PROJECT REPORT

Sustainability Education and Civic Engagement through Integration of Undergraduate Research with Service Learning

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Abstract

Integrating service learning with undergraduate research, the student biodiesel project converted all waste vegetable oil (WVO) from campus dining centers into a sustainable biofuel used by campus vehicles, allowing half of the campus diesel energy needs to be met by a material (WVO) that was formerly a waste. Biodiesel reduced air pollution from campus diesel vehicles, including the emission of greenhouse gases. This project connected students to their community and increased students' awareness of the *social/economic* aspects of environmental challenges in the world around them. Students felt a *great sense of responsibility to make a real product that would make a difference* in the real world. Students who participated in the research course became teaching assistants for another regular course in which biodiesel production was a component. This allowed biodiesel to be produced sustainably and provided additional students with hands-on bioenergy experience. Specific challenges and suggestions for future practices are also reported.

Introduction

Sustainably harnessing biomass and converting it into usable fuels (bioenergy) is a critical part of combating climate change and addressing other environmental problems associated with fossil fuels. The success of bioenergy depends upon well-informed professionals, consumers, and citizens. Universities play a unique role in addressing climate change and creating a sustainable society through demonstrating best practices, researching solutions to real-world problems, educating future communities and leaders, and promoting sustainability (Brundiers et al., 2010; Bacon et al., 2011; Barth et al., 2014; Ralph & Stubbs, 2014; Evans et al., 2015; Moura et al., 2021).

Producing biodiesel fuel from campus waste fryer oil offers an outstanding opportunity for bioenergy education and civic engagement through community service. Biodiesel is a clean-burning, renewable substitute for petroleum diesel that can be manufactured from new and used vegetable oils, animal fats, and waste restaurant grease. Using biodiesel as an alternative petroleum diesel reduces lifecycle carbon emissions (U.S. Department of Energy [US DOE], 2017) and the emission of harmful air pollutants such as asthma-causing soot (U.S. Environmental Protection Agency [US EPA], 2018). Waste fryer oil retains almost all its energy content even after it is discarded from cooking. Illinois State University (ISU) creates about 6000 gallons per year of waste vegetable oil (WVO) that the university must pay to dispose. If properly treated, this WVO can be used to make biodiesel. Producing biodiesel fuel from campus waste fryer oil presents several advantages as a bioenergy and sustainability education topic (Christiansen, 2008; Jin & Bierma, 2013) because

1. It converts a waste into a valuable product.
2. It involves a feedstock that is very familiar to students (fryer oil).
3. The fuel can be utilized to operate campus vehicles.
4. It provides opportunities to educate the campus as well as local communities about bioenergy and sustainability.

In this paper, we present our experience of a campus biodiesel project where students who were enrolled in the undergraduate research course at ISU converted WVO from campus dining centers to biodiesel fuel used in university vehicles. Students who participated in the undergraduate research course were later recruited as paid teaching assistants for another regular course in which biodiesel production was a component. This allowed biodiesel to be produced continuously and provided additional students with hands-on bioenergy experience. This project is unique in that it is completely student-driven, student-run and financially sustainable once the initial capital cost is in place, whereas other similar projects require full-time personnel, paid from a separate budget (Christiansen, 2008; Waickman, 2022).

Project Description and Outcomes

The student biodiesel project began a few years ago as an idea of environmental health (EH) students and faculty. The EH undergraduate curriculum has an elective research course with variable hours (1–3 credits). After successfully completing this course, students should be able to

- use library and other tools to search for existing body of research relevant to a given research topic,
- collect and analyze data using appropriate techniques,
- apply problem-solving skills to constructively address research setbacks, and
- communicate research to others in the field and to broader audiences through presentations.

We integrated this research course with service learning and civic engagement in mind by guiding students through producing biodiesel fuel from campus waste vegetable oil (WVO). Learning activities included sampling and analyzing WVO from campus dining centers (Figure 1); producing and testing small-scale (1-gallon) batches of biodiesel; researching large-scale (50- gallon) biodiesel production technology; producing and testing large-scale batches of biodiesel (Figure 2); researching recovery technology of methanol and glycerin from biodiesel glycerin waste; designing and building a solar-powered methanol and glycerin recovery unit; and presenting research findings in classrooms as well as community outreach activities.

FIGURE 1. Students Sampling and Analyzing WVO

FIGURE 2. Students Producing Biodiesel

Faculty worked closely with students throughout the undergraduate research course with a typical enrollment of 8–10 EH students each semester (about 60% females). In addition, faculty had weekly classroom meetings with students to discuss literature and data interpretation and analysis and to brainstorm with students on problem-solving ideas when there were research setbacks; faculty also worked with students in the lab and field to troubleshoot process/equipment. Students formed a close relationship with faculty in this course, evidenced by frequently dropping by during faculty office hours to discuss academic and career plans.

After several semesters of efforts, biodiesel has been produced in 50-gallon batches and has received American Society of Testing Methods (ASTM) certification. Approximately 6,000 gallons of biodiesel have been produced per year and have been used in a variety of campus diesel vehicles.

Students in this undergraduate course also hosted tours and demonstrations for junior high and high schools in the community. Signs on the truck, as well as in dining halls, have educated ISU students about the waste-to-fuel practice on campus. News media coverage educated the community about local bioenergy and sustainability practices (Figure 3). Biodiesel production has also become part of another regular course called Renewable Energy and Agriculture (AGR 225). Students in the three STEM majors (about half females) typically take AGR 225 in their junior and senior years. ISU students

FIGURE 3. Students Doing Education Outreach Activities

who participated in the undergraduate research course were recruited as paid teaching assistants for AGR 225 providing approximately 30–50 students per year with

hands-on bioenergy experience while allowing continuous production of campus biodiesel fuel.

Student Feedback

Student feedback was collected from standard college course evaluation with one open-ended question: "Write a short paragraph about your experience with the biodiesel project. How did this experience influence your connection to the community?" In addition, instructors' observations of student comments during the biodiesel production process, classroom discussions, and education outreach activities are also presented as anecdotal evidence.

In the standard college course evaluation, students were asked to rate in a Likert scale of 1 to 5 with 5 being the highest score. Over 90% students rated their progress on relevant course objectives as 4 or 5. All students rated learning to apply knowledge and skills to benefit others or serve the public goods as 4 or 5.

In addition, students felt a *great sense of responsibility* to *make a real product* (i.e. biodiesel fuel) that had to pass a fuel quality control test run by themselves … and when it didn't, they had to figure out what went wrong and *how to fix it*! It was a lot of work, but students felt *inspired to do it* and it felt *rewarding to help people in the wider community*. Students also feel that they are more aware of *community needs* and have a deeper understanding of the social and economic impact of environmental problems on *a community*. Students felt *strongly connected to the local community*, because they *took actions and were able to serve* the local community.

Discussion and Suggestions for Future Practice

Integrating service learning with undergraduate research, the student biodiesel project allowed half of the campus diesel energy needs to be met by a material (WVO) that was formerly a waste (N. Stoff [Illinois State University Facilities Management], personal communication, July 31, 2018), an example of greater sustainability through resource-conserving technologies and practices. Biodiesel reduced air pollution from campus diesel vehicles, including the emission of greenhouse gases. This project allowed students to learn basic laboratory and research skills and apply them in a campus sustainability challenge, connected students to their community, taught civic responsibility, and increased students' awareness of the *social/economic* aspects of environmental challenges in the world around them. Students felt *empowered* by being trusted to work on a research project that is *meaningful* and *important* because it is *real* research and *makes a difference* in the real world. Students developed a profound personal attachment to achieving positive change in both the environment and their communities. These student outcomes were consistent with many studies that showed that service learning resulted in gains in academic engagement (Covitt, 2006; Mpofu, 2007), self-efficacy and interpersonal and problem-solving skills (Chen et al., 2018; Bielefeldt & Lima, 2019), civic responsibility and attitudes toward community service (Kahne & Sporte, 2008; Manning-Ouellette & Hemer, 2019).

The student biodiesel project leveraged funding and support from several sources to establish biodiesel production on campus. Besides a gift from the Omron Foundation and a grant from ISU Student Sustainability Fund, space in the department of agriculture shop was provided for production without charge. A used pickup truck for WVO collection was donated by the university. Finally, ISU purchased our biodiesel at market price. This revenue paid for materials and supplies, student teaching assistants, and recapitalization of equipment, with the result that biodiesel production on campus was financially self-sustaining.

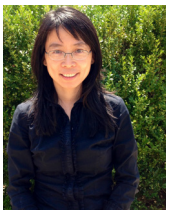
Specific challenges encountered in this project included substantial initial capital investment, the requirement for campus-wide support in infrastructure and logistics, and the fact that financial self-sustainability of the project was subject to changes in the price of materials, product/ biodiesel as well as labor cost of student teaching assistants. Despite the challenges, we believe this type of service-learning on university campuses presents great opportunities for sustainability education and civic engagement through community service.

Our next steps will be seeking methods to make the process more labor efficient, recover more methanol, and find a way to generate more revenue from glycerin, for example by using it to make soap. We will also seek

donations of WVO from local small business to increase our biodiesel output to further serve the local community.

Institutions with limited resources could implement an adapted form of the project such as Biodiesel on Wheels, where a flatbed trailer could be used to house all components required for making biodiesel. This setup requires much less space and fewer resources but could produce good-quality biodiesel from campus WVO, and it could be used as an excellent community education outreach tool.

About the Authors



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