Relevance of Sustainable Design Projects in Environmental Engineering Education

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Abstract

The need for preparing engineering students through hands-on experiences and real-world projects can never be overstressed. Environmental engineering students require more emphasis on sustainable design to solve the complex environmental issues though real-world projects. This approach was applied in our environmental engineering elective and graduate civil engineering courses in which undergraduate and graduate students worked together to provide sustainable design and solutions for water desalination, wastewater treatment and biofuel production. Four projects received support from the US Environmental Protection Agency over the past three years which focused on 1) sustainable design tools for small communities; 2) low-cost water desalination; 3) anammox microbial desalination cells for enhanced energy and water recovery; and 4) innovative in-situ extractive-transesterification of algal lipids. This article discusses the relevance of the sustainable design projects undertaken by the undergraduate and graduate civil engineering students for engineering education in deepening their course content and environmental engineering principles.

Keywords

Engineering education, environmental engineering, engineering design, student learning, and sustainability

Introduction

Sustainable design and engineering has become the corner stone of the many engineering programs around the world with recent emphasis on- and recognition for- sustainable practices in the professional world. Sustainability education can be provided in numerous ways which include project-based learning, open problem solving, classroom discussions, design competitions and service based learning such as participation in engineers without borders and other professional societies[1-5]. The goals of sustainable design and sustainability education in engineering should aim beyond the technical knowledge and skills to emphasize on the values of sustainable behavior required for professional career and its development. In essence, sustainable design and sustainability education should achieve three primary objectives; graduates should know about sustainability issues, they should have the skills to act sustainably if they wish to and they should have the personal and emotional attributes that require them to behave sustainably apart from engineering rigor and judgement skills[6,7].

On the other hand, the outcomes of engineering education are heavily influenced by the higher taxonomic levels recommended by Bloom et al[8] which include analysis, evaluation and synthesis for graduating engineers. ABET criterion 3 lists out the desired outcomes for engineering programs around the world[9]. While some of these outcomes can be easily achieved in classroom setting and laboratory instruction, there are a few outcomes that are intangible and hard to accomplish. These outcomes include (f) An understanding of professional and ethical responsibility; (g) An ability to communicate effectively; (h) The broad education necessary to understand the impact of engineering solutions in a global and societal context; (i) A recognition of the need for and an ability to engage in life-long learning; and (j) Knowledge of contemporary issues. Higher taxonomic levels of learning and the intangible ABET outcomes and sustainability education outcomes can be accomplished through project-based learning and sustainable design projects and competitions. In this paper, we discuss our recent experiences in sustainable design projects and provide an outlook on student learning and reinforcement of the course content through hands-on real world projects.

Sustainable design projects

Students were encouraged to participate in the sustainable design project proposal writing, submission and execution (after a grant is awarded). The USEPA' P3 program which stands for ***P****eople*, ***P****rosperity and the* ***P****lanet* inspires the college students to benefit from this program to promote sustainable environmental solutions for prosperity and environmental protection[10]. The focus areas of the competition include water, energy, and agriculture, built environment, and materials and chemicals. The competition has two phases in which the phase I award is at $15,000 to develop a sustainable design project and present and compete for phase II funding of $75,000. Phase II grant is to help further the project design, implement it in the field, and move it to the marketplace. Objectives and goals of the sustainable design projects are summarized in Table 1 below.

Table 1. Objectives and brief description of sustainable design projects

Project 1 – Novel process for algal biofuel production This project develops an integrated process which includes an ultrasonic-biopolymer enhanced flocculation step for algal biomass harvesting followed by microwave/ ultrasonic single-pot extractive-transesterification step to improve the energy foot print of the overall algal biodiesel process.
Project 2 – Integrated wastewater and desalination systems for energy and water recovery This project develops an integrated microbial desalination system to treat wastewater with nitrogen removal for electricity generation and desalinated water production simultaneously. The anode chamber with wastewater and cathode chamber with anammox separated by a desalination chamber, accommodate for simultaneous wastewater and saline water treatment and electricity generation.

Project 3 – User-friendly design tools for wastewater treatment in disadvantaged communities This project develops appropriate low-cost and effective nutrient removal alternatives for wastewater treatment for rural and low-income disadvantaged communities in the Mississippi delta and coastal communities. It identifies existing wastewater treatment facilities in disadvantaged communities and select specific communities for model development and systems analysis for their long-term sustainability.
Project 4 – Sustainable low temperature solar desalination using natural vacuum Low temperature desalination using waste heat sources or solar collectors is an attractive option since the energy required for desalination can be provided with minimal cost and environmental pollution. The main objective of this design project is to investigate the technical feasibility of a multi-effect low temperature desalination process with higher thermodynamic efficiency and low environmental impact.

Relevance of environmental engineering courses in sustainable design projects

Table 2 shows the relevance of environmental engineering courses in sustainable design projects. Course title, short descriptive narrative, relevance to EPA P3 project and the applied environmental engineering concepts and principles are summarized. Courses CE 4843, 4863, 4883 and 4893 are offered at split level meaning that both undergraduate and graduate can take these courses.

Table 1. Connection between the sustainability design projects and the environmental engineering courses

Course title	Descriptive words	Relevant EPA project	Applied concepts and principles
CE2803 Environmental Engineering Issues	An overview of the scientific, social and legal issues impacting environmental management and protection in the United States.	Algal biofuel production Solar desalination User-friendly design tools - WW	Water quality, air pollution, eutrophication
CE 3823 Introduction to Environmental Engineering	Environmental process design. Analysis and design of systems for water treatment, wastewater treatment, air pollution control, and hazardous waste engineering.	Microbial desalination User-friendly design - WW	Coagulation, flocculation, sedimentation, reaction kinetics, BOD, nutrients
CE 4843/6843	Introduction to advanced theoretical concepts in sanitary	Algal biofuel production	Colloidal chemistry,

Environmental Engineering Chemistry	engineering analysis with special emphasis on inorganic, organic, and physical chemistry.	Microbial desalination	extraction, organic chemistry
CE 4863/6863 Water and Wastewater Engineering	Evaluation of municipal water and wastewater characteristics and flows; application of various unit processes/unit operations for the treatment of municipal water and wastewater.	Microbial desalination Solar desalination User-friendly design - WW	Coagulation and flocculation, sedimentation, filtration, activated sludge, oxidation ditch, wetlands
CE 4883/6883 Engineered Environmental Systems	Evaluation and characterization of storm water quality; selection, design and application of various treatment technologies; surface water quality management and modeling; and sustainable engineering.	Microbial desalination Solar desalination User-friendly design - WW	Design of small wastewater systems including treatment lagoons, oxidation ditches, wetlands
CE 4893/6893 Hazardous and Solid Waste Management	Examination of state-of-the-art technologies available for the handling treatment; storage; and disposal of hazardous waste materials.	Algal biofuel production User-friendly design - WW	Sludge management, waste disposal and management

Results and discussion

Students were asked to answer a set of questions framed around the concepts of sustainable design, engineering judgement, project management, engineering education, scientific research, critical thinking skills and the relevance of civil and environmental engineering courses. This survey was given to a total of 15 graduate and undergraduate students who participated in the four sustainable design projects over the three years. All of the students have responded positively towards the potential of sustainable designs to provide skills related to the above categories. Student responses to application of environmental engineering principles and concepts learnt in course content and the relevant projects are shown in Figure 2. All undergraduate participants have agreed that CE 2803 Environmental engineering issues course has provided the broader context for understanding the current environmental engineering challenges applicable to all sustainable design projects. 60% of the undergraduate students agreed that CE 3823 content was useful in projects 1-3 while all graduate students who have taken a relevant course in their undergraduate curriculum mentioned that this course content was useful in projects 1 and 3. 80% of graduate students agreed that CE 4843/6843 content was applicable to projects 1 and 3. All undergraduate students agreed that CE 4863/6863 content was applicable in all projects while 33% of graduate students agreed that this course was more applicable to projects 3 and 4. Again, all undergraduate students agreed that CE 4883/6883 content was useful in projects 2-4 while 60% of graduate students agreed that it was more applicable to project 3. All graduate students who have taken CE 4893/6893 agreed that this course content was applicable to projects 1 and 3.

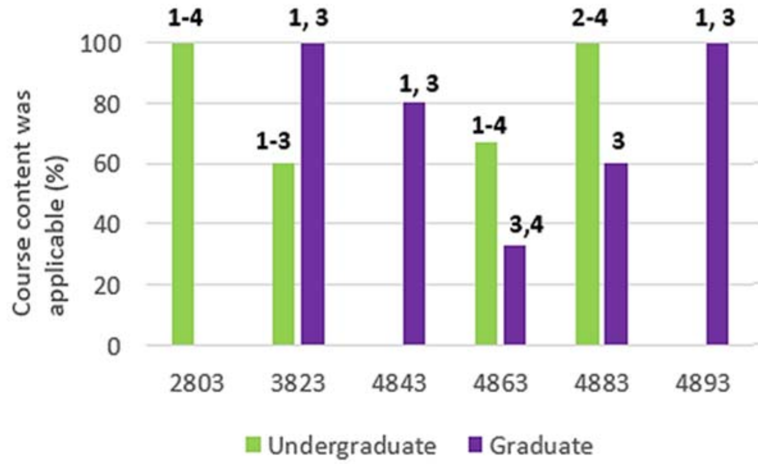

Figure 1. Students' responses to applicability of environmental engineering course content to sustainable design projects.

Student opinions and perspectives

These projects have offered several opportunities for improving their engineering design skills, project management, team work and collaboration and other essential critical thinking skills to develop sustainable products. Figure 2 shows the participants demonstrating their design project at the national sustainable design expo held in Washington DC. However, there were several lessons learnt through these projects.

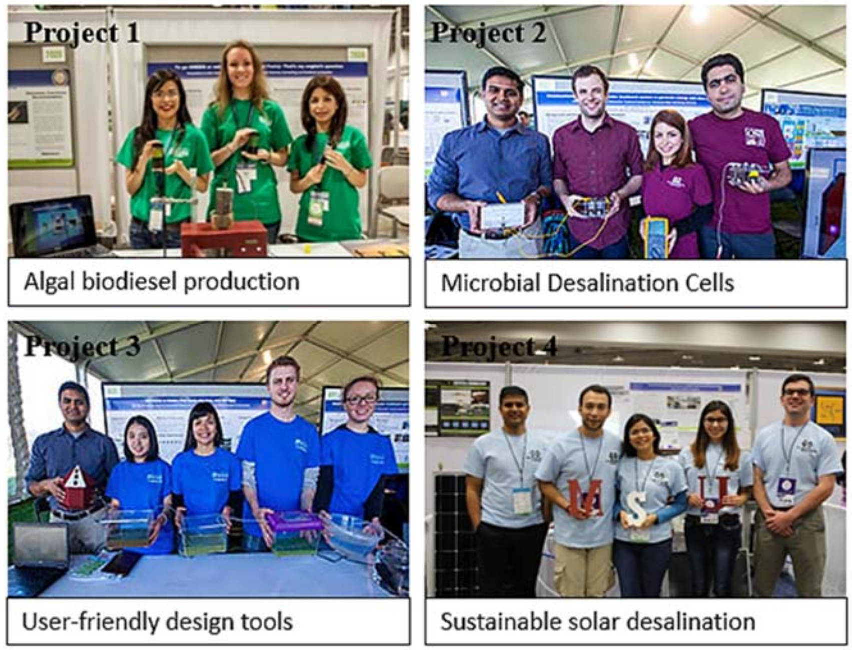

Figure 2. USEPA-P3 National Sustainable Design Competition participants.

Some responses representing students' perspectives of these projects and related issues are presented below.

A student's response to a question about* P3 aspects *in Project 1 (unmodified):

> **People**: *This project addresses "People" in that ultimately the goal of the project was to provide an alternative fuel source that does not compete with readily utilized resources, which would allow these resources to continue to be used by the general population.*
>
> **Planet**: *The "Plant" was addressed because the project's goal was to produce a cleaner fuel source and production process while using algae and chitosan, which are byproducts from other processes. Also, by producing a high lipid yield, the process becomes more efficient and wastes less of the planets valuable resources.*
>
> **Prosperity**: *"Prosperity" was addressed because this project strove to make use of an otherwise unused resource, algae. Chitosan is also a byproduct, so its use also utilized a resource not commonly used. The use of these resources to produce a viable fuel would theoretically allow other, more competitive, resources to be used less often.*

A student's comments on Project 3, when asked about the most difficult part of the project (unmodified):

> *"This project involved multiple aspects that were completed by individual students. Toward the end of the project, these components were combined into a single, cohesive final product. Individuals were very familiar with certain portions of the project, but were not as knowledgeable pertaining to the other students' work. This limited expertise with regard to the entire project may have limited the success of the final presentation of the project".*

Conclusions

This article discussed the effectiveness of the environmental engineering courses offered in civil and environmental engineering program at Mississippi State University. The innovative approach of involving students in real-world sustainable design projects has allowed them to apply the course content and materials to synthesize sound and environmentally friendly solutions. These projects also provided opportunities for the participants to gain from the benefits of specific outcomes defined in ABET criterion 3 and higher taxonomic learning levels of bloom's taxonomy. Other intangible benefits from this approach are scholarship through scientific publications, project proposal and report writing, effective oral and written communication skills and a broader understanding of the sustainability concepts in environmental engineering profession.

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