Including Design for Environment Tools in an Undergraduate Design Class

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Abstract

How do you get students thinking about the impact of product design on the environment? Usually, we think of including Design for Environment (DFE) as one of the tools in the Design for X (DFX) section of a design course. Rather than apply DFE ideas after the conceptual design is developed, we are focusing on making the students aware of how environmental impacts and sustainability fit into a corporation's culture through research and development (R&D), product development and manufacturing. We start this process by educating the students on the impact of the industrial revolution on the earth, then discuss the environmental impact of products through the use of streamlined life cycle assessment (SLCA). As part of learning the SLCA approach, we introduce a case study of the impact and redesign of a videocassette. Finally, we have the students put their newfound skills to work in a design exercise.

Introduction

According to David Orr, "One of the principal tasks of education in the coming century is to foster ecological design intelligence."[1] We decided to undertake this challenge in one of the core courses of a new university minor in Technology Management and Policy. [2] This core course, Product and Technology Life Cycle, [3] is open to all third and fourth year undergraduate students, but the class has primarily consisted of a majority of engineers and a number of commerce students. This course encompasses the "technology life cycle" which we break down into four modules: Research and Development (Basic and, Applied), Product Development, Commercialization, and Product Retirement and Revitalization. This course has several goals:

- introduce non-engineers to technology and process and product development in a corporate setting,
- introduce engineers to the decision making process, especially in an economic context,
- introduce the ideas of industrial ecology and design for environment into the life cycle framework,
- develop open-ended problem solving and design skills, and
- develop written and oral presentation skills.

Throughout the course, we emphasize the concept of developing technologies and products and making decisions within a resource-constrained environment.

The Technology and Product Life Cycle course meets twice a week for 75 minutes. Technical concepts are taught by an engineering professor and economic decision-making tools are taught by a commerce professor. Both professors attend all classes. At the beginning of the semester, the students fill out a questionnaire in which they record their major, work experience, interests and skills. Students also complete a personality profile (i.e., Myers-Briggs). Based on these questionnaires, the professors assign the students to multi-disciplinary teams in which they work for the remainder of the semester. The teams are given three project assignments. The first is to research and find a new emerging technology and select a real company that might logically be interested in this type of technology. They are asked to prepare a written proposal to "management" describing the technology, asking for specified development funding and resources and justifying this request in terms of its fit with the company's mission and goals, its existing technology strategy and the expected return on the investment. The written proposal is handed in as part of a formal presentation to a fictional set of management decision makers—the professors. We evaluate the students' work on both content and presentation. The second assignment is generally a design assignment and the third assignment has varied. For example, in 1997, we worked with the School of Architecture to evaluate the environmental impact of an existing auditorium chair and to propose a new, more ecologically friendly design.

Education: Introducing the Concepts of Sustainability

We interweave the concepts of sustainability and industrial ecology throughout the technology life cycle model using Graedel and Allenby's *Design for Environment* text [4]. First, we discuss the impact of the industrial revolution on the earth's environment in the R&D module. We introduce for both products and processes, the concepts of material flow; the master equation describing the impact on the environment in terms of industrial and economic activity and population; and life cycle. We discuss these topics in relation to the technology S-curve and the pressure on companies to improve their environmental performance. Then, students are asked to consider how a corporation can use R&D to position itself for improved environmental performance through the development of new "cleaner" technologies. By design, we leverage the effort invested in completing the first assignment to accomplish most of this learning objective. Consider the following two projects tackled by two of our student teams. One group proposed that Volkswagon invest in the further development of the flywheel engine from Rosen Motors [5] for adoption in a new line of energy efficient automobiles. Another group proposed that Dow Chemical invest in a molecule discovered 20 years ago, but until recently uneconomical to produce in volume, for cleaning up residual oil in industrial waste.

In the next section of the course, the students are introduced to new product development, its various philosophies and phases. We include concepts, such as Design for Recycling, Design for Environment, and SLCA. To introduce SLCA, we introduced Graedel and Allenby's rating matrix through the use of a case study. "Shape, Incorporated" describes the situation of an OEM provider of cases for computer, video and audio storage media. In the late 1980's, Shape developed a totally recyclable videocassette case for the promotional market. This case requires students to assess the environmental impact of an industry standard videocassette using SLCA, then to recommend redesign activities to improve the ecological friendliness of the case. The students are then shown Shape's environmentally friendly, recyclable design. This case allows us to demonstrate how designers can attain the goals of recyclability, superior performance *and* low cost. [6] A second case, "DesignTex Fabric," [7] is used to show another example of designers realizing the goals of sustainability through design. Through these activities, the students see that the goals of sustainability can be realized and are being realized by designers today. The class also attended a lecture on sustainability by Dean of the University's School of Architecture William McDonough, [8] an environmental designer and philosopher.

In the Product Development module and leading to the Commercialization module, the students are introduced to the basics of costing, planning, budgeting, cash flow and life cycle costing. In the Commercialization Module, we discuss how to implement DFE into a corporate culture. In this section, the topics include the mechanisms for DFE management, DFE's major goals and principles and examples of companies committed to industrial ecology, such as Lucent Technologies and Xerox. In the last module, Product Retirement and Revitalization, we discuss recycling and the consequences of ignoring industrial ecology in the development of new products.

Practice: Using the Tools

We provide several occasions for the students to apply the tools and principles presented in class. First, in the Shape, Inc. videocassette case we require that the students use an SLCA to assess the environmental impact of a standard videocassette on the environment. Last year, we assigned the student groups to assess the environmental impact of an auditorium chair (specifically, the School of Architecture is remodeling two of its auditoriums; one using standard purchasing procedures and the second guided by the principles of industrial ecology). Rather than ask each group to assess the whole chair, we divided the chair into its constituent parts and asked each team to assess one part. The chair decomposed into five parts: the gray iron base and seat support, the laminate covering for desk, the wooden armrests and particle board desk, the plastic back, and the foam cushion. The seating fabric was excluded because its impact had already been considered via the DesignTex fabric case study.

Each team gathered information about the life cycle of their assigned component material, including pre-manufacture (e.g., materials extraction and processing), manufacture, delivery, use and disposal. The teams then prepared a report detailing their findings and recommendations for improvement. The component part-level reports were then distributed to all student teams so that each team had a complete impact assessment of the chair. This information became the basis for the final design assignment.

The Design Challenge

In the last project, the student teams were asked to design a new chair based on the impact assessments and using the design process and industrial ecology principles learned in the class. The design goals were to design a chair with a decreased environmental impact, that would meet student needs of utility and comfort and that would meet the Architecture School's cost target of less than $250 per chair. The students produced some innovative concepts in the redesign activity; all resulting in a chair with reduced environmental impact. The conceptual designs included: a park bench concept using recycled lumber; a chair similar to the standard design but using alternative materials, such as down for the cushioning and hemp for the fabric cover; a step-like structure similar to amphitheater seating made of recycled PET and Foamex, made of 100% recyclable, carpet-based products. Figures 1 and 2 contain drawings of two of these design concepts.

Conclusions

The students' reports have been given to the School of Architecture for their use in the redesign effort. Although none of the designs may find use in their initially proposed form, the impact assessment reports and the design concepts are being used to guide the work with a chair design company contracted by the Architecture School.

The students had mixed reviews of the assigned projects. Some enjoyed the challenge of designing a chair for a "real world" application under tight cost constraints. However, other students were frustrated with the lack of information on the material content and manufacture of the constituent parts of the chair. They were also frustrated with the openness of the assignment, which is in contrast to the textbook problems they are assigned in most of their other courses.

Both instructors of this course have spent time in industry and one of the goals of the course is to challenge the students with the types of open-ended and ambiguous problems that they will be assigned to solve in their corporate jobs. Despite the frustration among some of the students, we saw our students grow in their ability to seek out and assimilate information from a wide range of sources, to prepare well-reasoned arguments supporting their course of action, and to answer tough questions in the oral presentations. Informal feedback from students confirmed our intuition; they learned a tremendous amount but the frustrations became counter-productive. Thus, we learned we must take greater care in designing the assignments for future iterations of the course.

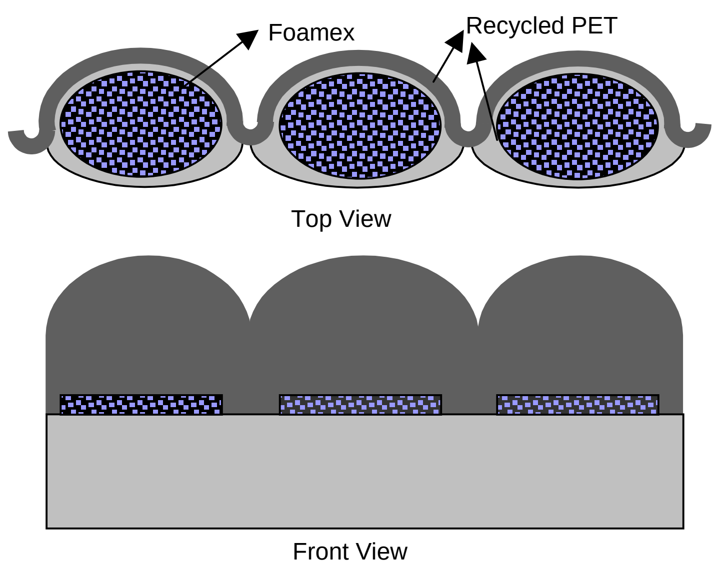

Figure 1: Serpentine Amphitheater-style Seating.

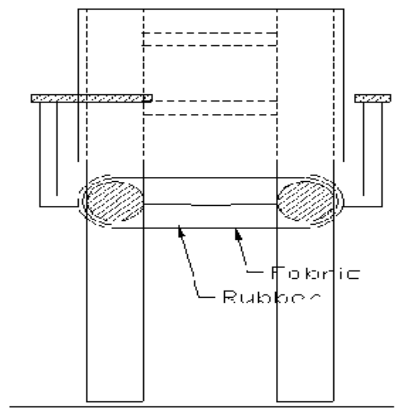

Figure 2. Front view of hemp, rubber, and plastic chair.

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References

[1] Orr, David, "Ecological Design," Earth Ethics: Evolving Values for an Earth Community, Vol. 7, No. 1, Fall 1995, pp. 11-12.
[2] Technology Management and Policy web page, http://vlead.mech.virginia.edu/classes/tmp.html
[3] Technology and Product Life Cycle course web page, http://vlead.mech.virginia.edu/classes/classes.html.
[4] Graedel, T. E. and B. R. Allenby, Design for Environment, Prentice Hall, Upper Saddle River, New Jersey, 1996.
[5] Rosen Motors web page, http://www.rosenmotors.com/
[6] Carlson-Skalak, S., J. P. Leschke, M. Sondeen, and C. Lovecky, "Shape, Inc.'s Videocassette: A Nearly Sustainable Design," submitted for publication in *Interfaces*, contact the authors for information.
[7] Mehalik, M. and M. Gorman, "DesignTex Fabric Case Study," Division of Technology, Culture and Communications web page, Ethics, http://repo-nt.tcc.virginia.edu/ethics2/cases.htm
[8] Dean William McDonough, Dean of the School of Architecture, University of Virginia, http://arch.virginia.edu/Dean/

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