AC 2007-1818: BRINGING NEW TOPICS INTO THE INDUSTRIAL ENGINEERING (IE) CURRICULUM

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Bringing New Topics into the IE Curriculum

Abstract

The need to focus efforts on environmental concerns rings important to young people as well as to the National Academy of Engineers. The need to raise awareness about the environmental impact of decisions in manufacturing and product design should be at the forefront of curriculum enhancement efforts. Industrial Engineers are typically viewed as “systems thinkers” and need to analyze the larger eco-system when new designs are put in place. Thus, the systems-approach to environmentally responsible design and manufacturing has a natural place in the Industrial Engineering curriculum.

The challenge to engineering faculty may be found in bringing in a new course into an already packed curriculum. A new course, IME540 Environmentally Conscious Design and Manufacturing, will be offered for both undergraduates and graduate students as an engineering elective across all disciplines in the university and will reside within the Industrial & Manufacturing Engineering Department. In an attempt to reach as many students as possible, the course is being offered with minimal prerequisites and will be team-taught by faculty from various disciplines including Business, Liberal Studies, Mechanical Engineering and Chemistry.

The multidisciplinary faculty group will have completed two offerings of IME540 as a senior engineering elective course by the time this paper is presented at the ASEE 2007 conference. Preliminary assessment data will be available and plans for the next offering will be in place. Discussion will center on pedagogical methods and tools used within the class that enable students to incorporate environmental concerns into product and process designs. Emphasis will be placed on the economic impact of alternatives.

An overview of the topics contained in the class will be presented in detail. The course modules begin with a module exploring historical and ethical perspectives on the environmental impact of industrial processes. Technical content and engineering tools comprise the middle weeks of the course, as life cycle concepts and material choices are introduced. The course concludes with a module presenting business and management perspectives, and will include a case study that illustrates how environmental considerations can be incorporated in the design process.

In addition to the multi-disciplinary faculty component, an industrial advisory board made up of local industry professionals and university professors has been created to oversee the project. The advisory board meets annually to review technical progress by the group and also to provide guest speaker and plant trip opportunities. Ford Partnership for Advanced Studies has offered a set of modules for use in adaptation and implementation of the course.
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**Background**

The purpose of this paper is to illustrate the adoption of a new undergraduate course in environmental consciousness into a university Industrial & Manufacturing Engineering Department curriculum. In addition to the new topic, the course presents new ideas using innovative teaching styles and an interdisciplinary development team to improve student learning. Assessment data is gathered throughout the course development process. Quantitative, qualitative and anecdotal assessment data will be presented during the conference presentation.

**Why Environmental?**

The environmental focus of a new course is in response to the National Academy of Engineering (NAE) book *The Engineer of 2020*. In the book, the NAE states that “Engineering practices must incorporate attention to sustainable technology, and engineers need to be educated to consider issues of sustainability in all aspects of design and manufacturing.”¹ Former Vice President Al Gore published an intensely compelling video titled “Inconvenient Truth” that tells the tale of global warming and the importance of our renewed focus and commitment to the needs of the environment.²

Industrial Engineers (IEs) are traditionally involved with improved productivity and quality control initiatives. According to the Institute of Industrial Engineers (IIE), the IE professionals have the responsibility to “Make the world a better place through better designed products.”³ In order to make the world a better place, it’s important to think of the world as a closed-loop system with limited resources. Design responsibility necessarily includes utilizing such resources in an infinitely sustainable fashion. The term Industrial Ecology has been used to define the role of industry in the concerns of the environment. A similar term, Occupational Ecology, has been defined by IIE as “Study of the worker, his environment and the interaction of worker with environment. The occupational ecologist is interested in matching man and environment for optimal ergonomic efficiency and minimal disturbance to the environment.”⁴

Authors of a paper published in the Industrial Engineering Research Conference suggest that “Sustainability is an issue gaining importance with all built environment stakeholders. Users, owners, designers, constructors, and maintainers from all sectors are actively seeking techniques to create a built environment which will efficiently use all resources, minimize waste, conserve the natural environment, and create a healthy built environment for existing and future generations.”⁵ Several other papers relating the concept of the role of the IE to environmental design have been published through the Institute of Industrial Engineers. Industrial engineers have attempted to define metrics for environmentally conscious design⁶ citing the importance of measuring the potential environmental impact of a product during the design phase rather than waiting until the design is completed.
Why Multidisciplinary?

The traditional IE is not equipped with all of the skills necessary to tackle such a multi-faceted topic. In fact, no single engineering discipline appears to have all of the skills necessary to address the topic of designing products with the environment in mind. Thus, a multi-disciplinary approach to understanding environmental concerns is a fundamental decision to adequately address the topic.

The NAE states that “engineers have been aware that solutions to many societal problems lie at the interstices of subdisciplines” and that “there is a growing need to pursue collaborations with multidisciplinary teams of experts across multiple fields.”

In addition to the NAE citing the need for multidisciplinary efforts, The National Institutes of Health (NIH) have noted that scientific advances are being made at the interfaces of traditional disciplines. They further state that approaches to science are becoming more integrative in nature and that an interdisciplinary engineering education is a realistic model for training future leaders in the engineering sciences to advance research ability.

It makes sense that an interdisciplinary course would reside in a department that claims to be “systems oriented.” In fact, almost half of the courses offered in the Industrial & Manufacturing Engineering Department contain the word “Systems” in the course title. Core courses include such titles as Systems Modeling, Systems Analysis, Quality Systems and Enterprise Systems. It follows that environmental criterion and metrics must be considered systematically over the full product and process life cycle.

References exist to show that learning, retention and professional development can be enhanced through collaboration. In the book Women’s Ways of Knowing, the authors assert that a passion for learning is experienced when students witness first-hand the process of problem-solving, rather than merely being “handed” theories. This idea was put into practice by having six faculty members attend every class during the first session. The lively discussion benefited the faculty members as much as or maybe more than the students.

Objectives

The objectives of this new undergraduate class include both technical course learning objectives as well as innovative teaching objectives. Technical objectives are related to the actual content of the course. The industrial ecology team argued, debated, researched and finally agreed on the important topics to be included as critical skills for the undergraduate engineering student related to the environmental conscious design of products and processes.

An advisory board was formed to aid in the developing the technical content of the course. The advisory board consisted of executives from local companies with an interest
in designing products and processes with the environment in mind as well as academic faculty with similar interests in the education of undergraduates. The industrial component of the advisory board was firm in their conviction that this class must focus on the cost impact of environmental decisions. Since companies will only stay in business when they are making a profit, environmental decisions must be analyzed from a cost-benefit perspective. The academic component of the advisory board shared common courses, programs and curriculum that exist on their campuses and offered words of wisdom for the development of this new course. Members of the advisory board have participated as guest speakers on campus. They also participate in an annual advisory board meeting held at various industrial locations throughout the state. This annual meeting provides a means for stakeholder input to the university industrial ecology team.

Once agreed upon, the technical objectives were turned into course learning objectives and eventually into six specific modules that would comprise the course. Each module is presented in a series of three one-hour time slots with a focus on content and teaching style. It’s important to note that any of the modules contained in the course could be enhanced to a full course as part of a larger curriculum. The modules and corresponding teaching objectives were agreed upon as a structure for presenting course material.

Technical Objectives

The focus of the new undergraduate IE course addresses the issue of environmental sustainability in both the design of the product and the design of the manufacturing process. Development and class discussion surrounds technical and cultural changes within a framework of the economic impact of implementing such changes.

The primary technical objective of this course is to introduce undergraduate students to the need for environmental responsibility during the entire life cycle of a product. The course will contain six distinct modules designed so that each will stand alone or flow together. The modules can be moved into existing classes and may be useful in future educational outreach programs. Each module will be scheduled for three, two-hour blocks. A brief summary of the modules as outlined in the NSF grant proposal (DUE #0511322) is as follows:

**Module 1: Technology, the environment and industrial ecology** - In this module students will be introduced to the broader implications of the environmental impact of industrial activity. This will include a discussion of the historical, social and ethical motivations for a sustainable society. This will be followed by a discussion of the notion of industrial ecology and sustainable business practices. Finally, students will be introduced to basic environmental science and specific environmental performance metrics.

**Module 2: Life-cycle concepts and assessment** - This module presents students with the notion that environmental impact extends beyond production to material extraction, product use and end-of-use strategies. Such a perspective is often novel to engineering students who have spent much of their time in college focusing on product development and production. Students will discuss life cycle stages for a variety of example products.
Strategies for assessing the impact of each life cycle stage will be presented and the students will explore the advantages and challenges associated with each. This discussion will include discussions of the role of suppliers in minimizing the impact of the life cycle of a product.

*Module 3: Material selection strategies and requirements* - A frequent challenge faced by corporations is eliminating or minimizing the use of environmentally hazardous materials or materials that require large amounts of energy to produce or manufacture. In this module students will be introduced to environmental impact measures, industrial standards and guidelines, and decision-making strategies that can be used for material selection.

*Module 4: Process design and improvement* - Another common challenge faced in industry is to reduce the environmental impact of an existing manufacturing process. Students will be introduced to methods of identifying the most damaging part of the process flow through material and energy balances. Common practices for reducing energy consumption and waste will be discussed. In addition, strategies for product packaging and delivery will be presented.

*Module 5: End-of-use strategies* - This module begins with a lecture on Green Chemistry. It addresses strategies and challenges associated with reducing the environmental impact of a product after it has been used by a consumer or business. Discussion will address re-use, remanufacturing, recycling, and disposal options. Design for recycling tools will be demonstrated and practiced on real products. In addition, the current economic and legislative realities of end-of-use strategies will be presented.

*Module 6: Environmentally responsible management* - Industry also faces the challenge of communicating the technical and financial advantages of environmentally conscious design and manufacturing within their corporations both to engineers and managers. This module will present current best practices in promoting design for the environment within the corporation. In addition, the module will introduce students to current trends in environmental management systems, green supply chains, lean manufacturing and total cost accounting.

**Teaching Objectives**

As defined by the National Research Council\(^\text{11}\) the design of the learning environment will have an impact on the student’s ability to learn. In particular, the degree to which learning environments are learner centered, knowledge centered, and assessment centered, will have an impact on students learning. Thus, the classroom community must be designed to strategically include these aspects.

To develop a learner centered classroom, this class begins with a pre-test for self assessment of students skills coming into the class. An excerpt from the self assessment is included as Figure 1. In addition, a participative classroom experience encourages students to share their outside work and personal experiences related to the topic being
discussed. Students provide real examples that can relate to their life at the moment as well as their career in the future. The instructor’s task is to connect every day decisions with their impact on the future of the environment. In addition, the use of case studies enables the instructors to relate theoretical concepts and ideas to the real world.

To develop a knowledge centered classroom, selected course topics must give students a body of knowledge to draw from that will give them the tools necessary to solve environmental problems. In addition to technical skills, they should also have a mental model that allows the systematic approach to solving such problems. Further, the class attempts to make sense of environmental decisions from a historical perspective to explain why poor environmental decisions were allowed to occur.

The development of an assessment centered classroom will allow the class to continuously improve. Both formative and summative assessment was expected as an outcome of the project. Formative assessment occurred throughout the course by way of student surveys and faculty assessment. At the completion of each module, students were asked to fill out a survey with questions related to the instructor’s effectiveness as well as the ability to meet the learning objectives for that particular module. Students were further asked to assess each module using the SII Assessment technique advocated by the Pacific Crest Teaching Institute. An essay format listing strengths, areas for improvement, and insights gained for each module will be summarized at the culmination of the class and presented at the conference.

In addition to student assessment, the faculty team met weekly for an informal lunchtime discussion. One outcome of each weekly discussion was an SII assessment from the faculty perspective. Anecdotal remarks from classroom discussions are carried into the faculty meetings and included in the faculty weekly SII assessments. Strengths, areas for improvement, and insights were compiled for each module as well as for the overall course. Qualitative and quantitative assessment data will be shared at the conference and in future publications.

The formal formative and summative assessment is enhanced with the help of an outside evaluator. This institutional effectiveness professional has attended meetings and met regularly with the industrial ecology team. Further, the evaluator has created surveys and assessment rubrics for use in the class and as part of the larger project.

The varied experiences of the multi-disciplinary faculty are shared throughout the course illustrating a community centered focus. The industrial ecology team faculty has worked together and is committed to both the technical objectives as well as the teaching objectives of this innovative classroom experience.
Module 1  Technology, the environment and industrial ecology

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Figure 1. Excerpt from the Pre-Test Knowledge Self Assessment

Conclusions

First course offering assessment

The first offering of this course occurred during the Winter 2007 academic term. Since a prerequisite for the class is senior standing, the students are mature and have been acting in the role of engineer during their mandatory cooperative work experiences. Since the class is a free elective, only students with an interest in the topic of environmental consciousness are likely to register for the class. In theory, each of the six faculty members would contribute one-sixth of the course load. In practice, for the first offering, all faculty members were committed to attending every class period to understand the overall flow of the modules.

Six students enrolled in the first course offering, each with a diverse background. The small class size was optimal for a first offering to enable individual participation and discussion freely by all students. Informal student assessment happens throughout the class due to a low teacher to student ratio (1:1) where senior-level students are treated as colleagues and a great deal of discussion naturally occurs during every class period.

During the first weekly assessment meeting following the course introduction the team cited that one of the strengths of this course was the intellectual stimulation that the discussions offered. The positive intellectual spirit gave them increased excitement about coming to work every day. The team agreed that the personality of the individual faculty members was the critical factor in making this multidisciplinary arrangement successful. The faculty expressed sadness that this type of intellectual conversation didn’t happen more often.

Future

Members of the faculty team have been publishing papers, presenting at conferences and been involved in various media articles highlighting the outcomes of the project for the purpose of sharing the story with others and disseminating collective knowledge. Previous ASEE conference presentations and papers have been published in the Environmental Engineering Division, and the Interdisciplinary Engineering Division.
In addition to the new course, the objective of the larger Industrial Ecology project is to bring the topic of environmental consciousness to the entire campus. The project has spawned a student group, held regular advisory board meetings, maintained a guest speaker series, and is in the process of building a website. The student interest group, Green Engineering Organization (GEO), is involved in community activities to cultivate plantings around the campus and local areas as well as assisting with bringing in industrial guest speakers. The guest speaker series has provided industrial expert knowledge to the entire campus. The upcoming website is intended to disseminate the outcomes from this project to others with a similar interest.

The faculty team intends to pursue further funding sources to continue offering the course, expanding the curriculum, and reaching out to the community. The interdisciplinary nature of the course offers challenges for pay equity and workload compensation that must be overcome to sustain the course for future offerings. The class size will need to be increased substantially to sustain the course and justify six faculty members for one class.

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