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Incorporation of Liberal Education into the Engineering Curriculum at a Polytechnic

Dr. Devin R. Berg, University of Wisconsin, Stout

Devin Berg is an Associate Professor and Program Director of the B.S. Manufacturing Engineering and B.S. Mechanical Engineering programs in the Engineering and Technology Department at the University of Wisconsin - Stout.

Dr. Tina Lee, University of Wisconsin, Stout

Dr. Tina Lee is an Associate Professor of Anthropology and the Program Director for the Applied Social Science Program at the University of Wisconsin-Stout.

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Abstract

Traditional engineering education often falls short when it comes to the inclusion of issues related to social justice, ethics, and globalization. While engineering programs are required to include ethics content for accreditation, most seem to rely primarily on general education electives, providing only a high-level overview and including the bare minimum in the program core. This can lead to an inconsistent student experience and minimal exposure to topics which are critically important for achieving worldwide equity and operating responsibly in the engineering workplace. Given the role that engineers play in economic development, this is unacceptable. It is therefore the responsibility of engineering educators to find a better way to shape the future of the engineering profession. This paper outlines the early efforts at integrating the topics of ethics, social justice, and social responsibility more directly into the engineering curriculum. This is approached from the perspectives of pedagogy, curriculum development, and service learning opportunities. It is within this context that the authors hope to influence students' awareness of and connection to social and environmental issues as well as the ethical frameworks they develop and carry with them into their professional careers. This paper centers around the creation and delivery of a new introductory engineering course combining liberal education topics and introductory engineering topics. This course also includes a substantial design project which incorporates a cultural engagement component through collaboration with international partners. The first offering of this new course revealed that, while some reservations persist, students found value in exploring what it means to be an engineer in a broader global context.

Introduction

A traditional engineering curriculum will likely fail to provide students with the critical skills of cultural engagement necessary to live and work in a globally connected world and profession. It is not surprising that much of the traditional engineering curriculum has been focused on providing solutions to the problems of the world's wealthiest citizens.[1] In response, a more modern vision for engineering education promotes "a world where all people have access to basic resources and knowledge to meet their self-identified engineering and economic development needs."[2] By providing students the opportunity to explore the engineering curriculum as it applies to the challenges of globalization, population explosion, resource depletion, and so on, we are promoting and contributing to a more socially aware and responsible profession: "Addressing the needs of clean water, sanitation, energy, shelter, etc. is no longer an option for the engineering profession; it is an ethical obligation. Both engineering practice and engineering education need

to be considered."[3] Educational experiences that integrate liberal education content into the engineering curriculum have expanded as the role of an engineer in the workplace and in society is reexamined.[4,5] Indeed, as argued by Grasso in 2002, it is engineering faculty's responsibility to complement technical curriculum with a humanistic approach to meet the needs of society.[6] This content can take many forms such as enhanced discussion of ethics or service learning opportunities. Other examples include integration of curriculum modules covering social justice directly into technical coursework, thus forcing students to examine technical concepts more holistically and blurring the traditional disciplinary boundaries.[7]

Often these approaches are suggested as a means to broaden the appeal of engineering education to a wider range of gender and ethnic categories.[8] These activities seek to engage students in critical thinking processes while simultaneously achieving a greater sense of civic and social responsibility. However, depending on the approach there are inherent technical, cultural and political limitations which can privilege students and teachers at the expense of the communities being served.[9] With that in mind, we note that analysis of practices such as service learning show positive effects on students' attitudes, social behavior, and academic performance.[10] As such, finding the most effective means by which these topics and pedagogical approaches can be integrated into the engineering curriculum has the potential to influence the engineering profession for great benefit to society. As noted by Chan and Fishbein:

> "As the world becomes more complex and interrelated, so do the problems engineers face. The engineering profession and individual engineers need to adapt or else risk getting lost in these global changes, thus abandoning our social responsibilities."[11]

The University of Wisconsin-Stout's institutional mission encourages faculty and staff to "integrate applied learning, scientific theory, humanistic understanding, creativity and research to solve real-world problems, grow the economy and serve a global society." However, with the polytechnic designation comes an increased focus on applied learning techniques and career focused curriculum, which can lead students to have a narrow view of what curriculum is relevant to their careers. If we are to achieve the tenets of a polytechnic institution then it is important to both understand what skills employers seek from our graduates as well as the pedagogical methods we can employ to best achieve these skills. For example, it is important to first ensure that both instructors and students make the connection between personal and professional views of their own social, environmental, and ethical obligations.[12] While industry claims to desire students who are well prepared to work in a global, cross-cultural environment, the curriculum which will produce these outcomes can often be pushed aside. The reasons for this are likely varied and range from industry advisory boards for academic programs pushing for increased technical content to ever decreasing university budgets requiring academic departments to become more internally competitive for student credit hours. Students at this institution have available a variety opportunities for pursuing these topics ranging from "general education" courses to independent service learning involvement. However, few of these are integrated directly into the engineering curriculum.

This paper outlines the authors' first efforts at integrating topics such as ethics, social justice, and social responsibility into engineering education at a polytechnic institution. The long-term approach includes perspectives of pedagogy, curriculum development, and service learning opportunities. The first effort described here focuses on the development of an introductory

course for undergraduate engineering and non-engineering students that incorporates some aspects of service learning. It is within this context that the authors hope to influence students' awareness of and connection to social and environmental issues as well as the ethical frameworks they develop and carry with them into their professional careers. The following sections include discussion of early experiences with these efforts and anticipated future developments of this work-in-progress.

Curriculum Development

Currently, engineering students at UW-Stout are exposed to the topics of ethics, social justice, and social responsibility through general education electives and through limited discussion in capstone courses. In addition there is a selection of "extra-curricular" opportunities for student engagement, most notably a chapter of Engineers Without Borders USA, however these opportunities don't carry curricular integration. The first effort at more directly integrating these topics into the engineering curriculum was through the development of a new course called "Impacts of Engineering," which is described in the course documentation as:

> "A comprehensive study of the engineering design process from initiation to completion. Definition and history of engineering disciplines with comparisons among them. Investigation and exploration of past and present impacts of engineering on people, society, and the environment. Examination of contemporary and emerging issues related to engineering. Introduction to engineering in practice through engineering design projects."

and has the stated course objectives as presented in Textbox 1. This course serves as an introductory engineering course and is being integrated as a required course for all engineering programs at the institution. While the course is required for students in an engineering major, the course is also open to non-engineering students. This enables non-engineering students to gain exposure to engineering principles and also creates opportunities for students from diverse backgrounds to come together and work on engineering problems. The content coverage of the course includes much of the curriculum typically found in introductory engineering courses such as historical perspectives, the engineering design process, and computational techniques. However, additional content was included related to social consciousness, social justice, and globalization. This course serves to satisfy the institutional general education requirements relating to global perspectives, contemporary issues, and social responsibility and ethical reasoning. This was accomplished through a collaboration between the engineering faculty and faculty from the Social Science department. In particular, objectives three through seven were written to address the spirit of these general education categories.

As this course was newly developed, it has been delivered in full for one semester and is currently being delivered for the second time. The course is organized with two major components, first a traditional lecture setting in which the curriculum is explored and discussed in both presentation and small group discussion formats. The in-class discussions are supplemented by out-of-class discussions making use of social media[13] and by writing assignments which encourage thoughtful consideration of both the technical aspects of engineering and the non-technical aspects such as

Successful completion of the course will enable students to:

1. Demonstrate an understanding of the historical philosophy of engineering and identify the effects of engineering design decisions throughout history.
2. Describe the various engineering disciplines and the differences between them.
3. Demonstrate an understanding of the comprehensive nature of engineering design.
4. Develop a systems perspective regarding the context of engineering design on a global scale.
5. Evaluate the ethical, social, economic, and environmental impacts of engineering during the design, production, and end user phase of a product's life from multiple perspectives.
6. Synthesize ethically, socially, and environmentally conscious design judgments and decisions.
7. Evaluate trends and future impacts of environmental and social consciousness and globalization on engineering design and manufacturing from multiple perspectives.
8. Demonstrate an experiential understanding of engineering design impacts relevant to the various engineering disciplines.
9. Apply basic calculation procedures and computational tools used in engineering.
10. Apply the engineering design process and employ it to solve real-world issues.

Textbox 1: Stated educational objectives of the Impacts of Engineering course.

the roles and responsibilities of an engineer in society. More in depth coverage of the writing aspects of the course will be presented in a later work. The second component of the course is organized around a laboratory setting in which students explore the course curriculum through the completion of a comprehensive engineering design project. The intent behind the engineering design project is to expose students to various aspects of the engineering design process while at the same time having a positive impact on the world.

The design project incorporated into the first delivery of this course involved the design of a paper recycling process and resulting product. This project was conducted in partnership with an organization known as Gift 2 Change,[14] founded by Fombah Lasana Kanneh of Monrovia, Liberia (Figure 1). The organization's mission is to "help reduce poverty and build a middle class society through waste recycling." The organization currently operates by collecting discarded clothing and furniture and reprocessing these items into products that can be sold. The money raised through this process is used to provide employment for the men and women of Monrovia and to fund youth programs which provide clothing, books, educational materials, and training to the poorest children in Monrovia and the surrounding rural areas. The goal of the course project was to explore new directions for Gift 2 Change involving the collection and reprocessing of paper products for review and possible implementation by the organization.

As the course progressed, students were guided through the design process through both lecture content and small group work. Students were able to communicate with Fombah for assistance with their questions as they arose. In addition to the technical aspects of the design, students had to research societal and environmental considerations in Liberia to ensure that their design made sense for the region and the result would be marketable to best ensure success. In the first semester, seven student groups pursued designs to develop a recycled paper product for Gift 2 Change.

Figure 1: Fombah Lasana Kanneh runs Gift 2 Change in Monrovia, Liberia[14]. Used with permission.

Results and Discussion

Each of the seven students groups developed independent solutions drawing from a variety of possible processing techniques. The end products that student groups proposed for implementation included decorative and functional bowls, fire briquettes, papercrete bricks, disposable pillows, and a paper-based soil additive similar to compost. While these ideas are not necessarily novel as means of producing goods out of paper and paper pulp, students were forced to think about what form of processing techniques would be accessible to Gift 2 Change and its employees. Further, these solutions suggest that students looked to a variety of industries for inspiration such as agriculture, construction, and medical care as well as basic home comfort. As shown in Figure 2, students explored various means of processing recycled paper. Students also investigated various aspects of their intended product in order to develop the best result. For example, in Figure 3a students are packing a mold to make a papercrete brick. These students tested various ratios of paper to concrete to better understand how the ratio affects the curing time and the quality of the resulting brick. In Figure 3b, students are testing various shapes and densities of fire briquettes to better understand burn time, heat output, and smoke or soot production. The final products of the students' designs demonstrate the results of their testing and iteration.

Students who completed the first offering of the course were given an open ended survey regarding their primary takeaway from the course and how the course has influenced their views of society and the role of engineers within it. Student responses (n=27 of 35 enrolled students) were qualitatively coded and sorted into broad themes as described below.

(a) (b)

Figure 2: Examples of students testing the paper-concrete brick making using both (a) hand processing and (b) powered mixing. Figure files available under CC-BY.[15]

When asked about their primary takeaway from the course, the most common student responses were:

- Must think about impact your solution/design has on community/world (n=8)
- More about what engineering is and what being an engineer means (n=8)
- Design process (n=3)
- Role of ethics (n=3)

These responses revealed that for some students, the role of comprehensive design became more apparent and the role of engineers in society more clear. Some specific quotes from students' responses included:

> "The primary thing I have learned from this course is that all people, especially engineers, should feel obligated to serve their fellow community and the world from an ethical stand point always taking into account social and ethical responsibilities they have when designing and conducting business."

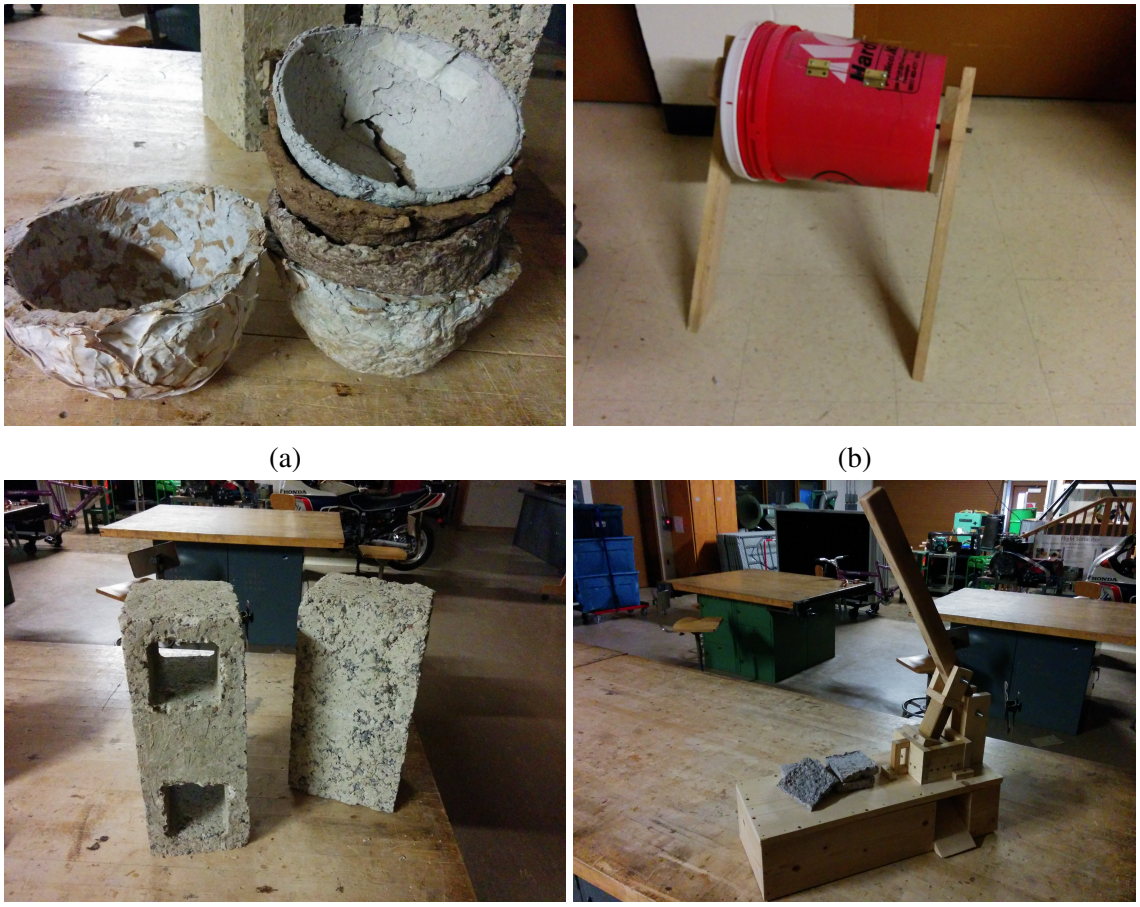
and

> "I have learned to think a lot more broadly about my design decisions. This class put into perspective the effects your decisions can have on society. Therefore, there is a lot more thought that has to go into decisions than I originally thought."

(a)

(b)

Figure 3: Examples of student project progress including (a) paper-concrete brick packing and (b) testing the fire briquettes. Figure files available under CC-BY.[15]



(a) (b) (c) (d)

Figure 4: Examples of student project designs including (a) bowls, (b) paper-based compost, (c) bricks, and (d) fire briquettes and a briquette press. Figure files available under CC-BY.[15]

These sentiments speak directly to the intended course outcomes described in Textbox 1. While there is certainly room for improvement, the course seems to be communicating the desired message to students regarding our goals for the future of engineering development.

When asked how the course has influenced their views, the most common student responses were:

- Positive role engineers can have in the world (n=4)
- It hasn't (n=4)
- Solidified career choice (n=3)
- Must stand behind morals and ethics (n=2)
- You must take into consideration all who might be effected by your work (n=2)

From these responses we can see that some students were less influenced by the course when it came to changing their outlook. It is unclear whether the lack of influence reflects that some students came into the course already sharing the viewpoint presented and their views did not change for that reason or whether some inherently disagreed with the notions communicated in this course and the course did not change their minds. These results may also indicate that greater repetition of these messages is necessary before the ideas take hold and they begin to mold more closely held beliefs such as their world views. Some examples of student responses to this question included:

> "View of the world, we learned basics of engineering but I felt there was a theme of how to view ahead of yourself and to take into consideration everyone else you could be affecting, including through your ethics."

and

> "This class has changed my views of the world in that we should all work together to solve problems, because people from different backgrounds bring different ideas and ways of doing things."

In contrast to those students who claimed unchanged views, there were also those for whom the course had an influence. These quotes include some insightful commentary on the need for inclusivity not only in the considerations factored into an engineering design but in the make-up of the design team itself. This idea hints at an understanding of the value and importance of diversity both in engineering education and in the engineering workforce.

A quantitative survey instrument is being developed[16] as an adaptation of the Sustainability Skills and Dispositions Scale[17] in order to assess the impact of course curriculum on student learning outcomes. This instrument asks students to rate themselves in terms of their confidence in technical design and in working with communities and measures their sense of their responsibilities as professionals in a global, social and environmental contexts. Also included are some items from the Engineering Professional Responsibility Assessment.[18] This survey asks students to rate to what degree their professional responsibilities include such things as volunteering, doing pro bono work, changing designs with input from communities, etc. Finally, some questions from the ethnocentrism scale developed by Neuliep and McCroskey[19] were

included. This survey measures attitudes towards cultural differences and will be useful in seeing if students grow in their knowledge of and attitude towards the differences they encounter when designing engineering solutions in a different culture. Finally, basic demographic information (race/ethnicity, gender, etc.) was collected. However, as this is an early report of this work-in-progress, analysis of the survey data has not yet been completed. This analysis will be reported at a later date.

Conclusions and Future Directions

As these efforts progress and the authors expand their understanding of the influence of liberal education on engineering curriculum, we plan to continue to explore the means by which these two areas are more closely integrated and are then less viewed as separate areas but more as two sides of the same issue. While the course discussed here is only a small start, looking to the work of others, there are opportunities for greater integration of topics such as ethics, sustainability, and social justice into core engineering courses.[7] Students at this institution currently have access to a chapter of Engineers Without Borders USA. However, it is not clear whether participation in such a group achieves the desired effect on students' professional outlook. Perhaps integrating similar service learning opportunities more directly into the engineering classroom provides a more controlled environment where progress towards the desired outcomes can be monitored more closely.

Through future work, the authors intend to expand on these efforts and develop a new undergraduate course on Global Engineering, which will further solidify the connections between the fields of Engineering and Technology, Social Science, and Ethics. The new course will grow out of careful study and in-depth analysis of the needs facing the engineers of today and how to best prepare students for this reality, building upon the foundational principles introduced in the course presented here and thus providing repetition of the core themes of the curriculum. The course will include content on the responsibilities of corporations working both domestically and internationally as well as on global development work with careful considerations for impacted populations in both situations. Chan and Fishbein[11] refer to the "global engineer" as one with a defined sense of social responsibility and ethics, entrepreneurism, and the ability to deal with complexity and systems thinking. The new junior level Global Engineering course will possibly be offered as a university general education course, and included as an elective for all engineering and technology and social science students. Through this course, we hope to meet the call "to integrate development or critical studies in the required curricula for students working with 'underserved' communities. Humanities scholars, social scientists, and engineers who teach in and coordinate these programs should instill in students a sense of long- term responsibility towards their projects by challenging them to explore long-term evaluation of current and past projects and to learn from past successes and failures."[20]

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