

AC 2010-2088: INCREASING SUSTAINABILITY ENGINEERING IN EDUCATION AND RESEARCH

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Introduction

Changes in our environment and the rising needs for natural resources are prompting societal demands for the inclusion of sustainable engineering in every facet of modern day life. These demands are pressing researchers and industry to develop new and better materials and processes that will allow industries as well as the average consumer to be significantly greener. Moreover, increasing numbers of manufacturers are beginning to evaluate their products and even their product packaging for sustainability, whether to meet mandatory retail initiatives or to reap some of the rewards associated with greater environmental stewardship. This shift in product design means that engineering education needs to produce engineers that can provide technological innovation while protecting the environment. These demands also mean that universities across the nation need to build bridges between undergraduate engineering education and sustainability engineering in both research and industry.¹ This paper describes an approach to include sustainability engineering within an existing engineering program through *1) curriculum development, 2) student research and mentoring, and 3) outreach* at a Hispanic Serving Institution. In this way, students learn concepts important to sustainability engineering, use these concepts in research, and have the opportunity to contribute to research and society.

Sustainability is no longer just a buzz word for the manufacturing/retail industry. It is a reality that affects every level of the supply chain. The question is no longer whether to implement sustainable principals and goals but rather how the companies can do it in the most effective way. Sustainable engineering is an emerging area that is inherently multidisciplinary^{2,3,4} As such, engineering education must also be able to prepare students to perform within a multidisciplinary environment.

This paper describes an approach that will design new curricula based on the current trends for developing commercial products that are manufactured from renewable and biodegradable materials, and that will have a minimal environmental impact given our nation's agriculture, economy, environment, manufacturing, and engineering resources. Through the development of this curriculum, students will gain a background and an appreciation of the complexity of our nation's agricultural system as well as awareness for possible careers within the agriculture/environmental sustainability/biomaterials manufacturing engineering fields while developing their professional skills.

Through this approach, we plan to generate new courses that present students with current state-of-the-art knowledge and research in sustainability design, manufacturing sustainability, and sustainable systems. Our students will experience that real problems are not in any single domain but they cross boundaries of several domains, not only among pure engineering disciplines but between engineering, business, ethics, social sciences, and agriculture sciences, etc. Thus, this project will cover material that demonstrates the intersection of design and manufacturing, sustainability aspects, as well as agriculture issues such as shown in Figure 1. As a result, the students will be trained to open excellent career opportunities for them.

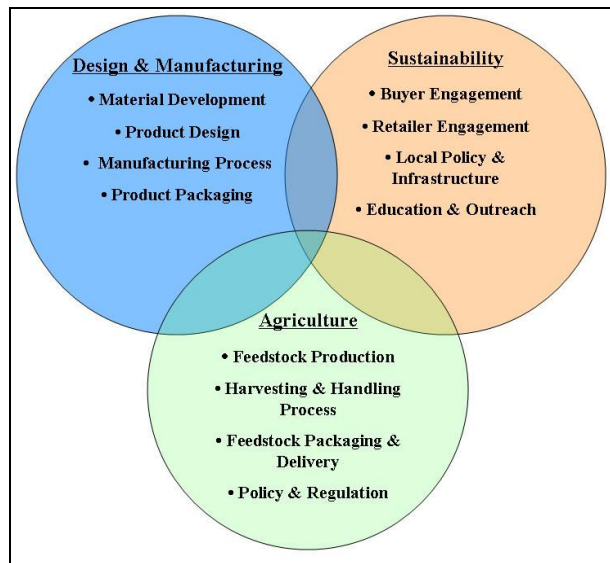


Figure 1. Interaction between Sustainability, Design & Manufacturing, and Agriculture.

This project aims to attract underrepresented students to newly developed courses in the area of biomaterials engineering manufacturing. At least 100-120 undergraduate students during the next 3 years will be mentored with state-of-the-art topics related to this area. One of the term projects for the undergraduate students will be the preparation and presentation of a topic regarding sustainability of our environment to high school students of the El Paso area. The Texas State Data Center predicts that by 2025 the Hispanic population of Texas will exceed non-Hispanics in the state.⁵ We hope that by exposing minorities early in their academic career with some of the research being currently performed, they will be inspired to pursue graduate education and careers in agriculture sciences and engineering fields. Also, a new course will be developed to be offered to graduate students enrolled in the MS in Manufacturing. As well, this course will be implemented as one of the courses of the interdisciplinary PhD in Manufacturing. With the support of this grant up to 96 underrepresented undergraduate students and 3 underrepresented graduate students will receive assistantship. This monetary support will help them continue and finish their careers.

Curriculum Development

Curriculum development includes the development of an undergraduate junior/senior level course and a graduate level course. The curriculum must span sustainability design, sustainable manufacturing, and the interaction between sustainability and entrepreneurship. The proposed curriculum implements teaching modules and a team teaching approach. The modules are problem-based and result in creating an interdisciplinary educational experience for students.

Therefore, one of the main goals of our team will focus on reshaping Manufacturing Engineering curricula to respond to current demands to produce environmentally conscious engineers capable of understanding biomaterials manufacturing processes and their implications. There is no doubt that more attention is needed to be able to create a sustainable environment. Then, most of the material covered and research to be produced will rest on the sustainability principle that mainly

states that we must meet the needs of the present without compromising the ability of future generations to meet their own needs.

This curriculum is inherently multidisciplinary because it draws from the areas of design, manufacturing, reliability, and materials, among others, to develop sustainable systems. The multidisciplinary nature of sustainability education is evident in current efforts made by universities such as Carnegie Mellon, University of Texas at Austin, and Arizona State University.^{6,7,8} Moreover, it is reported that the population of individuals who are involved with or affected by technology (e.g., designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary.^{7,8} Our program can be adapted to serve at other Hispanic Serving Institutions to increase sustainability education and research. The program will also bring together researchers to identify and address some of the current problems facing sustainable systems engineering, sustainability design, material degradation modeling, and ecological foot printing standardization. As illustrated in Figure 2, sustainable engineering integrates design for sustainability, cost evaluation, systems engineering, carbon foot printing, material selection and life cycle analysis. These areas are crucial to 1) designing biodegradable, reusable, or recyclable products, 2) commercializing sustainable products, 3) developing infrastructure to minimize the environmental effect of these products, and 4) developing a stable supply chain for continued and responsible production of greener products

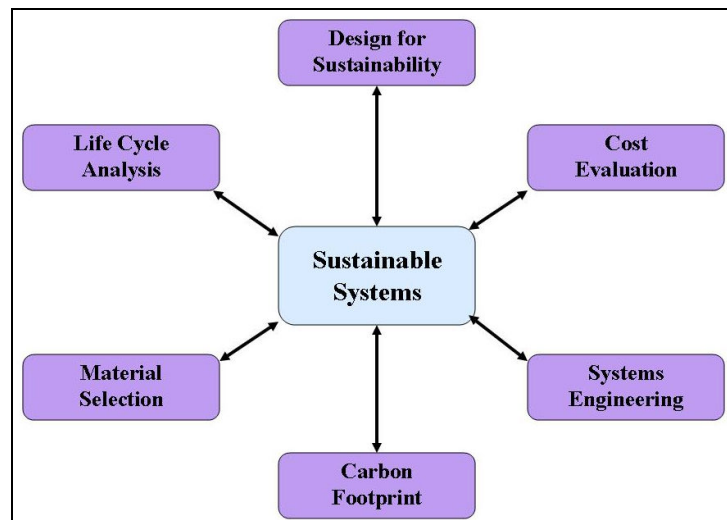


Figure 2. Concepts to be included in Sustainability courses

Student Research and Mentoring

Fundamental to this approach is the opportunity to participate in sustainability research at the undergraduate and graduate levels. Students involved in research will have both practical hands-on experiences as well as mentorship from engineering faculty. This mentorship is crucial to increasing the number of students seeking graduate degrees involving sustainability. Research also bridges undergraduate and graduate education by allowing students to begin research as undergraduate students and to continue research as graduate students. By means of these experiences, our students will gain valuable technical skills before seeking positions in industry

or pursuing research sponsored graduate studies. Some of the anticipated results from this project are:

- a) New curricula development and new courses offered at undergraduate and graduate levels. These courses will aim to target students from interdisciplinary programs with interests regarding topics such as concepts on sustainable design, environmentally friendly manufacturing, biomaterials life cycle analysis, entrepreneurship on biomaterials, among others.^{9,10,11}
- b) Through the newly developed courses and planned outreach activities, we expect to increase environmental awareness and educational opportunities for underrepresented students in the field of Biomaterials based Manufacturing Engineering.
- c) Through the exposure of students to innovations in biomaterials based products, this project will motivate students to engage with faculty in undergraduate and graduate state-of-the-art research.¹²
- d) Through the planned outreach, particularly through our contact with area schools and the local population, this project will increase consumer interest, acceptance, and demand of Biomaterials based products.⁷
- e) Additionally, the information campaigns will increase local government awareness to the future infrastructure needs for processing biomaterials based products).

Outreach

Students' research contributions will be publicized to the community via local sustainability conferences, through high school outreach, and a bilingual website. Using these dissemination methods, sustainability research, sustainability careers, and sustainability solutions will be accessible to the community in order to increase awareness and to increase student interest in this field.

A bilingual project website will be developed and launched during the fall 2008 semester to serve the needs of our surrounding community. The website will highlight the main objectives, and developmental activities in the sustainable biomaterials manufacturing project, educational opportunities for underrepresented K-12 students and teachers, undergraduate and graduate students, consumers, other Hispanic-Serving Institutions, and local businesses seeking to make environmentally friendly choices. The project directors will regularly update the website and will link it to the project directors' departmental pages, investigators professional web pages, and our university's webpage.

During Spring 2010 and 2011 the different student projects will be presented at annual seminars on Biomaterials Manufacturing Engineering for students on campus. These seminars will encourage student participation within the fields of biomaterials, sustainability, product design, and development using biomaterials and serve as professional training for the effective presentation of official results at national/international conferences. During the Fall 2010 term a conference on Building a Sustainable Environment will reach the surrounding community. This conference is intended to attract government agencies/non-profit organizations personnel and local business owners to promote the use of sustainable practices for their businesses.^{13,14} Additionally, the results obtained from research projects carried out by the project faculty members and students will be submitted for publication.

Moreover, the developed curriculum will increase the awareness of traditional engineering students to careers in food, agricultural sciences and engineering. This project will monitor recruitment, retention, and the number of students seeking careers in any aspect of food and agricultural sciences for publication in education and engineering journals and for presentation at sustainability and biomaterial conferences. During outreach, information will be disseminated to students in area schools and they will be encouraged to participate in environmentally friendly activities as well as seeking their college education.

Evaluation

Each module of this approach has specific goals our team wishes to obtain. The deliverables of this project are: (1) new undergraduate and graduate courses, open to junior/senior students enrolled in industrial/mechanical/civil engineering and environmental sciences, to students in the MS program in manufacturing, and to students enrolled in the PhD program in manufacturing and interested in interdisciplinary research. (2) A seminar on Biomaterials Manufacturing Engineering that serves as a forum for undergraduate and graduate students to present their research. (3) A conference on Building a Sustainable Environment open to the El Paso/Ciudad Juarez community to provide more education and awareness about sustainability and to promote sustainable alternatives for local business owners. (4) Increase the enrollment of students pursuing undergraduate and graduate studies in the biomaterials manufacturing field or other interdisciplinary engineering/agricultural science related fields.

The number of students influenced will determine our impact. The numbers are expected as follows: mentorship to undergraduate students, with at least 60 students receiving support. An additional three graduate students will receive full support. Under the direction of our team, talks about environmental sustainability and biomaterials manufacturing will be given to at least 300 high school students by the supported students as part of one of their term projects.

The different modules of this approach will be evaluated based on the number of students engaged in sustainability education and sustainability research, the number of student research papers, posters, and presentations generated and the number of students that continue and complete at least a master's degree to determine the effectiveness each component.

Student evaluations as well as personnel not directly involved in the project will assess the performance of the current initiative. Student evaluations and questionnaires will assess the performance of the current initiative, their satisfaction with the curricula content, and their interest toward careers in sustainability engineering/environmental sciences. Members from the IE and ME advisory boards will evaluate the results and impact of the project. In conjunction with the advisory boards, our university's Center for Effective Teaching and Learning (CETaL) will evaluate the effectiveness of the curriculum for increasing underrepresented groups in the sustainable biomaterials manufacturing engineering program each semester. Based on the findings of these evaluations each semester, the curricula materials and outreach activities will be modified to increase the impact and effectiveness this approach.

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