AC 2011-2137: EXPERIENCES WHILE INCORPORATING SUSTAINABILITY ENGINEERING INTO THE INDUSTRIAL ENGINEERING CURRICULA

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Experiences While Incorporating Sustainability Engineering into the Industrial Engineering Curricula

Abstract

According to The Engineer of 2020 (National Academy of Engineering, 2004), to maintain the nation's economic competitiveness and improve the quality of life for people around the world, engineering educators and curriculum developers must anticipate dramatic changes in engineering practice and adapt their programs accordingly. Current environmental issues have caused society to realize that industries and individuals must have sustainable systems to meet the needs of the present without compromising the ability of future generations to meet their own needs (Report of the World Commission on Environment and Development, 1987). Therefore, one of the main goals of the present paper is to show how sustainability engineering curriculum has been included into the Industrial Engineering curricula to respond to current demands to produce environmentally conscious engineers capable of understanding sustainable practices and their implications. For the authors, creating a special topics class for the new course within the industrial engineering department seemed very appropriate since industrial engineering has always focused in the optimization of resources, thus there is a natural connection between the sustainability definition and what industrial engineers have always practiced.

The main objective of this paper is to present the approach used to integrate sustainability engineering content into the engineering curriculum at our University. The approach involves offering a multidisciplinary class in sustainability engineering which was offered to junior or senior engineering students as a technical elective class with no prerequisites. The class was divided in four main modules which are Life Cycle Assessment, Energy Management, Design for Sustainability, and Ethical Consumerism.

A team teaching approach was used to teach the class with faculty members from the departments of Mechanical Engineering and Industrial, Manufacturing and Systems Engineering Department. In the class, students were required to work in teams to solve two different projects. The first project was mainly related to life cycle assessment (LCA) in which students were asked to perform an LCA for a particular product and provide an analysis of their results. The second project involved a presentation to expand one of the main modules of the class. Finally, the course was evaluated using student questionnaires and exit interviews. Moreover, one additional survey was sent to the students six months after they took the class to collect data and assess student learning.

1. Introduction

Given the finite capacity of the earth, it is recognized that engineers of the future must be trained to make decisions in such a way that our environment is preserved, social justice is promoted, and the needs of all people are provided through the global economy. According to The Engineer of 2020 (National Academy of Engineering, 2004)[1], to maintain the nation's economic competitiveness and improve the quality of life for people around the world, engineering educators and curriculum developers must anticipate dramatic changes in engineering practice and adapt their programs accordingly.

Sustainability engineering seeks to preserve natural resources by finding creative solutions to satisfy the needs of the present generation without compromising the ability of future generations to meet their own needs. Sustainability engineering is an emerging area that is inherently multidisciplinary [2-4].

There is a need to better understand how complex systems can achieve both short-term continuity and long-term ecological integrity. As we move to a more carbon-constrained world, businesses will ultimately have to meet customer needs in a way that generates fewer carbon emissions. Therefore, it is essential to bridge current engineering education to sustainable product design, manufacturing, and processes, which requires new curriculum development, research, and manufacturing experiences, as presented in this paper.

This paper presents the approach used at our institution to integrate sustainability engineering content into the engineering curriculum at our university and to disseminate sustainability engineering concept to regional Middle/High School students and teachers. The work we describe next involves a three year project funded by the United States Department of Agriculture. This paper presents the first year outcomes and experiences learnt from the implementation of this project.

2. Model components

The approach we used followed a model whose main components are 1) curriculum development, 2) student engagement and 3) outreach to Middle/High school students and teachers.

2.1. CURRICULUM DEVELOPMENT. In the Fall 2009 semester, new curriculum in Sustainability Engineering was developed with the main objective to provide a general perspective about sustainability and provide the students with the necessary tools to analyze systems and make informed decisions about the impact their decisions have on the environment. The new 3-hour credit course covered four main topics which are Life Cycle Assessment, Design for Sustainability, Carbon Footprint Management, and Ethical Consumerism. In the Spring 2010 semester, the new course was offered for the first time with an enrollment of 17 Hispanic undergraduate engineering students (9 were female students). To be able to provide multidisciplinary point of view of the topic, the Sustainability Engineering course has been taught following a team teaching approach with two professors from the Industrial, Manufacturing and Systems Engineering department and two professors from the Mechanical Engineering department. The class is being currently offered as a technical elective with minimum prerequisites open to all junior and senior engineering students.

2.1 Curriculum evaluation. The course was evaluated using student questionnaires and exit interviews. The feedback from students who took the course was strongly positive. On the interim survey of class quality, the students ranked the overall rating of this class to be a 4.8 (on a scale of 1 to 5) and the overall rating of the main instructor was 4.8 as well. The participants gave positive evaluations about the learning acquired and were interested in pursuing graduate studies in areas related to sustainability. Out of the 17 students (16 senior, 1 junior) who received support, 6 indicated their desire to continue their graduate studies; 8 graduated in December 2010 and 2 are now enrolled in graduate school. Additionally, through an exit interview, the investigators were able to learn more about how students feel

when they are lectured by four professors instead of one. Most of the comments were very positive.

2.2. STUDENT ENGAGEMENT. In addition to teaching courses, another great impact of this project is advising students, especially graduate students, on conducting research and bringing in the on-going research topics into the classroom to challenge and stimulate students' creative thinking and problem-solving capability.

2.3. OUTREACH TO MIDDLE/HIGH SCHOOL STUDENTS AND TEACHERS. In the Fall 2009 semester, a presentation titled Sustainability Engineering and current initiatives at UTEP was prepared by two of the graduate students supported under grant. This presentation was given to 36 high school teachers from Parkland High School with the main objective to interest high school students in environmental related careers. Moreover, in summers 2009 and 2010 using the infrastructure of the UTeach Miners Program, the project directors offered two modules to 50 middle/high school teachers to introduce students to Sustainability related topics. Additionally, a Sustainability Engineering Session was offered directly to 30 middle/high school students participating in the 2010 UTEP ExciTES Summer Institute.

3. Project Outcomes

In this section we present the first year outcomes of our project:

1) increased student awareness of environmentally sustainable development,
2) increased knowledge in sustainability,
3) changes in engineering students' perceptions about how their decisions affect the environment, and
4) increased job market opportunities.

These outcomes have been achieved through all the activities carried out as part of the project. For instance, the new multidisciplinary class in sustainability engineering was developed to provide hands-on training to undergraduate and graduate students in topics such as Life Cycle Assessment (LCA), Carbon Footprint Management, Design for Sustainability, and Ethical Consumerism. According to exit interviews, the students had no previous exposure to sustainability related topics but after taking the class they were able to understand how different production systems and designs affect our environment and the quality of our life.

In the Spring 2010 semester, the undergraduate students enrolled in the class worked in projects such as: The Sustainability Game (who was awarded the best project and will be presented by the students at the 2010 Institute for Operations Research and the Management Sciences Conference Annual meeting, Austin, TX., Nov. 7-10, 2010), Sustainability in the Supply Chain, Sustainability as a Business Strategy, Green Buildings, and LCA study of Biodiesel Using Soybean Oil versus LCA of Petroleum Diesel (see Figure 1). As a result of the attention that each student received from the project directors, all of the students were committed to the success of their projects, gained confidence and developed new communication and team building skills.

Figure 1. Sustainability Engineering class term project presentations

In Fall 2010, the course is currently being offered to undergraduate and graduate students. This allows the students to work on more challenging projects since teams are formed by both undergraduate and graduate students. Examples of current term projects are Biodiesel Production Made from Recycled Cooking Oil from El Paso Area Restaurants, and Design of a Solar Water Heater Using Recycled Materials. Participating undergraduate students have expressed their desire to attend graduate school and continue working in sustainability related topics; others have indicated their desire to obtain a Certificate in Sustainability Engineering. Due to the multidisciplinary nature of the class and the hands-on material covered, the students will have a competitive advantage after graduation since they are now better prepared for the green jobs market.

The project also outreached 30 middle/high school students through the ExciTES summer program. The main objectives of the ExciTES program are to 1) create awareness of the diverse fields of engineering and science and 2) encourage participants to attend college; specifically, UTEP's Colleges of Engineering and Science. The 2-hour session covered an Introduction to Sustainability, global warming, a practice to show them how their lifestyles impact the

environment, and the estimation of their carbon footprint using an online carbon footprint calculator. At the end of the session, the students expressed their interest in pursuing a career with environmental focus.

4. Impact to date

The impact we had achieved during the implementation of the presented approach can be separated into internal, and external impact.

INTERNAL IMPACT: The project has significantly impacted the education curricula in the College of Engineering at UTEP. Faculties have realized the importance of sustainability engineering education; as a result, a concentration in sustainability engineering is under development. There is no doubt that the new Sustainability Engineering class has been very well received by the students, however the professors team-teaching the new course firmly believe that sustainability topics can be easily be implemented as modules in several other engineering and science courses. Moreover, the project has directly impacted 17 undergraduate and 3 graduate students, 86 Middle/High school teachers, 30 Middle/High School students through the ExciTES summer program and indirectly impacted many more via the modules developed for High school teachers and the project website. Students and Teachers learned what sustainability is and how their life styles affect the environment.

EXTERNAL IMPACT. The presented approach in this paper has been disseminated through presentations at regional and national conferences as well as with a project website.

5. Conclusions

This paper presented an approach used at our institution to integrate sustainability engineering content into the engineering curriculum at our university and to disseminate sustainability engineering concept to regional Middle/High School students and teachers. The project outcomes and the impact we have had through its implementation are also presented.

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