AC 2009-1222: DEVELOPMENT AND OUTCOMES OF A "DESIGN FOR THE ENVIRONMENT" COURSE

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Abstract

We have developed a *Design for the Environment* (DfE) course which is a dynamic mix of non-traditional lectures and hands-on DfE laboratory experiments that are infused with real-world interactions. Our engineering teams (E-teams) partner with local green industries and organizations to identify and engineer relevant product and process innovations in the context of sustainability. The DfE course was partially designed using objectives from the Sustainability in Higher Education Assessment Rubric (SHEAR), an ABET-aligned rubric that identifies and describes eight elements essential to courses aiming to teach concepts of sustainability to students. The key feature of this course is a semester product or process development project where the students work closely with green industries with the aim of addressing sustainability challenges. Students learn about product design and innovation in concert with issues of sustainability. During the semester the students interact with the companies and participate in hands on learning labs that develop an understanding of methods to solve problems related to sustainability. We will discuss the concepts of this course as well as discuss course assessments.

Introduction

The *Design for the Environment (DfE)* course has been incorporated into the undergraduate and graduate engineering curriculum within the Swanson School of Engineering (SOE). DfE was funded by the National Collegiate Inventors and Innovators Alliance (NCIIA) whose focus is on encouraging the incorporation of sustainability and product innovation into curricula. The learning objective of the DfE course is for students to understand the social, economic, and environmental impacts between product and process design decisions. Since green technology is emerging as the most important industry of the 21st century[1], it is critical that students are provided the opportunity to understand the linkage between their decisions, engineering designs and sustainability. This course is one of a growing number of sustainability courses offered within Pitt's SOE. The course is a dynamic mix of authentic learning and hands-on DfE laboratory experiments that are infused with real-world interactions. Our engineering teams (E-teams) partner with local green industries and organizations to identify and engineer relevant product and process innovations and/or improvements. At the close of the semester, E-Teams participate in a design competition; winning E-Teams are awarded a residency at their partner company to implement their design. Most importantly, the aim of the course is for students to gain an understanding of how their actions and designs have a significant impact on global sustainability efforts.

Incorporating sustainability into product and process design as a design constraint is clearly a necessity as all designers must understand the limits on natural resources. As environmental concerns such as global warming and energy security continue to weigh on society, the next generation of students will need to be prepared to solve complex sustainability challenges. DfE is one element of moving towards sustainable development, and is a concept that has developed and evolved since the early 1990's, largely initiated by the electronics industry. In general, DfE is a "specific set of design practices aimed at creating eco-efficient products and processes"[2]. DfE and industrial ecology are centered on the idea that industries can simultaneously achieve increased environmental and economic interests. The United States Environmental Protection Agency (EPA) has a DfE program that works in collaboration with many industries to reduce environmental impacts. The program has reached more than 200,000 business facilities and approximately 2 million workers. In 2006 alone, DfE reduced the use of chemicals of concern by 183 million, illustrating the importance of DfE efforts[3]. The proposed course infuses DfE concepts with hands-on lab and industry collaboration, the students are able to understand, engineer, and manage sustainable growth and development.

The University of Pittsburgh's Swanson School of Engineering has made significant commitment to sustainability education. The Mascaro Center for Sustainable Innovation (MCSI) is spearheading sustainability research and education with foci in green building design and construction, infrastructure, and materials. MCSI fosters through the School of Engineering departments both graduate and undergraduate programs in sustainable engineering. In conjunction with MCSI's mission, the Department of Civil and Environmental Engineering (CEE) has committed to sustainability engineering and green design. The faculty authors have recently formed the CEE's Sustainability and Green Design (SGD) group and have been charged with developing CEE and SOE sustainability curriculum. The PIs have begun to develop and teach a handful of sustainability courses including Life Cycle Assessment, Green Buildings: Design and Construction, Sustainable Engineering and Development, and Product Realization for Global Opportunities. The DfE course expands Pitt engineering students' experiences and involves them in cross-disciplinary inquiry and problem-solving with students throughout the university.

Course Description

The students' experience includes introduction to concepts, labs, tools, and case-studies related to DfE. During the course, students will interact with two different local partners where they learn about the organization and discuss potential DfE challenges with the partner through a field trip to the partners' facilities and a lab experience developed with the partner. The field trip will be utilized to introduce students to the organization and to brainstorm potential projects with the organization.

Multidisciplinary E-Teams will be assembled (approximately 3 to 4 students per team) from the class members; the E-Teams will be challenged to identify a sustainability-related problem with one of the industry/organization partners and to propose a DfE solution that is both practical and sustainable. Throughout the semester, the teams will develop a plan and DfE solution. Funded by the NCIIA curriculum improvement grant, E-Teams have a prototyping budget to enable them to actually build and test their design solutions. E-Teams will present their final product innovations during a design competition at the close of the term. The panel of judges will be made up of the PIs, partner representatives, and at least one guest expert judge. Selected teams will be awarded with residencies where they will have the opportunity to implement their proposed project during the summer. E-Teams will spend a portion of their time at Pitt and their partner site– depending on the needs of the project. The project will culminate in a report for the partner and dissemination of the project.

An important element to the course is collaboration with industry since they provide a realistic platform for product development. Within the DfE course, we focused our relationships on nonprofit organizations within the Pittsburgh area, which has a strong non-profit and green community. Organizations that have agreed to partner with us include the Urban Redevelopment Authority of Pittsburgh (URA), the Green Building Alliance, Sustainable Pittsburgh, Riverlife Task Force, Phipps Conservatory, GTECH Strategies, and Steel City Biofuels. One or two partners are involved with the class each year. Partners committed to conducting site visits, serving as advisors for E-Teams, and hosting the winning E-Teams for summer project implementation.

Course Development

This course has been developed in two phases. The first phase included creation of learning outcomes, development of corporate sponsors, and the development of general course outline. The second phase consisted of content development, laboratory planning, and creation of assessments. The instructor team meets weekly to delegate relevant tasks, finalize the details of the course, and discuss content delivery. The focus for the preliminary phase was on identifying overarching principles and learning outcomes while the secondary phase requires attention to details to insure a beneficial experience for the students.

Preliminary Course Development Phase. Our main educational outcome is to enable students to design products or processes that have the most beneficial impacts on the Triple Bottom Line (TBL) - the society, economy, and environment. In order to successfully achieve this broad goal, we decomposed our main outcome into smaller goals and began to develop the outline of the course. We utilized ABET Criteria[4], the Civil Engineering Body of Knowledge for the 21st Century (ASCE BOK)[5], and the SHEAR[6] to assist in decomposition of our main outcome into goals. These resources also provided the guidance and validation of non-traditional forms of curriculum delivery that provide opportunities for learners with varying learning styles to receive content in their preferred method. It has been shown that learners are more successful when their preferences are met[7]. The DfE course has several learning goals and content delivery methods that provide for an exciting and dynamic educational experience.

There are many goals that a successful learner must meet in order to design for optimal impact on the TBL. This course teaches the goals through lecture, discussions, hands-on experiences, and product/process design to solve an overarching corporate guided design problem. Table 1 lists the course goals and the curriculum delivery method. It should be noted that most goals in this course are delivered several times and with different methods to improve learner outcomes. The design problem requires substantial effort on the learners part and is necessary to provide real-world relevance and application to knowledge that has been learning through other portions of the course.

ABET Criteria were used to validate the relevance of the course goals. Table 2 briefly summarizes several ABET criteria and shows the relationship to the learning goal of the DfE course. The criteria are not a limiting factor in course design but ensure that overarching principles are rigorously covered through a learner's course of study in a program. Criteria also relate to assessment and continuous improvement of curriculum (Criterion 4). This also validates our use of formative assessment which will be discussed later.

Our course also meets many learning outcomes from the ASCE BOK, Table 3. It is interesting to note, if our course was delivered in a traditional format without a design problem the learner was required to solve, the course would not meet many of these learning outcomes. These outcomes further validate the necessity of a realistic and relevant design component to any course.

Table 1. Delivery Methods for Learning Goals of a Design for Environment Course

	Delivery Method			
Learning Goal	Lecture	Discussion/ Mini-Project	Hands-on Experiences	Design Problem
Product Development	X			X
DfE Guiding Principles	X	X		X
Impacts of Design on Energy Usage	X	X	X	X
Material Selection and Impacts	X	X	X	X
End of Life Impacts	X	X	X	X
Utilizing Relevant Standards in Design	X	X	X	X
Life Cycle Assessment	X	X		X

Table 2. ABET Criteria and DfE Course Learning Goals

	DfE Course Learning Goals						
ABET Criteria	Product Design	DfE Guiding Principles	Impacts of Design on Energy Usage	Material Selection and Impacts	End of Life Impacts	Utilizing Relevant Standards in Design	Life Cycle Assessment
3.c- Ability to design a system or product that meets multiple constraints	X	X	X	X	X	X	
3.d- Ability to function on multidisciplinary teams	X		X	X	X	X	
3.e- Ability to identify, formulate, and solve engineering problems	X	X					X
3.f- Understanding of professional and ethical responsibilities	X	X	X	X	X	X	
3.g- Ability to communicate effectively	X						
3.h- Understand impacts of solutions in multiple contexts	X	X					X
3.j- Knowledge of contemporary issues	X	X					X
5.b- Ability to iteratively apply basic science, math and engineering to solve a problem	X						

A curriculum development tool created by Pennsylvania State University was also used to aid in curriculum development. The Sustainability in Higher Education Assessment Rubric (SHEAR) is designed to aid faculty in creating effective courses in sustainability. Through the knowledge and use of this rubric, we increased our focus on group learning and reflection opportunities for the learner. The rubric also suggests greater success can be achieved through long-term mutually beneficial relationships with corporate/community partnerships. This category has helped us ensure that we are mindful of both our learners and our partners needs throughout the course and in the future.

Table 3. ASCE BOK Learning Outcomes Covered in the DfE Course

Outcome	Description
Design	Evaluate the design of a complex system, assess compliance with customary standards and relevant constraints
Sustainability	Analyze systems of engineering works, whether traditional or emergent, for sustainable performance
Contemporary Issues and Historical Perspectives	Analyze the impact of engineering solutions on the economy, environment, and society
Communication	Communicate projects and ideas to technical and non-technical audiences
Leadership	Organize and direct the efforts of a group
Teamwork	Function effectively as a member of a multidisciplinary team
Professional and Ethical Responsibility	Justify a solution to a problem based on professional and ethical standards

Secondary Course Development Phase. The second phase of curriculum development required substantially more attention to detail. The lectures were finalized and project milestones were developed to insure success for the product/process design component of the course. Past experience with design courses has shown that students need milestones throughout the course to be successful in the design process. Project proposals, creation and communication of alternative solutions, and prototype dates are all critical milestones that students must meet during the semester course. In order to provide students with the tools necessary to design products with an environmental concern hands-on learning labs were finalized.

The development of the learning labs to provide the learner a toolbox of resources occurs in conjunction with the course. The initial concept and main learning objectives of each lab were established during the preliminary phase. However, time and effort are required to turn these ideas into a reality. The university has a substantial amount of old materials that offer great examples for students to see the impacts of designs that lack attention to the environment in their design. For instance, there are a substantial amount of computers that can be acquired for free from our surplus department. These computers when compared to present computers such as the Apple G3 lack easy disassembly which is critical to the recycling of components in that end of life phase of a product. The benefit of searching internally for resources provides inexpensive solutions and provides for the reuse of resources.

The disassembly of a computer and the proper disposal of its components are used to help learners realize the impacts of design on end-of-life concerns. Another lab that we developed, the Energy Lab, utilizes an infra-red camera to measure hot and cold spots in a building or system. Through further analysis learners will gain the understanding that efficiencies, proper installation, and proper design can have a significant impact on the energy requirements. Towards the end of the semester learners are asked to develop their own eco-label for their design project or verify that their design will meet any current eco-labels or related standards. Finally, we have the learners participate in a chair disassembly lab that compares a new chair with evidence of DfE too older chairs that can be found through university surplus. The entire learning lab experience is developed to offer the learners the opportunity to apply what they have learned in lecture. The designed and controlled lab experiences provide a beneficial learning environment to apply or reinforce the new knowledge before application to their design projects.

We will use both formative and summative assessments to evaluate our course objectives. Utilizing internal curriculum development resources, we will ensure that assessments and learning activities align with the overarching learning outcomes of the course and program. Assessments focus on assessing attitude changes toward sustainability and related careers, development of skill sets to address sustainable product innovations that are viable and marketable, and develop cross-disciplinary collaboration and communication skills. Additionally, it is important to our program evaluation and sustainability that we evaluate the program expectations and value from the perspective of our organization partners.

Conclusion

While there is comfort in, and funding for, team teaching, it does come with its own set of challenges. First, quality team teaching does not actually mean that less time should be spent on the course. With three primary instructors, we expected that the effort of developing and running the course would be one third of an individually taught course. In actuality, we ended up having more meetings where decisions about both major and minor things are made in committee. Decisions made in committee inevitably take more time to make than decisions made unilaterally. Additionally, having no definitive leader means that low-priority, shared tasks like re-organizing the course web site don’t get done in the time frame that they should. The solutions we developed were to have more meetings were we could talk about and make the decisions, having agendas for those meetings, and using an online task management too with responsibility for tasks assigned explicitly.

Formative assessments were employed to collect critical information from the students with the aim of modifying course content and objectives in an iterative fashion. However, the results of the formative assessments could not be evaluated in a timely fashion that enabled iterative course development. The necessity for early planning in the course means that reacting to the information from the assessments will occur in subsequent years. This information will be invaluable for planning the next instantiation of the course.

Summative assessments are not available at the present time. This data will be available shortly and will be presented at the upcoming conference. The data will allow us to make conclusions regarding the effectiveness of our team teaching approach and the course curriculum.

Having corporate involvement in the course is very important, but developing a corporate *partnership* is absolutely critical. The involvement means that the students have real-world problems to tackle and to apply the concepts of DfE to, but the partnership means that there is a constructive back-and-forth between the students and the company to develop a list of projects that: are doable by the students in a semester, are helpful to the company, and are exciting for both sides.

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