X.5 Hydrogen Education Curriculum Path at Michigan Technological University

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Objectives

The objectives of this project are to educate university students on the advantages, disadvantages, challenges, and opportunities of hydrogen and hydrogen fuel cells within the United States energy economy. In particular, this project will:

- Develop and/or refine courses in hydrogen technology.
- Develop curriculum programs in hydrogen technology.
- Develop modules for core and elective engineering courses.
- Develop modules to supplement commonly used chemical engineering texts.

Technical Barriers

This project addresses the following technical barriers from the Education section (3.9) 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

(B) Mixed Messages

(C) Disconnect Between Information and Dissemination Networks

Contribution to Achievement of DOE Education Milestones

This project will contribute to achievement of the following DOE milestones from the Education section (3.9) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 21: Launch new university hydrogen education program. (4Q, 2009)

Accomplishments

The major accomplishments of this project to date are listed below:

- We have developed and taught one lecture and one laboratory course in hydrogen energy and two courses in fuel cells.
- Effective April 2009, students can receive an "Interdisciplinary Minor in Hydrogen Technology." The minor includes the elective courses mentioned above and project work in the alternative fuels group enterprise.
- The elective courses are also a component of the "Graduate Certificate in Hybrid and Electric Vehicles" approved May 2010.
- Nearly three dozen modules have been developed to introduce students in core chemical engineering courses to hydrogen and fuel cell technology; similar efforts are underway for mechanical and electrical engineering courses.
- Ninety example problems have been created as supplementary material to be used in the sophomore level introductory chemical engineering course.
- Over the entire project, eight oral presentations have been given and five conference proceedings have been published, with five oral presentations and four conference proceedings during the past year.

Introduction

There is a strong need for a transformative curriculum to train the next generation of engineers who will help design, construct, and operate fuel cell vehicles and the associated hydrogen fueling infrastructure. In

this project, we build upon the project-based, hands-on learning that has been a cornerstone of engineering education at MTU. This teaching and learning style is supported by the engineering education literature which indicates that students learn by doing, particularly through team-based interactive projects with a real-world flavor.

This project has resulted in the formation of an "Interdisciplinary Minor in Hydrogen Technology" at MTU. We focus on student centered design projects, and add additional technical material through elective courses, modules for core courses, and textbook supplements. As a final note, aggressive dissemination of the project results will occur through presentations at the annual meetings of several professional societies.

Approach

The ultimate goal for the hydrogen education program should be to establish an educational infrastructure and database of hydrogen and fuel cell related educational materials, particularly projects and problem sets. The efforts of this project support this mission.

At MTU, we have embraced the concept of hands-on learning as the cornerstone of a newly approved "Interdisciplinary Minor in Hydrogen Technology." Students that obtain this minor are also required to take newly developed elective courses in fuel cells and hydrogen technology. Focusing on a subset of graduates who choose these options is not enough. In order to reach a wider audience at MTU, modules are being developed for the core curricula in chemical engineering, mechanical engineering, and electrical engineering. Each module stands alone and can be assigned to students as an in-class problem, a homework assignment, or a project. The modules use the fundamental concepts taught within the core course and apply them to hydrogen generation, distribution, storage, or use within a fuel cell. Thus, students are able to see the applications of the fundamentals from their courses. Finally, we are creating supplements to two of the most popular chemical engineering textbooks as another way to introduce hydrogen technology and fuel cells to university students.

The core course modules are to be tested throughout the nation. The results of this curriculum project and testing results are to be disseminated through professional societies in chemical engineering, mechanical engineering, electrical engineering, and engineering education. Course materials, modules, and textbook supplements will be available for use by engineering educators worldwide.

Results

Results for Task 1.0, Develop and/or refine courses in hydrogen technology:

- To date, we have created two new courses, "Fundamentals of Hydrogen as an Energy Carrier" to be taught in fall semesters and "Hydrogen Measurements Laboratory" to be taught in spring semesters (Figure 1). The courses have been taught during the most recent academic year and were well received by students.

Results for Task 2.0, Develop curriculum programs in hydrogen technology:

- The "Interdisciplinary Minor in Hydrogen Technology" was approved by the university effective April 2009.
- The "Graduate Certificate in Hybrid and Electric Vehicles" was approved by the university effective May 2010.
- During the 2009-2010 academic year, there were several group projects in the "Alternative Fuels Group" Enterprise. This Enterprise consisted of undergraduate students in chemical, mechanical, and electrical engineering, as well as materials science and engineering. Students were in their sophomore, junior, or senior year of study. By participating in the group projects, students earned credit towards their degree and (if desired) towards the new minor mentioned above. Student projects included:
  - Hydrogen Student Design Contest (Figure 2)
  - Combined Heat and Power from a Fuel Cell
  - Carbon Dioxide Sequestration from a Large-Scale Hydrogen Production Plant

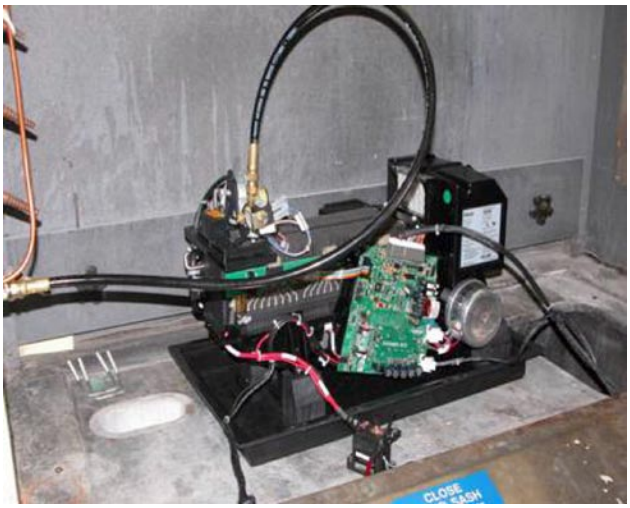

FIGURE 1. 1.2 kW Hydrogen Fuel Cell used in Hydrogen Measurements Laboratory Course

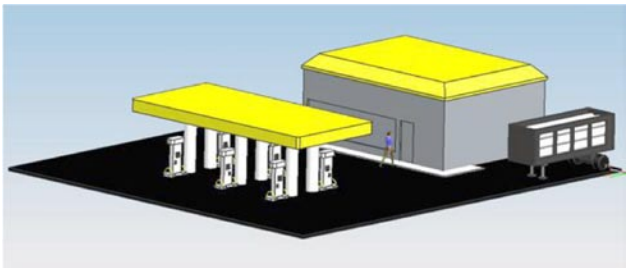

FIGURE 2. Hydrogen filling station and convenience store designed by Alternative Fuels Group students.

  - Alternative Energy Cabin
  - Wind Energy and Hydrogen Generation First Year Curriculum

Results for Task 3.0, Develop modules for core and elective engineering courses:

- The third task of this project is to develop modules for core courses in chemical, mechanical, and electrical engineering courses. Up to this point, nearly three dozen chemical engineering modules and one dozen mechanical engineering modules have been developed. It is noted that the modules are available online at: http://www.chem.mtu.edu/~jmkeith/fuel_cell_curriculum/.

Results for Task 4.0, Develop modules to supplement commonly used chemical engineering texts:

- We have developed a set of 90 examples to supplement the textbook *Elementary Principles of Chemical Processes* authored by R. M. Felder and R. W. Rousseau and published by Wiley. The problems are organized in "workbook" format where there are blank spaces for students to insert numbers in order to carry out the solutions. It is noted that this textbook is used in the very first chemical engineering undergraduate course at most universities in the nation. The main emphasis of the course is on engineering problem solving for chemical engineers. Students learn best by solving a large number of problems. This supplement is intended to meet the student's needs while teaching them about hydrogen technology and fuel cells.

Conclusions and Future Directions

The most significant result of this project to date is the approval of a new minor at MTU with title "Interdisciplinary Minor in Hydrogen Technology." The groundwork is in place to teach new courses in hydrogen and fuel cell technology and to introduce these concepts in the core chemical engineering curriculum at MTU.

Future work will include the following:

- Future work for Task 1.0, Develop and/or refine courses in hydrogen technology: Continue to teach hydrogen and fuel cell courses, while improving curriculum material.
- Future work for Task 3.0, Develop modules for core and elective engineering courses: Continue to develop modules for core courses in mechanical engineering and electrical engineering curricula; test chemical engineering modules at MTU and other national universities.
- Future work for Task 4.0, Develop modules to supplement commonly used chemical engineering texts: Test supplementary material for Felder & Rousseau textbook; continue development of supplementary material for Geankoplis textbook (Transport Processes and Separation Process Principles, published by Prentice Hall, for junior chemical engineering courses).

Special Recognitions & Awards/Patents Issued

1. Jason Keith was named by MTU as the 2010 recipient of the Frederick D. Williams Instructional Innovation Award in recognition of using active learning in his courses and in leadership in the development of modules for hydrogen and fuel cell education.

FY 2010 Publications/Presentations

1. Oral Presentation & Conference Proceeding: A. Mukherjee, J.M. Keith, D. Crowl, D. Caspary, J. Allen, D. Meng, J. Naber, J. Lukowski, J. Meldrum, and B. Solomon, "Fuel Cells and Hydrogen Education at Michigan Technological University," International Fuel Cell Science, Engineering & Technology Conference, June 2010.

2. Oral Presentation & Conference Proceeding:. J.M. Keith, D. Crowl, D. Caspary, J. Allen, D. Meng, A. Mukherjee, J. Naber, J. Lukowski, J. Meldrum, and B. Solomon, "Interdisciplinary Minor in Hydrogen Technology at Michigan Technological University," ASEE Conference Proceedings, June 2010.

3. Oral Presentation & Conference Proceeding: D. Blekhman, J.M. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, H. Salehfar, "National Hydrogen and Fuel Cell Education Program Part I: Curriculum," ASEE Conference Proceedings, June 2010.

4. Oral Presentation & Conference Proceeding: D. Blekhman, J.M. Keith, A. Sleiti, E. Cashman, P. Lehman, R. Engel, M. Mann, H. Salehfar, "National Hydrogen and Fuel Cell Education Program Part II: Laboratory Practicum," ASEE Conference Proceedings, June 2010.

5. Oral Presentation: J.M. Keith, D. Crowl, D. Caspary, J. Allen, D. Meng, A. Mukherjee, J. Naber, J. Lukowski, J. Meldrum, and B. Solomon, "Hydrogen Education Curriculum at Michigan Technological University," 2009 AIChE Annual Meeting, Nashville, TN.