GETTING STUDENTS TO THINK ABOUT ALTERNATE ENERGY SOURCES

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Abstract

The College of Engineering at Rowan University was initiated as a result of a $100 million donation in 1992 from the Rowan Foundation. The engineering faculty use innovative methods of teaching and learning to better prepare students for entry into a rapidly changing and highly competitive marketplace. To best meet these objectives, the four engineering programs of Chemical, Civil and Environmental, Electrical and Computer, and Mechanical Engineering have common engineering clinic classes throughout their programs of study, in which undergraduates work in teams on hands-on open-ended projects. The primary goal of Rowan University's engineering clinic classes is to involve students in multidisciplinary design/research projects that teach engineering principles in both laboratory and real-world settings. The clinics further encourage students to address environmentally conscious design and issues related to sustainable development. The Sophomore Clinic students work on a semester-long design project every year. Faculty drawn from all engineering disciplines teach the course. The design project for Fall of 2001 was to design, build and test a semi-autonomous robot that uses power provided by batteries charged up with microorganisms. This project allowed students to focus on alternate energy sources such as biofuels. Biofuels are alcohols, ethers, esters, and other chemicals made from cellulosic biomass such as herbaceous and woody plants, agricultural and forestry residues, and a large portion of municipal solid and industrial waste. The term biofuels can refer to fuels for electricity and fuels for transportation. Biofuels are good for the environment because they add fewer emissions to the atmosphere than petroleum fuels and use wastes that currently have no use. Biofuels are renewable and an inexhaustible source of fuel unlike petroleum which is non-renewable. This paper focuses on how this project encouraged engineering students to think about alternate environmentally friendly sources of energy.

Introduction

Multidisciplinary design projects are an integral part of the Rowan Engineering curriculum. The innovative Rowan Engineering curriculum allows all engineering students to work on a design project as early as their sophomore years through the engineering clinic courses. The Rowan Engineering clinics have been well documented in recent years[1-5]. The Sophomore Clinic focuses mainly on the *design build* and *test* theme. The course has been enhanced by the integration of technical writing taught by a team of faculty from the College of Communications. The composition component presents critical thinking, reading, writing, research and augmentation. The two major goals of the Sophomore Engineering Clinic are to provide the foundation required for engineering students to become:

- Creative, competent designers, and
- Effective communicators.

The overall objectives (both for technical communication and engineering design) as listed in the course syllabus are as follows:

Technical Communication

- *Summarize* and *paraphrase* text.
- *Analyze*, *evaluate*, and *synthesize* multiple sources.
- *Research* thoroughly a complex, college-level subject
- *Analyze* a communication situation and *respond* effectively within its parameters.
- *Communicate* technical information clearly and concisely.
- *Interpret* technical information for various audiences.
- *Produce* properly formatted and edited documents.
- *Integrate* graphics and text.

Design

- *Recognize* the need, *identify* the customer, *assess* the market and *define* the constraints for a design problem.
- *Develop* engineering specifications for a "quality" design.
- *Generate* multiple engineering design solutions using various brainstorming techniques.
- *Choose* the best solution.

- *Evaluate* and *benchmark* team design.

The course was team taught by five engineering and two communications faculty. Engineering faculty represented all four disciplines namely Civil and Environmental, Chemical, Electrical and Computer and Mechanical Engineering. The course is 4.0 credits, which includes both the communications and engineering parts. The course web pages are located at http://engineering.eng.rowan.edu/~vonlocke/soph_clinic_F01.

Design Project for Fall 2001

The design project for Fall 2001 for the Sophomore Engineering Clinic was to design, build and test a semi-autonomous robot (Lego Mindstorms ^{TM} System 2.0 Kit) that used power provided by batteries charged with electricity generation using microbes. The entire class was divided into teams of 5/6 students. Each team further was grouped into subteams for carrying out the following major tasks:

- Develop code to navigate the robot through a given maze
- Design a biofuel cell capable of powering 6 1.5V batteries to power the robot
- Machine and fabricate the biofuel cell

This paper focuses mainly on activities focusing on the design and testing of the biofuel cell. Electrical activity of microbes is an interesting topic and leads into the topic of alternate energy sources. Most engineering programs are integrating green engineering and sustainable development topics throughout their curriculum. This project allowed all sophomore-engineering students to focus on alternate energy sources and sustainable technology.

Research in microbial fuel technology (MFC) has been gaining popularity within the past decade or so worldwide. MFCs can use various types of microorganisms for metabolism of various organic materials. The organic materials include agricultural, industrial and residential wastes. Microbial electrochemistry provides immense opportunities for promoting multidisciplinary approaches in engineering education. Benetto[6-8] developed simple and advanced experiments to demonstrate microbial generation of electricity. A simple microbial fuel cell costing less than £50 is available from the National Center for Biotechnology Education at the University of Reading. Each biofuel subteam was provided with such a fuel cell at the start of the semester to

investigate the effect of experimental variables on the performance of the fuel cell. The microbial fuel cell used by the students is illustrated in Figures 1 and 2. These illustrations are available on the internet at http://www.ncbe.reading.ac.uk/NCBE/MATERIALS/menu.html.

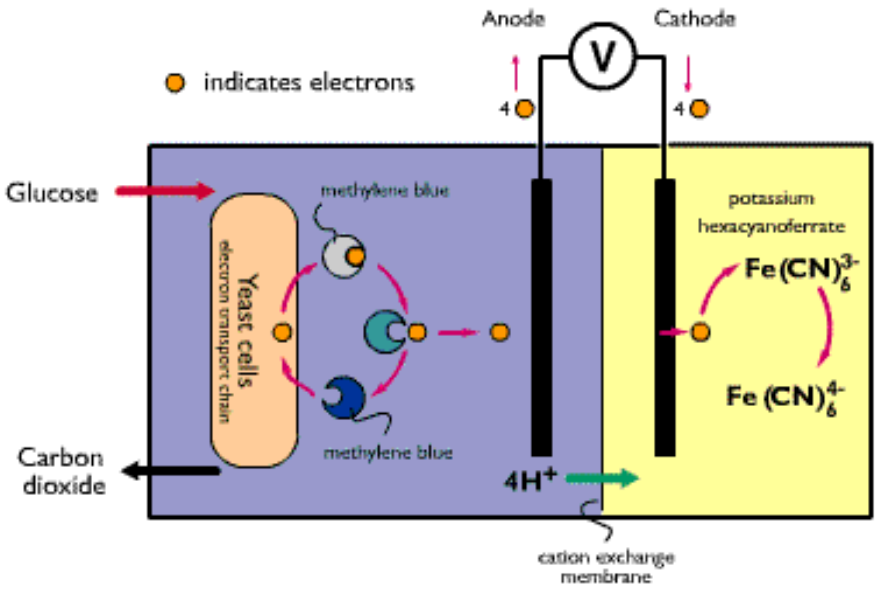

Figure 1: Microbial Fuel Cell Schematic

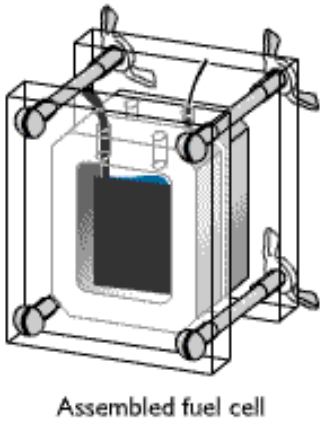

Figure 2: Assembled Fuel Cell

(National Center for Biotechnology Education, University of Reading, U.K.)

Students' tasks and deliverables identified and carried out throughout the semester are outlined in Table 1. Each team was also required to submit a design proposal and a final report as written deliverables. Student presentations were made in poster format by each team. Written deliverables were graded by all faculty from engineering and communications.

Table 1: Course Schedule with Deliverables

Week	***Laboratory***	***Deliverables***
1	Labor Day – no class	
2	Introduction to faculty team Introduction to design project • Robot demonstration Fuel cell demonstration	
3	Team formation Introduction to design Safety	
4	Introduction to sustainable technology and fuel cell design Build prototype fuel cell	
5	Introduction to robotics Build prototype robot	
6	Work on prototype fuel cell and robot	Demonstrate prototype fuel cell and robot
7	Brainstorming time • Develop ideas for robot design • Develop ideas for fuel cell design • Develop test / assessment plan for fuel cell	Show candidate designs to faculty
8	Fuel cell / robot fabrication	
9	Fuel cell / robot fabrication	Design proposal due
10	Midterm presentations	Midterm progress report
11	Engineering economics Fuel cell / robot fabrication	Design proposal revisions due
12	Fuel cell / robot fabrication and testing	
13	Fuel cell / robot fabrication and testing	Draft of fuel cell test report
14	Battery charging and final testing for the Big Event	Finished fuel cells
15	THE BIG EVENT- Robot rally	Finished robot and maze Charged batteries Final report

As evident from Table 1, students had to focus on the following issues relevant to their biofuel cell design:

- Design Constraints (e.g., material availability, size of membranes and carbon fiber material)
- Costs (Material, Chemical Costs)
- Time (Machining and Fabrication Time)
- Safety

Impact of the Design Project

The biofuel cell project generated much enthusiasm and was able to capture the attention of the engineering students irrespective of their major in engineering. Students were exposed to core scientific principles from their chemistry, physics and biology classes. They were able to understand the application of basic scientific principles to bioengineering or biotechnology-a very exciting new field in engineering. Furthermore this design project reinforced engineering measurements and experimental design. Basic electrical measurements (voltage, current, power) using data acquisition systems was an integral part of the project. Students also had to focus on fundamentals of microbial metabolism, electrochemistry and redox reactions-all important topics in engineering. Computer skills in word processing, spreadsheets and computer-aided design were also a major requirement. Multidisciplinary teams allowed students to utilize their skills and maximize team output. The course also allows students to understand the importance of technical writing an integral part of engineering.

Some of the course challenges included having adequate resources and materials available for biofuel design and testing throughout the semester. Plexiglass used for construction of the biofuel cell incurred high costs. These issues can be resolved with better planning in the future. Providing students with cost constraints in the future may also prove to be beneficial. Course assessment results indicate that the students found the project to be stimulating and interesting. Students liked the multidisciplinary nature of their design project where each student could lend his or her discipline specific expertise. However there were concerns voiced about the time

available, workload allocation versus course credits and the overall ambitious scope of the project.

Conclusions

The microbial fuel cell project was successful in integrating multidisciplinary topics in science and engineering for a multidisciplinary group of students. Integrating technical writing as part of the project made it more realistic and meaningful. The project also helped reinforce issues about the need for research on alternative fuel and energy sources.

Acknowledgement

We gratefully acknowledge the support of the College of Engineering at Rowan University for funding the clinic project. We would like to offer our sincere appreciation to the technicians of the College of Engineering for their overwhelming support. Special thanks to Fan Lau, an undergraduate of the Department of Agricultural and Biological Engineering for developing the project as part of an NSF REU experience at Rowan University.

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Biography

Kauser Jahan
Kauser Jahan is an Associate Professor of Civil and Environmental Engineering at Rowan University, Glassboro, New Jersey. She completed her Ph.D. studies in the Department of Civil and Environmental Engineering at the University of Minnesota, Minneapolis in 1993. Dr. Jahan is a registered Professional Civil Engineer in Nevada and is actively involved in environmental engineering education and outreach for women in engineering. Her research interests include biodegradation of petroleum compounds and surfactant enhanced remediation of slightly soluble organic compounds.

Dr. Linda Head

Dr. Linda Head is an Associate Professor in the Department of Electrical and Computer Engineering at Rowan University. She holds an appointment as a Guest Researcher at the National Institute of Standards and Technology (NIST) in the Semiconductor Electronics Division. Her collaboration with scientists and engineers at has led to improvement in industry standards for accelerated testing of VLSI interconnect materials and to new techniques for extracting dimensional parameters of the interconnects from electrical measurements. Dr. Head is also the SWE Faculty advisor at Rowan University.

Dr. Kathryn Hollar
Dr. Hollar recently joined the chemical engineering faculty at Rowan University as an Assistant Professor. She received her Ph.D. from Cornell University. Dr. Hollar has been exposed to a wide variety of systems in biochemical engineering, from thermoacidophilic bacteria to plant and animal cell culture, and is interested in applying her expertise to developing methods for cost-effective pharmaceutical production and bioremediation.

Eric Constans
Dr. Constans is an Assistant Professor in Mechanical Engineering at Rowan University. He received his Ph.D. from Pennsylvania State University. Dr. Constans has taught Mechanical Design and Synthesis, Vibration and Machine Design. He is currently serving as coordinator for Sophomore Clinic. His current research interests include the study of smart elastomeric materials and Genetic Algorithms.

Paris R. von Lockette
Dr. von Lockette is an Assistant Professor in Mechanical Engineering at Rowan University. He received his Ph.D. from University of Michigan at Ann Arbor. Dr. von Lockette's primary work focuses on uncovering the relationships between the microstructure of elastomers and polymers and their microscopic behavior. Dr. von Lockette's forte is the construction of computational simulations of the gelation (network formation) process in macromolecular materials. He also constructs constitutive and optical models to predict material behavior.

Fan Lau
Fan Lau is currently a senior in Agricultural and Biological Engineering at Cornell University. She developed the biofuel cell module as part of her NSF REU experience at Rowan University in the summer of 2001.