IX.6 Hydrogen Technology and Energy Curriculum (HyTEC)

Barbara Nagle
University of California, Berkeley
Lawrence Hall of Science #5200 (LHS)
Centennial Drive
Berkeley, CA 94720-5200
Phone: (510) 642-8718; Fax: (510) 642-3131
E-mail: bnagle@berkeley.edu

DOE Technology Development Manager:
Christy Cooper
Phone: (202) 586-1885; Fax: (202) 586-2373
E-mail: Christy.Cooper@ee.doe.gov

DOE Project Officer: Reginald Tyler
Phone: (303) 275-4929; Fax: (303) 275-4753
E-mail: Reginald.Tyler@go.doe.gov

Contract Number: DE-FG36-04-GO14277

Subcontractor:
Schatz Energy Research Center,
Humboldt State University, Arcata, CA

Project Start Date: September 1, 2004
Project End Date: February 28, 2012

Objectives

- Develop, field test, revise, publish, and disseminate three curriculum modules and integrate hydrogen and fuel cells into existing 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 (3.9.5) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Lack of Readily Available, Objective, and Technically Accurate Information

(C) Disconnect Between Hydrogen Information and Dissemination Networks

(D) Lack of Educated Trainers and Training Opportunities

(E) Regional Differences

(F) Difficulty of Measuring Success

Contribution to Achievement of DOE Education Milestones

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

- **Milestone 26:** Develop modules for high schools. (4Q, 2007)
- **Milestone 27:** Launch high school teacher professional development. (4Q, 2008 through 3Q, 2011)

Accomplishments

- Three high school teachers–two in the San Francisco Bay Area and one in Bellevue, Washington–field tested the curriculum module in their classrooms.
- The curriculum materials were revised significantly based on classroom trials, scientific review, and input from teachers.
- Teacher professional development workshops were developed and delivered to a total of 20 high school teachers in Berkeley in July, 2007 and June, 2008.
- Development of teacher leaders for dissemination of the curriculum was initiated.
- The first phase of development of a Web site that supports the curriculum implementation and dissemination was completed.
- Three presentations were made to educators and hydrogen and fuel cell professionals.
- A HyTEC teacher associate and four of her students who field-tested the curriculum represented the U.S. at the Hydrogen and Fuel Cell Education Forum held during the World Hydrogen Energy Conference.

Introduction

This project is producing a curriculum module about hydrogen and fuel cells for high school students. 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 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 is also developing professional development workshops to prepare teachers to teach the curriculum and develop teacher leaders. Project evaluation focuses on investigating students' progress toward the intended learning goals and evaluating the professional development workshops.

In the past year, work has focused on gearing up for a national field test during the 2008–2009 school year by finalizing the activity sequence in the curriculum module and providing professional development and additional support for teachers who will teach the module during national field-testing. This has included revising and enhancing the student pages, teachers guide, and kit for the curriculum, developing and refining a teacher professional development workshop, and developing a Web site to support students and teachers using the curriculum.

Approach

The curriculum materials are developed and revised through a close collaboration between curriculum developers at the LHS, scientists and engineers at the Schatz Energy Research Center (SERC), experienced teacher associates, and local and national field test teachers. They are first tested by LHS and SERC staff, then by expert teachers, and finally by a broader group of teachers from California and national sites. 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.

Teachers who field-test the curriculum receive extensive professional development before they use the materials. This prepares them to give thorough feedback on the curriculum and serves as the foundation for development of future professional development activities. These early professional development workshops for field-test teachers also identify teachers who will assist with dissemination and implementation of the published curriculum.

Results

The curriculum module addresses Education Technical Barriers A and C by providing information about hydrogen and fuel cells in a curriculum format that is usable by teachers and students in typical classrooms and building on the dissemination networks of the LHS and partners. Curriculum activities were revised based on the previous year's classroom testing. These revisions included a new activity sequence and culminating activity for students and addition of extensive teacher background and support for instruction to the Teacher's Guide. Eight complete classroom kits with eight laboratory setups per kit were also produced for next year's testing of the curriculum. The six activities in the module are:

1. Energy for Transportation: Students examine data and analyze trade-offs of various vehicle/fuel combinations to set a context for the activities.
2 Obtaining Hydrogen through Electrolysis: Students generate hydrogen and examine the required energy input, stoichiometry, and electrochemistry involved in the process.
3. Putting a Hydrogen Fuel Cell to Work: Students generate H_2 and O_2, and use a single cell fuel cell to perform work.
4. Modeling a Fuel Cell Redox Reaction: Students use model pieces and a fuel cell simulation to explore the fuel cell reaction.
5. Fuel Cell Efficiency: Students measure fuel cell efficiency.
6. Hydrogen for Transportation: Students conduct research and engage in a simulated City Council Meeting to apply what they have learned and present the advantages and challenges of using hydrogen and fuel cells for a city bus program.

During the 2007–2008 school year, three teachers tested the curriculum in their classrooms, with no assistance from LHS or SERC. Two of the teachers (at Berkeley High School and Emery High School in the San Francisco East Bay) taught the materials in chemistry classes, while the third (at Robinswood High School in Bellevue, Washington) taught the curriculum in an AP Environmental Science class. These teachers provided feedback to the project about the curriculum activities and the kit.

Two teacher professional development workshops were conducted at the LHS in Berkeley. Teacher leaders who have worked on the curriculum and staff from LHS and SERC lead the workshop sessions. The workshops address Education Technical Barriers C and D by providing teachers with an in-depth professional development experience on the science of hydrogen and fuel cells, applications of fuel cells, and the use of the curriculum. A small pilot workshop was held on July

30–31, 2007. Participants provided feedback that led to a revision of the workshop agenda and the decision to expand from two days to three. The second workshop was held on June 24–26, 2008. Fifteen participants included 12 high school teachers from the San Francisco Bay Area, 2 high school teachers from Dublin, Ohio, and a summer intern from Lawrence Berkeley Laboratory. Participants conducted the curriculum activities and explored the equipment (see Figure 1), heard scientific presentations and participated in question and answer sessions with workshop leaders, and went on a half-day field trip to AC Transit (see Figure 2). The field trip included presentations from AC Transit on their hydrogen and fuel cell bus program, observations of the hydrogen fuel cell bus and fueling station, and an opportunity for participants to drive a hydrogen fuel cell car. In the workshop evaluation, participants ranked aspects of the professional development workshop on a scale from 1 (not adequate) to 5 (excellent). The results of the workshop evaluation are presented in Table 1.

FIGURE 1. Teachers Conduct a HyTEC Curriculum Activity

FIGURE 2. Teacher Field Trip to AC Transit

Teacher leaders working with the project will contribute to future conference presentations. Laura Baumgartner, the teacher who participated in both workshops as an activity leader, took a group of four students to represent the United States at the Hydrogen and Fuel Cell Education Forum held during the World Hydrogen Energy Conference. She also contributed to a workshop for 50 teachers at the National Science Teachers Association annual meeting in 2008.

The first phase of the project Web site (www.sepuplhs.org/hytec) was completed in June, 2008. The home page of the Web site is shown in Figure 3. For classrooms using the curriculum, the site provides clips

TABLE 1. Professional Development Evaluations

Aspect of conference	Score (out of 5)
Curriculum activities	4.4
Activity presentations	4.7
Scientific presentations	4.9
Field trip to AC Transit	4.7
Schedule	4.9
Conference arrangements	5.0
Comparison to other workshops*	4.7

* The question asked: Compared to other workshops and professional development sessions I have attended, overall I would rank this one as. . .

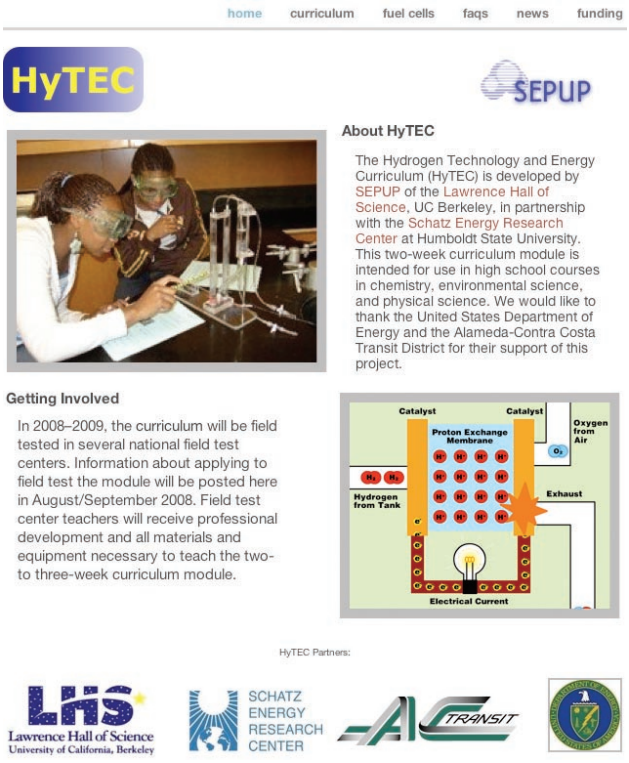

FIGURE 3. HyTEC Project Web Site

from a video field trip that illustrates hydrogen and fuel cell applications and the fuel cell simulation developed with the previous year's funding. The video and simulation are integral to the curriculum. The site also provides answers to Frequently Asked Questions about hydrogen and fuel cells and Project News, as well as information about the curriculum and project partners. Although the primary purpose of the site is to support the curriculum implementation and dissemination, the site is available to the general public as well.

Conclusions and Future Directions

Conclusions:

- The instructional materials and kit can be used by high school teachers working independently in their classrooms. Students and teachers continue to be enthusiastic about these materials.
- The professional development workshop provides teachers with scientific and technical background and experiences that prepare them to use the curriculum activities and equipment for classroom instruction. In evaluations of the workshop, teachers rated the workshop 4.7 out of 5 in comparison to other workshops and professional development sessions they have attended.

Future work will focus on:

- Professional development for teachers and curriculum trials in national field-test sites that will test the curriculum and provide feedback during the 2008–2009 school year. This will help to address Technical Barrier E, regional differences, as we fine-tune the curriculum and professional development workshops.
- Commercialization of the print materials and kit for the curriculum module.
- Evaluation of student learning in field test classrooms.
- Expansion of support for teachers in the curriculum Teacher's Guide and on the HyTEC website.
- Dissemination of the curriculum by project staff and teacher leaders.

FY 2008 Publications/Presentations

1. L. Baumgartner and B. Nagle. "Teaching Chemistry with Hydrogen Fuel Cells," National Science Teacher's Association Conference, March 28, 2008, Boston, Massachusetts.

2. B. Nagle, J. Zoellick, and P. Lehman. "Hydrogen Technology and Energy Curriculum (HyTEC) for High School Science," National Hydrogen Association Conference, March 31, 2008, Sacramento, California.

3. L. Baumgartner. "Teaching with Hydrogen and Fuel Cells," Hydrogen and Fuel Cell Education Forum held at the World Hydrogen Energy Conference, June 18, 2008, Brisbane, Australia.