AC 2010-1854: ENGAGING ENGINEERING STUDENTS IN A DESIGN-BASED SERVICE LEARNING COURSE EMPHASIZING CONNECTIONS BETWEEN TECHNOLOGY AND SOCIETY

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Engaging Engineering Students in a Design-Based Service Learning Course Emphasizing Connections between Technology and Society

Abstract

History has shown that there is a complex relationship between technological projects and the individuals that a technology is intended to serve. Failure to understand or anticipate the social environment in which a technology is implemented often leads to unintended consequences. If an engineer is to implement technology in a manner that is beneficial to society he/she must learn to consider the social environment in which the technology is to be used.

In this paper, we describe the design, implementation and assessment of a unique undergraduate course (Technology and Society: A Regional Perspective) that helps students to develop their own ideas regarding the relationship between technology and society. This course is a required component of the Engineering Science degree at Sweet Briar College, a women's college in located in central Virginia. The program at Sweet Briar includes an emphasis on the idea of "socially-conscious engineering" and the course described in this paper is offered as part of our effort to recruit and retain students. Research has shown that the idea of "making a difference in the world with engineering" often resonates with high school students, especially women.

The content of the course consists of two major components. In the first, students are asked to read selected portions of the text for the course, Richard Pool's "Beyond Engineering: How Society Shapes Technology." These readings partly consist of case studies of technical projects that were profoundly affected by unanticipated societal factors. The second major component of the course is a "socially-conscious" design project. In 2009 this project consisted of the design and fabrication of specialized tooling and fixtures to assist developmentally-disabled employees at a local light-assembly plant. Students were engaged with these employees and their managers in order to get feedback on their designs and to develop an understanding of the unique problems that developmentally-disabled individuals face in performing their jobs.

In our paper, we discuss the implementation of the pedagogical approach described above in the context of the course learning goals. We also present assessment results in the form of evaluations of student work, post-course interviews, and student course evaluation data. Guided by these assessment tools, we suggest improvements in future versions of this course.

Introduction

It is widely recognized that there is a need in engineering education for an increased emphasis on the role of the engineer within the larger society.[1] Engineers are often accused of implementing technology for its own sake, with little consideration of sociological issues. This view is supported by numerous historical examples in which a lack of understanding of social forces has resulted in unanticipated, damaging effects of the use of technology.[2] The importance of social considerations as a significant component of an undergraduate engineering education is embodied in ABET Outcome h, "…to understand the impact of engineering solutions in a global, economic, environmental, and societal context."[3] Despite the inclusion of this outcome in the ABET criteria, research by Vanderburg and Khan suggests that social issues are not given significant time or emphasis in engineering courses.[4] Their research finds that engineering courses are almost exclusively focused on the mastery of engineering theory and skills and that very little attention is paid to the role of the engineer as a member of society. They also find that humanities courses which are required by most engineering degree programs focus on narrow subject material and usually do not consider relationships between technology, society, and the practicing engineer.

In this paper, we describe our efforts to address this gap in engineering education through the development of a course dedicated to the study of the relationships between technology and society. This course is a required part of the Engineering Science degree at Sweet Briar College and is generally taken in the sophomore or junior year. We offer two versions of this engineering course: Technology and Society: A Global Perspective and Technology and Society: A Regional Perspective. This paper focuses on the regional course. The global version of the course was taught in the spring of 2007 and had similar goals. The students in the global course designed and built a water supply system for a school in the highlands of Guatemala.

Sweet Briar is a small, liberal arts college (650 students) for women located in central Virginia. The technical focus of the Engineering Science degree is on electromechanical systems; however the program also offers a strong focus on "socially-conscious engineering." This focus is reflected in the projects selected for our design courses, in the research focus of the faculty, in the extracurricular projects in which our students participate, and in the inclusion of our required course in Technology and Society. We find that the idea of "engineers making the world a better place" resonates strongly with our students and is a powerful concept in the recruitment and retention of female engineering students. The recruitment and retention aspect of the course is a component of our NSF STEP grant project (NSF DUE-0525388: Increasing the Representation of Women in STEM via a New Interdisciplinary Engineering Program at a Liberal Arts Women's College).

A unique aspect of our course is that, while it is required for engineering majors, it is also open to non-engineers. The course fulfills two of Sweet Briar's general education requirements: (i) Appreciate and apply ethical reasoning and (ii) Understand how economic, political, and legal systems shape the modern world. As a result, a percentage of the course is made up of humanities and business majors. While it is fairly common for engineering departments to offer courses for majors in non-technical fields, the goal of these courses is usually to increase the "technical literacy" of these non-majors.[4] This is a secondary benefit of our course, however our primary goal in bringing non-majors into a required engineering course is to expand the discussion of the relationship between technology and society to include the viewpoints of non-engineers. We feel that the quality of the course is improved by the inclusion of students whose world view may be radically different from that of the average engineer.

Structure of the Course

Our principle goals for the Technology and Society course are for students to gain an appreciation of the critical role that *social realities* play in engineering and technology, and for them to apply this knowledge to inform and motivate their own professional practice.

Towards these goals, the course is composed of two major components: 1) Directed readings and discussion of case studies and historical material and, 2) A "socially-conscious" design project.

The course was taught for the first time during the Spring semester of 2009. The directed readings were drawn primarily from the text for the course, Richard Pool's "Beyond Engineering: How Society Shapes Technology."[5] The reading topics in order of coverage were:

- Technology and social momentum: Edison and the development of the light bulb
- Just in time inventing: Development of the Chevy Volt REF
- The power of ideas: The birth of the U.S. nuclear power industry
- Agility vs. size: Development of the personal computer market
- The costs of complexity
- Social influences in technological choices: Steam vs. internal combustion
- Perception of risk: Use of rBGH hormones in dairy cattle
- The properties of high reliability organizations

The case studies were selected as a cross-section of projects that were profoundly affected by unanticipated societal factors. The object of these readings was to encourage students to think about the differences in how technology is perceived by engineers and scientists as opposed to the larger society. Students were asked to keep a reading journal that summarized their thoughts on the assigned material and to bring their journals to class. Classes were then completely devoted to an open discussion and debate of ideas from the assigned readings. We chose this open discussion format over a class lecture format in order to avoid the impression that the instructors knew the "correct" way of thinking about the issues. Rather, we wanted to encourage students to develop their own ideas regarding the relationships between technology, society, and the engineering profession.

While the reading component of the course emphasized learning from the past, the intent of the socially-conscious design project was to encourage students to consider how they want to shape the future through their own professional practice. We wanted our students to have the opportunity to experience first-hand the rewards of applying one's knowledge and skills in order to help others. This opportunity may lead our students to see the engineering profession in a new light and to consider paths for the future which they may not have previously considered.
Our partner for the design project was Lynchburg Sheltered Industries (LSI). LSI is a not-for-profit business whose charter is to assist people with disabilities or disadvantages to achieve greater independence and self-esteem through vocational training and employment. LSI employs people with a range of developmental disabilities to perform light manufacturing tasks on a contract basis. One of the products assembled at LSI is a contact block for a limit switch assembly that is used in commercial pipeline valves. The contact block is shown in Figure 1., in the hands of an LSI employee. A single block is an assembly of over 200 parts, most of which are quite small. This presents a serious obstacle to developmentally disabled employees as their disability is often accompanied by impaired hand/eye coordination.

Assembly of the contact block is performed in three stages, each of which consists of a series of manual operations to build a subassembly. Each of the three stages requires an increasing degree of manual dexterity and planning. The first assembly stage is the easiest and can be performed by several LSI employees. The second has more and smaller parts and can only be performed by a small group of employees. The final assembly of the contact panel is the most complex step, requiring a high degree of manual dexterity. Before our students took on this project this final assembly could only be performed by an LSI employee who had no developmental disabilities.


Figure 1: LSI employee holding a contact block assembly (in his left hand).

The goal of our design project was to analyze the switch block assembly process and to design fixtures and tooling that would decrease the degree of manual dexterity required for each step. This would increase the number of disabled employees able to perform each assembly stage. Since LSI's production is limited by the number of employees capable of performing each task, our project would, if successful, create new jobs for LSI employees with developmental disabilities.

We began the project by asking our students to perform research into design for the developmentally disabled. This research was presented and discussed in class in the context of its application at LSI. Next, the class met at LSI in order to learn the assembly process and to discuss the assembly process with the LSI employees. This was a critical design step as our students found that they could not always anticipate the steps of the process that were difficult for LSI employees. Only by listening to the developmentally disabled employees were the students able to identify the problems that needed to be solved.

The class was divided into three design teams in order to address each of the three assembly stages. Design work was loosely based on a structured design process. Each team was required to write a problem definition and preliminary specification. Teams then held brainstorming sessions to identify and rank solution variants. Preliminary designs were selected and modeled in Autodesk Inventor. Once preliminary CAD models were complete we returned to LSI for a preliminary design review with their employees. Based on feedback from this review designs were modified and CAD models and engineering drawings for prototypes were generated. Our students then fabricated the prototypes in our machine shop. Students then returned to LSI with their prototypes for testing and another round of input from employees. A final set of modifications was incorporated into the designs and a final set of engineering drawings was created. Finally, a full set of tooling was manufactured by our students and delivered to LSI.

Figure 2 shows representative samples of the tooling design by our students for this project. Each tool and fixture was designed to hold, clamp, and position groups of small parts as they are assembled. These tools significantly reduced the level of manual dexterity required for assembly of the contact block. This increased the number of developmentally-disabled employees who are capable of performing each assembly stage including the final, most difficult stage.

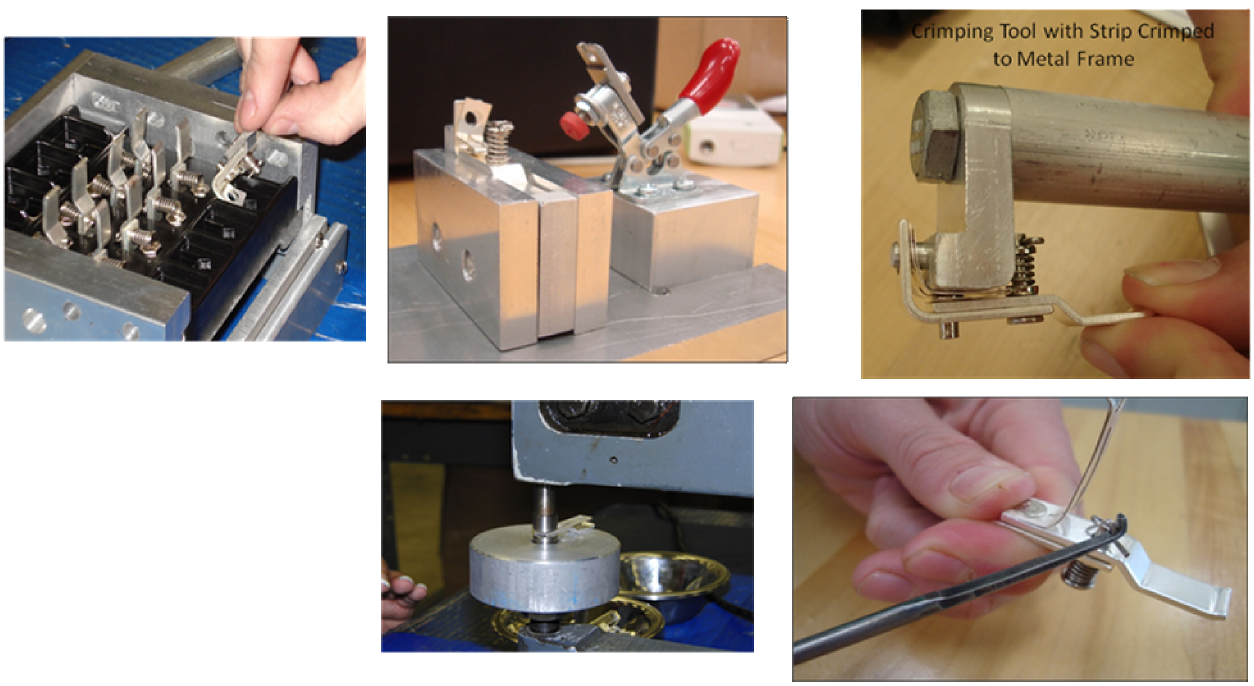

Figure 2: Prototypes of tooling designed by our students to aid in the assembly of contact blocks.

In order to document our work on the project, each design group was required to write a design report describing their work. The design reports from all three groups were entered into the National Scholar Award for Workplace Innovation, a design contest sponsored by NISH (www.nish.org) NISH is a national nonprofit whose mission is to create employment opportunities for people with severe disabilities. Our students who designed the tooling for the third stage of assembly of the contact block were rewarded with a tie for the third place award in this national design competition.

Assessment of Student Work

Student grades for the course were based on:

- Grading of reading journals. Grades were based on degree to which students demonstrated that they had read the material and thought through the salient points of the readings.
- Assessment of each student's participation in the course. Based on instructor assessment and on a written survey of each design group.
- Assessment of design project work.
- An essay-format final exam.

The assessment of the design project work was performed using a grading rubrick designed to judge the quality of the group's design ideas, the effectiveness of the group's interactions with each other and the customer, and the extent to which the group brought their portion of the project to completion. Assessment was performed independently by each of the course instructors.

The final exam was designed to measure the extent to which students gained an appreciation of the critical role that social realities play in engineering and technology. The final consisted of the following questions:

1) In the book "Beyond Engineering," the author states that "Engineers should pay more attention to the larger world in which their devices will function, and they should consciously take that world into account in their designs." Looking back to the accidents discussed in our text, how might engineers have behaved differently if they had taken the above quote seriously? Provide three examples of this.

2) In our work with LSI and their workers we tried to take the larger world into account. Describe how you did this and describe, more importantly, what else you could have done.

Students were also asked to write a short essay on the properties of "high-reliability organizations" and to explain how these properties account for social forces that can lead to a degradation of organizational reliability.

Results and Course Assessment

Table 1 lists the desired student learning outcomes and our assessment of those outcomes for the Technology and Society course. As indicated, our assessment is based on the student assessment instruments discussed in the previous section and on our own, subjective assessment of each outcome.

For outcomes related to internalization of the lessons of the case studies students met the target ratings. This would indicate that the readings, reading journal, and open discussions were an effective pedagogical approach. We were somewhat dissatisfied with the students' ability to characterize the properties of high-reliability organizations. This is a significant topic as development of such an organization requires a sound understanding of human and social factors. The readings for this topic came at the end of the semester and we were not able to devote the class discussion time to this topic that it deserves.

Ratings of the outcomes intended to assess student work on the design project were somewhat below our targets. This reflects our dissatisfaction with the efforts of two of the three design groups to collaborate effectively within their own group. It is clear that a greater emphasis on teamwork skills would be appropriate for the course.

ENGR 230 Learning Outcomes **At the end of the course, students will be able to**	**Assessment Method**	**Target Rating**	**Actual Rating**	**Instructor Rating** (1 below expectations, 2 progress toward criterion, 3 meeting criterion, 4 exceeding criterion)
1) Cite examples and explain how the profession and practice of engineering is often fundamentally defined by social realities and concerns that exert a deeper impact on engineers' professional practice than technical constraints or scientific fact.	Rubric, average of 6 reading journal entries	3 out of 4	3.4 out of 4	3
2) Assess examples of engineering safety failures in the context of societal impact and nontechnical factors	Final exam essay Q1a	8 out of 10	7.97	3
3) Compare their experiences with their project client in light of the nontechnical requirements of the class design project	Final exam essay Q1b	8 out of 10	8.23	3
4) Identify specific goals and/or tasks that accurately reflect the needs of the customer and that reflect appropriate constraints	design rubric (q1)	3 out of 4	3	3
5) Design an engineering solution to achieve the needs of the customer	design rubric (q3)	3 out of 4	2.67	2
6) Fabricate (or take responsibility for the fabrication of) final designs for the customer	design rubric (q5)	3 out of 4	2.67	2
7) Solicit and incorporate feedback from the customer in design revisions	design rubric (q6)	3 out of 4	3.33	3
8) collaborate in a way that makes effective use of their skills and manpower	design rubric (q9)	3 out of 4	2.67	2
9) communicate effectively within their design team and with the customer and vendors	design rubric (q10)	3 out of 4	3.0	3
10) compare and contrast the behaviors of high and low reliability organizations and explain the role of education in this organizations	Final exam essay Q2	8 out of 10	7.9	2

Table 1: Assessment of course learning outcomes

In addition to the outcomes listed in Table 1, at the end of the course students were asked to rank the degree to which the course helped them meet the SBC general education requirement, “To understand how economic, political, and legal systems shape the modern world.” Of the fifteen students in the class, two felt that they had made “no progress” towards this understanding, six said that they made “some progress,” six said that they had made “significant progress” and one felt that she had developed an “in depth understanding” of these social forces.

Finally, as part of the end of course survey students were asked to rank the degree to which they agreed with the statement, “I am a better engineer for having taken this course.” Of the twelve engineering majors who responded to this statement, one “strongly disagreed,” one was “neutral,” five “agreed,” and five “strongly agreed.”

Conclusions and Improvements

Our stated goals in the development of the Technology and Society course were for students to gain an appreciation of the critical role that social realities play in engineering and technology, and for them to apply this knowledge to inform and motivate their own professional practice. In this paper we have described our efforts towards these goals. Our assessment of student work indicates that the directed readings and class discussions were effective in helping students to appreciate the complex interactions between technology and society. The socially-conscious design project provided a vehicle for students to experience the professional satisfaction that comes with using one’s skills to help others. Based on student comments during the course and the degree to which students feel that the course made them better engineers we feel that the course will inform and motivate their future practice.

A key goal of the development of the Technology and Society course is to use the results of this educational approach to market our engineering program to high school women. Market research has shown that the idea of “making a difference in the world with engineering” often resonates with high school students, especially women.[9] Use of the Technology and Society course for recruiting has taken many forms, from our program newsletter and website, to discussing with prospective students at our on campus Explore Engineering at Sweet Briar events for high school women. We have found that many high school students that hear about our course walk away with a different perception of the field of engineering.
The most immediate improvement that needs to be made to the course is to address project collaboration skills. It was clear that many of our students did not know how to organize the work within their design groups for effective collaboration. Towards this end we are exploring the possibility of creating a “virtual design studio” where students can share design content and ideas without the need for face-to-face communication. This could help to alleviate scheduling issues that were at the core of some of the collaboration problems.

Finally, in the future, we would like to find a way to expand this course to include more non-engineering majors. A strength of a small college like Sweet Briar is the ease with which one can gather students with widely differing perspectives. We plan to investigate the possibility of teaching our Technology and Society course in conjunction with courses from other majors so that readings and discussions can include a broader range of views.

The course syllabus, schedule, and additional matieral is available online via http://hyochum.physics.sbc.edu.

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