Board 288: Fostering Sustainable Waste-Management Education Through Undergraduate Research

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Fostering Sustainable Waste Management Education through Undergraduate Research

Abstract

Approximately 7.6 billion tons of industrial waste are generated in the United States each year, among which only 30% of the waste stream is currently recycled. Whereas the remainder accumulates in landfills, posing a significant environmental challenge. To better promote sustainability, it is essential to equip the next generation of researchers with the knowledge and skills required for effective waste reduction, reuse, and recycling.

Through this ongoing NSF NSF-funded project, we have developed an innovative teaching and training methodology to address this critical gap and engage undergraduate students in STEM fields. We actively involve eight STEM undergraduate students in interdisciplinary and laboratory-based research activities focused on waste-to-value concepts. Through ten weeks of training, all participants were immersed in the practical applications of sustainable waste management strategies through self and peer learning. The project outcomes were evaluated by assessing the knowledge acquisition and skill development resulting from the 10-week training period of our eight student participants with diverse STEM backgrounds.

Our initiative extends beyond individual student growth; the insights gained from this NSF-funded project have broader implications for curriculum enhancement on a national scale. As we continue to refine and expand our teaching methodology, we anticipate that our efforts will contribute to developing a more environmentally conscious and skilled workforce to address the challenges of waste management and sustainability.

Introduction

Each year, the US alone generates about 7.6 billion tons of industrial waste[1], 111 million tons of dry crop residues and agricultural waste[2], 292.4 million tons of municipal waste[3], and 600 million tons of construction, and demolition waste[4]. Currently, the US recycles about 30% of its waste stream, substantially below the Environmental Protection Agency (EPA) estimate of up to 75% of our waste stream that is recyclable[1]. For example, the current recycling rates of plastic and tires from municipal waste are far below expectations. Recycling and reusing waste reduce landfilling needs, conserve natural resources, prevent and reduce pollution, and increase energy efficiency. To better serve the community, our recently funded Research Experience for Undergraduates (REU) site aims to use science and engineering to convert solid waste into valuable products that can build a resilient and sustainable infrastructure.

To achieve this goal, this three-year REU site targets to enroll eight undergraduate students each year to participate in a 10-week summer program on the University of Louisville campus. The intellectual focus of our REU site is to impart to students the knowledge and technical skills for converting solid waste into a new generation of sustainable construction materials. The educational focus is the SODOTO method (See One, Do One, Teach One), designed to help students grasp concepts in waste utilization and equip them with skills that are needed for fundamental and applied research. Using and recycling waste materials provides a good opportunity for collaboration between faculty and students with different backgrounds, which

mirrors the National Science Foundation (NSF) initiatives to catalyze interdisciplinary science and engineering research[5].

Site Development and Student Selection

The opportunity of this REU site was posted on NSF ETAP for solicitation. Thirty-nine applications were received. Eight undergraduates were selected to participate after the initial screening of all applicants. Ms. Valerie Clay, the Speed School Diversity, Equity, and Inclusion coordinator and this REU site Administrative Assistant, assisted the project directors in ensuring a diverse pool of applications. Phone, Zoom, and Microsoft Teams interviews were conducted to assist selection. Among the eight selected participants, three were from R2 schools, which have limited access to research facilities. Two of the participants were from EPSCoR states. Four faculty members and four graduate students also participated in the site.

Student Mentor Pairing

A month before the kick-off of the site, each faculty member provided one or two research projects with project titles and descriptions (see Fig. 1). The project list was sent to all students, and each of them was allowed to rank the top three projects that they were interested in the most. Students were then paired with faculty based on their project selection list. In both Civil Engineering and Chemical Engineering labs, graduate students worked closely with undergraduate students on experimental design, equipment usage, data collection, etc. To further enhance student-student and student-faculty interactions, the entire REU group met bi-weekly. Each team gave a short presentation about their research findings. Each meeting had a theme to help students excel beyond their technical knowledge/skills (see Table 1). The site directors moderated the meeting and used discussion questions to stimulate students' critical thinking, problem-solving, engineering design, teamwork, and communication. At the end of the program, all eight students participated in the Undergraduate Research Showcase hosted by the Graduate School of the University of Louisville with a poster presentation. Faculty and graduate students not involved in the site events were invited as judges. Awards were given to the top three posters who received the highest scores.

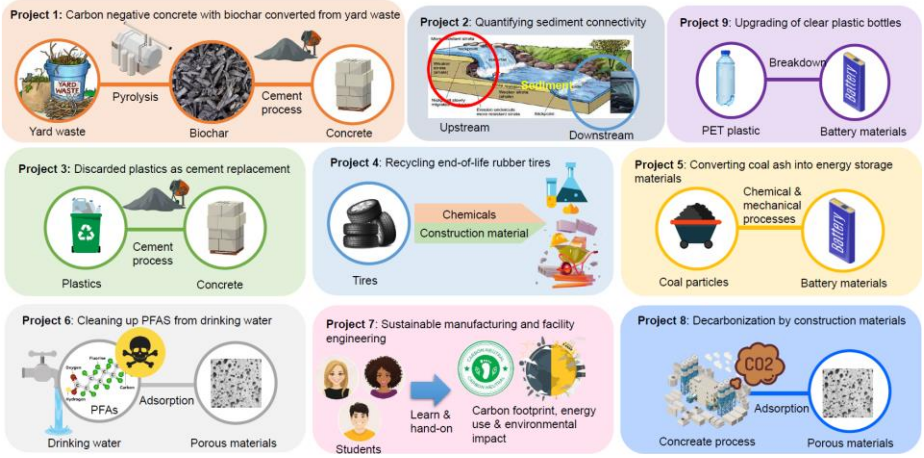


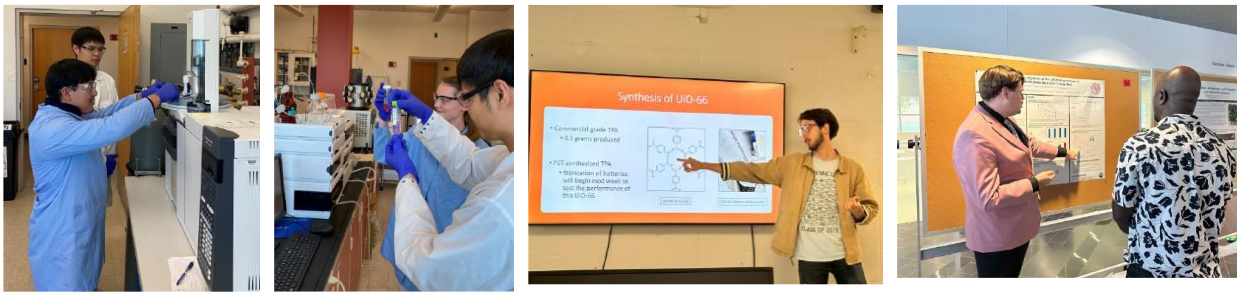
Fig. 1 Project list for student selection

TABLE 1. Engineering Fundamental Modules for Mentoring

Theme	Approach	Week
Critical Thinking	Students will learn the Paul-Elder critical thinking framework,[6] apply it when discussing engineering problems, and use it as a guide for reasoning.	2
Problem-Solving	Students will learn to use generic or ad hoc methods in an orderly manner to find solutions to problems.	4
Engineering Design	Students will learn steps in the engineering design process.	6
Teamwork and Communication	Students will learn practical strategies for dealing with interpersonal/communication problems that arise in teams.	8

See One, Do One, Teach One Methodology

Student activities were designed in three phases based on the See One, Do One, Teach One (SODOTO) method of teaching skills[7]. The SODOTO method not only trains but also promotes long-term retention of skills[8]. The "See One" phase (weeks 1-2) involved introductory lectures on industrial waste challenges and opportunities, scientific concepts of current industrial waste management, and the advantages and disadvantages of conventional disposal and conversion technologies. The "Do One" phase (weeks 3-8) focused on hands-on activities. The faculty mentor and the graduate students demonstrated the waste conversions and their applications in construction. In the "Teach One" phase (weeks 9-10), students created their power points slides and YouTube videos about their findings to teach their peers. Some examples of the SODOTO outcomes can be found in Fig. 2.



(a) (b) (c) (d)

Fig. 2 SODOTO Outcomes (a) Kevin Crespo performed analysis on Gas Chromatography; (b) Leah Hoffmann analyzed Congo red sample in High-Performance Liquid Chromatography; (c) Evan Myers presented his progress on breaking PET plastics during a bi-weekly group meeting; (d) Noah Valverde presented his poster in Undergraduate Research Showcase.

Student Outcomes

Through ten weeks of training, all students gained knowledge in real-world solid waste problems, experimental design and skills, and data interpretation. A pre- and -focus group survey

shows that the designed proactive activities helped students understand concepts and enhanced self-efficacy and confidence for entering the skilled workforce. For example, before the program, 50% of the students answered yes to the question, “I can do a good job in almost all my engineering courses.” This ratio improved to 100% by completing the program.

Realizing new applications of solid waste conversion also inspired students to embrace STEM fields. Incorporating the SODOTO method improved students’ learning skills, thereby achieving this site's educational objective. By the end of the program, all students agreed or strongly agreed that they could conduct experiments independently, they can analyze the data from the experiments and communicate the research findings, all of which improved significantly compared to the pre-program study. All students agreed that they now know how to use computers and technologies to assist research, while none answered yes to this question before the program.

Conclusions

This 10-week REU site successfully trained students with research skills through engineering projects in waste conversion and management. The insights gained from this NSF-funded project have broader implications for curriculum enhancement on a national scale. As we continue to refine and expand our teaching methodology, we anticipate that our efforts will contribute to developing a more environmentally conscious and skilled workforce to address the challenges of waste management and sustainability.

Acknowledgment

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