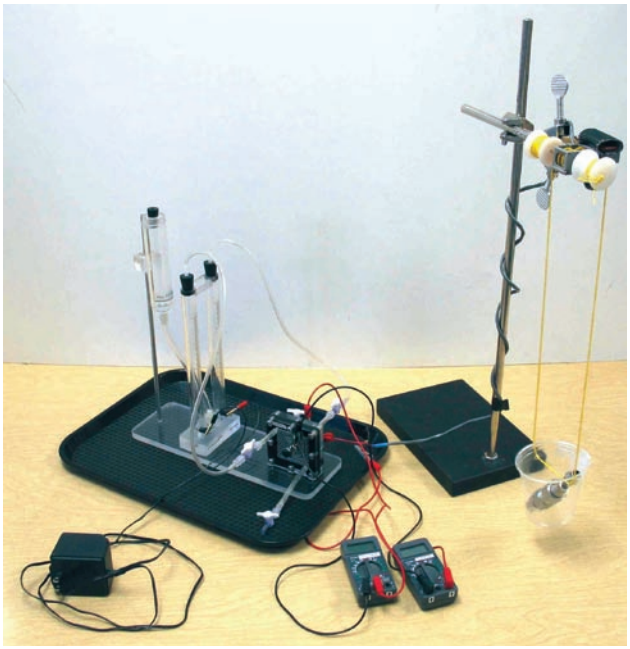

FIGURE 1. Improved Electrolyzers and Fuel Cells Used in 2007 Classroom Trials

or run a fan, calculating the efficiency of the fuel cell, the fuel cell half reactions, fuel cell components and their functions, and hydrogen fuel cell vehicles and a hydrogen economy. It also included the use of a video that presents an introduction to hydrogen and a virtual field trip on a hydrogen fuel cell bus. Figures 2 and 3 show the opening of the introduction and field trip portions of the video. An online web-based simulation of the fuel cell reaction was also piloted along with the curriculum activities. This simulation shows the fuel cell reaction and provides information about the components of the fuel cell and the reactants and products of the reaction.

The pilot was based on improvements made since the previous pilot to improve the kit and the flow of the materials for students, to clarify the written procedures and questions, and to connect the activities to students' lives and interests. A diverse population of approximately 160 students at Berkeley High School participated in the curriculum. Their teachers are positive about the module and its fit in their classrooms and will participate in a workshop this summer at the Lawrence Hall of Science. This workshop will prepare the teachers to use the materials independently in their classrooms. The Emery High teacher who was involved in the 2005–2006 trial testing also plans to use the materials and to attend the training this summer. Arcata High School, which participated in 2005–2006 classroom trials, has funded their own set of equipment.

The project was also presented at meetings of the California Science Teachers Association in San

FIGURE 2. Hydrogen and Fuel Cells Introduction from Video that Accompanies the Curriculum

FIGURE 3. Hydrogen and Fuel Cells Virtual Field Trip from the Video that Accompanies the Curriculum

Francisco in October, 2006 and at the National Science Teachers Association in St. Louis, Missouri, in March, 2007. A total of approximately 90 teachers attended these presentations.

Conclusions and Future Directions

The instructional activities and kit materials developed for the HyTEC module allow students to produce hydrogen and investigate fuel cells and the fuel cell half reactions in the context of chemistry or environmental science classrooms. They introduce students to efforts to develop hydrogen and fuel cells as a viable option for transportation and to some of the challenges that must be overcome to develop a hydrogen economy. Teachers and students are positive about the curriculum and excited by the opportunity to work with the fuel cells and learn about current research and development.

In the future, the module will undergo one more round of revisions and will be presented to additional teachers in Northern California and from additional sites from other regions of the U.S. These teachers will field test the module in a wide variety of classroom settings and provide feedback on its effectiveness. Each teacher will receive a demonstration kit of materials to keep and will be able to check out a complete set of eight electrolyzers and fuel cells for students to use in groups of four. The Stack-in-a-Box® fuel cell stack will be demonstrated in classrooms using the curriculum in the San Francisco Bay area through outreach visits from the Lawrence Hall of Science. A pre- and post-test developed during piloting will be used to assess student learning. A workshop has been submitted for presentation at the 2008 Annual National Science Teachers National Convention.

The web-based fuel cell simulation will undergo minor revisions and will be integrated into an educational website, to be developed and linked to the Science Education for Public Understanding Program (SEPUP)/Lawrence Hall of Science website, to support the curriculum. The additional funding received recently will also be used to explore commercialization of the kit and curriculum materials.

FY 2007 Publications/Presentations

1. Zoellick, Jim, "Hydrogen Technology and Energy Curriculum (HyTEC)," presentation to the 2007 DOE Hydrogen Program Review," May 18, 2007.

2. Nagle, B., and Zoellick, J. "Teaching Chemistry with Hydrogen Fuel Cells," California Science Teacher's Association Conference, October 21, 2006, San Francisco, CA.

3. Nagle, B. "Teaching Chemistry with Hydrogen Fuel Cells," National Science Teacher's Association Conference, March 31, 2007, St. Louis, MO.