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Biodiesel production, characterization, and performance: A hands-on project for first-year students

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ABSTRACT

Biodiesel fuel production and use has been used as the focal point of a semester-long, project-based introductory engineering course at Rowan University. Students worked in teams to conduct a series of laboratory investigations through which they explored the engineering aspects of biodiesel production and purification, properties characterization, quality control and performance testing. The experiments were designed to be cost–effective and transferrable.

The laboratory experiments were conducted within the How People Learn framework. An assessment instrument was used as a pre- and post-evaluation method to assess learning outcomes. Students' gained significantly in learning outcomes areas related to the application of mathematics, science and engineering principles; designing and conducting experiments; analyzing and interpreting experimental data, and solving engineering problems.

Keywords: First year project; Biodiesel; Sustainability

1. Introduction

Foremost among the Grand Challenges for the 21st Century set forth by the (United States) National Academy of Engineering (2008) are those that are essential to ensuring the future itself: the development of new sources of energy and simultaneously preventing the degradation of the environment. As climate change and depletion of fossil fuel resources have emerged as critical issues. the concepts of sustainability and life cycle thinking entered mainstream consciousness and have become priority issues for global corporations. Engineers play an important role in the development of alternative energy technologies that have the potential to contribute to a sustainable future. In this context, biodiesel fuel has been used as the focal point of a semester-long, project-based introductory engineering course at Rowan University.

Rowan University has pioneered a progressive Engineering program that uses innovative methods of teaching and learning to produce students who have the competencies to operate successfully in a dynamic and competitive global environment. Key features of the program include: (1) multidisciplinary education through collaborative laboratory and course work; (2) teamwork as the necessary framework for solving complex problems; (3) incorporation of state-of-the-art technologies throughout the curricula; and (4) creation of continuous opportunities for technical communication (Rowan, 1995). The Rowan program emphasizes these essential features throughout the curriculum, beginning with the first year engineering course, Freshman Engineering Clinic. One indicator of the success of our innovative program is the 88.4% retention rate of our entering first year students in the College of Engineering. This compares very favorably with first year retention rates for science and engineering students in the United States which average about 67% (CIDEA, 2002). Rowan's two-semester Freshman Engineering Clinic sequence introduces all freshmen engineering students to engineering in a hands-on, project-based learning environment. The two-credit course has one 50 min classroom meeting and one 3 h

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laboratory meeting each week. The classroom activities are structured to support the learning objectives of the project and the overall course objectives.

Integration of sustainability into the chemical engineering curriculum has received increasing attention in recent years. IChemE, Engineers Australia, and ABET now explicity include skills and knowledge related to sustainability within the requisite attributes and learning outcomes of a chemical engineer in their accreditation guidelines (ABET, 2012; Bradley, 2010; IChemE, 2012). Chemical Engineering programs have employed innovative strategies to integrate sustainability concepts throughout their curricula (Glassey and Hailey, 2012; Othman et al., 2012). Hesketh et al. (2004) describe a program to integrate green engineering throughout the curriculum at Rowan University, and Slater and Hesketh (2004) present a green engineering module that integrates sustainability concepts into a material and energy balances course. This paper describes a hands-on project based on biodiesel production and use that was used to integrate sustainability concepts into our first year introductory engineering course at Rowan University.

2. Course context

This project is integrated into the second semester of Rowan's Freshman Engineering Clinic. Freshman Engineering Clinic is a two-semester, hands-on, project-based course that introduces students to engineering principles. This required course has one 50-min classroom meeting and one 3-h laboratory meeting each week. Multiple sections of the course are taught, each having a project chosen at the discretion of the instructor. Engineering economics, statistics, intellectual property and ethics are topics common to all sections of the course. These topics are introduced through class-room based experiences and reinforced through a hands-on project. Each section of the course also has technical learning objectives that are addressed in the context of the project. Previous projects include the reverse engineering of common household products such as automatic coffee makers (Hesketh and Slater, 1997), hair dryers and electric toothbrushes (Ramachandran et al., 1999); beer brewing has been used to introduce unit operations and design of chemical processes (Farrell et al., 2001), and the human body has been used as a framework for exploring living systems and biomedical topics (Mosto et al., 2007). The biodiesel project described in this paper was developed to enhance our Department's recent efforts to integrate sustainability and life cycle thinking in the context of chemical processes and products throughout the chemical engineering curriculum.

Through a series of laboratory experiments students explore the engineering aspects of biodiesel production and purification, properties characterization, quality control and performance and emissions testing. Throughout the course, the hands on experiments are complimented by several in-class activities and out-of-class assignments that connect the bench-scale experiments with full scale production and explore ethics, policy, and contemporary issues in the context of biofuels. This paper focuses specifically on the hands-on learning modules that provide the framework for the entire semester-long course.

At the beginning of the 16-week course, students are challenged to compare the environmental impact of biodiesel to fossil diesel. After an introduction to the principles and tools for life cycle assessment (LCA), students set out to collect data necessary to develop the life cycle inventory (LCI) needed to compare the environmental impact of the two fuels. This provides the framework for a series of hands-on experiments in which students produce biodiesel, perform quality testing, and compare the properties and performance to that of fossil diesel. The LCA modules are described in detail elsewhere (Farrell and Cavanagh, 2013). At the end of the project, students should be able to do the following at a level appropriate for first year students: apply knowledge of mathematics, science and engineering; design and conduct experiments; analyze and interpret experimental data; design a chemical process to meet a need; and identify, formulate and solve engineering problems. These outcomes map to ABET criterion 3, outsomes A, B, C and E. The project-specific learning objectives are included in Appendix 1.

3. Pedagogical framework

The project was conducted in the context of the How People Learn (HPL) framework (Bransford et al., 2000). HPL has been used extensively in designing university bioengineering modules that enhance learning outcomes (Cordray et al., 2009; Greenberg et al., 2003; Roselli and Brophy, 2006; Vernengo and Dahm, 2012). Briefly, there are four main pillars of the HPL framework: knowledge-centeredness, learner-centeredness, assessment-centeredness, and, community-centeredness. A learner-centered approach pays close attention to the knowledge, skills, attitudes and beliefs that students bring to their educational experience. A knowledge-centered approach promotes conceptual understanding and organization. An assessment-centered course gives frequent opportunities for formative feedback, and a community-centered environment uses students' peers in the learning process.

The structure of each laboratory was based on the approach described by Linsenmeier et al. (2008) in which the How People Learn (HPL) framework was applied to a human metabolism laboratory. As mentioned above, the motivating challenge for the entire project was to compare the environmental impact of fossil diesel and biodiesel fuels. Associated with each laboratory experiment was a pre-lab introduction in which students' prior conceptions were uncovered through discussion, and new concepts were connected and built upon this knowledge. The pre-lab session began with a motivating problem that would be explored during the experiment, helping students to organize their body of knowledge (knowledge-centered). The assessment-centered leg of the HPL framework was provided by the pre-lab as well as lab notebook page reviews. During the pre-la the in-class discussion provided formative feedback to both the students and the professor. The professor was able to assess the accuracy and quality of students' pre-existing knowledge and linkages to new conceptual understanding, and to provide relevant formative feedback to the students. The lab notebook pages were also reviewed by the instructor before the students left the laboratory, and formative feedback was given regarding accuracy and quality of the investigation and analysis. The course was community-centered in the use of in-class breakout groups for brainstorming and discussion, followed by whole-class discussion. Students worked in teams of 3–4 throughout the project with cooperative learning structures employed to promote positive interdependence and individual accountability.