Bridging the Gap: Bringing Context into Engineering Education

Rei Marzoughi

Department of Civil Engineering, University of Toronto

Abstract

Standard engineering education often focuses on disseminating specialized, technical knowledge with the overall goal of training competent designers and decision-makers. Students learn to reach a desired outcome by focusing on improving the efficiency of the object or procedure in question; however, the social, historical and environmental context in which this problem exists is often dealt with marginally or completely ignored. As a result, in engineering practice, unexpected undesired outcomes often arise out of actions that were intended to improve a particular problem.

As a student, I have experienced two different engineering programs, each with a unique approach to addressing the lack of context in engineering education and practice. During my undergrad, I took part in the Engineering and Society program at McMaster University, and during my current graduate work, I am a part of the Centre for Technology and Social Development at the University of Toronto. Each program attempts to teach students how to think more broadly, balancing breadth and depth in order to develop a new approach to engineering problems. The Engineering and Society program uses a technique called "inquiry" throughout the curriculum and encourages engineering students to focus on a discipline outside of engineering throughout their undergraduate education. The Centre of Technology and Social Development builds a historical context for understanding the interaction between technology, society and the biosphere through a series of courses. Each program has benefits and drawbacks. This paper will discuss my personal experience in these programs and discuss a way in which the advantages of each one could be combined in order to help improve the overall engineering education experience.

Introduction

Engineering programs are known to be challenging, demanding and intense; most people view engineering education as very technical, rational and scientific. Throughout my engineering education I have experienced two different programs, both of which attempt to go beyond the typical engineering curriculum to provide a unique understanding of the profession. As an undergraduate engineering student, I attended the Engineering and Society program at McMaster University. Briefly put, the intent of this program is to enrich engineering education with breadth courses from the social sciences and humanities, while also providing core courses that focus on topics such as sustainable development, public policy, engineering ethics and the history of technology. As a graduate student, I have taken courses at the Centre for Technology and Social development, which place emphasis on building the historical and cultural context required to understand the interaction between science, technology, society and the environment, as well as where the engineering profession sits in relation to this interaction. The intent of both programs is to provide students with the context required to become more well-rounded engineers capable of seeing the complexity of problem-solving so that not all problems appear to be solely technical. When reflecting on my education thus far, I am faced with two questions: How well do these programs deepen our understanding of how technology is influencing human life, society and the biosphere? Are they successful in helping future engineers adjust design and decision-making to technically execute engineering endeavors but at the same time prevent or greatly minimize the harmful effects such endeavors may exert on society and the biosphere?

These two questions were the basis for a study of conventional undergraduate engineering education conducted by Vanderburg and Khan (1994) [1]. The study uses two research instruments, which were extensively tested, to score each component in a typical undergraduate engineering curriculum. The first instrument examines how well students learn to relate the implications of technical knowledge to human life and the environment and how prepared they will be to use this understanding to exercise professional responsibility. The second instrument measures the degree to which social sciences and humanities electives complement the technical core of the curriculum. Details of the scoring system are included in Table 1 and the research findings are included in Table 2. The overall picture reflects engineering curriculums that are highly specialized with lack of reference to context[2].

The implications of these findings are far reaching. Do the results imply that we simply have not faced the problem of how to get the technical core of the curriculum to work synergistically with the complementary studies component? What does this mean with regards to the ability of our profession to protect the public interest? The purpose of my paper is to interpret my own engineering education through the use of the two questions posed earlier, and in relation to the findings of the study described above.

The Engineering and Society Program

Engineering and Society (E&S) is a five year program in which students partake in the exact same courses as regular engineering students, with the addition of focus courses in a discipline outside of engineering, as well as a set of core E&S courses. As a result, students may obtain a minor in a discipline other than engineering while still obtaining a bachelor of engineering degree. There are seven E&S core courses, which focus on different issues related to engineering, development and technology. These seven courses include one full-year independent thesis project.

The Technical Core

Because the technical core of this program is identical to that taken by any other engineering student at McMaster University, much of the same criticism that arose from the education study applies here as well. Just like in any typical undergraduate engineering program, the courses are highly specialized and focused on teaching a very technically driven problem solving methodology. Most courses do not include any components that address the social or environmental implications of engineering practice. As a result, the curriculum is very fast-paced, with little time for reflection. I personally struggled to connect what I was learning in the technical core of my chemical engineering program with my desire to help people and participate in the profession in a way that inspires me. I think many students have a similar problem; it is note easy to connect abstract, scientific and technical knowledge to real world issues and problems, especially when the connection is rarely even addressed peripherally. This leaves many students asking, “What is the point of all these assignments?”.

Table 1. Research Instruments

Scoring System	Technical Courses
0	no reference to context issues.
1	minor reference(s) to context issues which remain peripheral to the thrust of the paper or course. Usually, this amounts to little more than outlining the context in which the problem arose, but once the problem is cast in engineering terms, little or no reference to context is made.
2	some reference to context issues with some consequences for the thrust of the paper or course.
3	major reference to context issues with substantial consequences for the thrust of the paper or course.
4	substantial consideration of context (as in 3) plus evaluation of consequences to adjust or reassess methods or theories (i.e., 4 includes some negative feedback; 3 does not).
Context Issues Include	
a)	implications of technology for human life, society, or nature.
b)	ethical considerations and relationships to values.
c)	nontechnical aspects of engineering education and the professional paradigm (following T. S. Kuhn).
d)	implications of engineering theories and practices, including the consequences of quantification and mathematisation, particularly of a qualitative sociocultural human reality.
e)	implications of engineering decision making, including the implicit and explicit values, beliefs, assumptions, and models which guide it.
Scoring System	**Complementary Studies Courses**
0	no reference to technological issues.
1	minor reference(s) to technological issues, which remain peripheral to the thrust of the paper or course. Usually, this amounts to little more than outlining the problem, but once the problem is cast in social scientific terms, little or no reference to technology is made.
2	some reference to technological issues, which have some influence on the thrust of the paper or course.
3	major reference to technological issues, with substantial consequences for the thrust of the paper or course.
4	substantial consideration of technology (as in 3), plus evaluation of consequences to adjust or reassess methods and theories used in engineering and technological practice or in the social sciences and humanities.

Table 2. Faculty Scores

	CHE	CIV	ELE	ESC	IND	MEC	MMS	MEAN
Core courses								
Year 1	0.5	0.5	0.4	0.1	0.8	0.3	0.5	0.4
Year 2	0.3	0.7	0.3	0.6	0.5	0.2	0.3	0.4
Year 3	0.7	1.2	0.7		1.6	0.7	0.9	1
Year 4	1.8	1.4				1.3		1.5
N	30	38	29	18		32	26	
Core and technical electives								
Year 1	0.5	0.4	0.4	0.3	0.8	0.3	0.6	0.5
Year 2	0.4	0.6	0.4	0.6	0.5	0.3	0.4	0.5
Year 3	0.7	1.1	0.6	0.7	1.5	0.8	0.9	0.9
Year 4	1.5	1.5	0.8	1.1	1.3	0.9	0.5	1.1
N	57	51	67	94	43	67	47	
Publications								
Score	0.2	0.6	0.1	0.2	0.6	0.2	0.3	0.3
N	367	237	306	204	121	290	169	

.

Complementary Studies

As mentioned, in the E&S program, there are two complementary study components. Because the program is extended by a year, students have more room in their schedules for electives, allowing for an average of two electives per year of study. This is very helpful for students who have interests outside of engineering that they wish to cultivate. It also breaks up the monotony of technical courses with courses that use different skill sets. For this reason, students who participate in E&S generally graduate with relatively developed writing skills and more experience with conceptualizing knowledge of history and culture. Potentially this could have an impact on the kinds of career choices these students make.

I chose to study art history and cultural studies as my focus outside of chemical engineering. As a high school student, I enjoyed English and art courses; I have always loved writing. Having this focus area to break up the routine of technical courses is what helped me finish my degree; without this opportunity, I think my educational experience would have felt very constrictive and maybe even unbearable. As PhD student, the cultural theory I was exposed to thanks to cultural studies courses has been very helpful in formulating some of my thoughts and ideas. Furthermore, because I was forced to write many academic papers, I feel very comfortable with writing – more comfortable than many of my friends who did not participate in the E&S program.

The second complementary study component is the set of 7 core E&S courses that all students participating in the program must pass. The core courses explore the way technology shapes society and is in turn shaped by society. A problem solving approach called *inquiry* is taught in the first core course and continually used throughout the entire program. Inquiry teaches students to formulate questions, carry out research and communicate findings; this is very helpful for students who are interested in pursuing graduate studies or careers in research and development. The core courses are briefly described below.

E&S 2X03 – Inquiry in an Engineering Context I – Year 2
This course introduces the idea of inquiry and uses the City of Hamilton as a case study to allow the exploration of civic and public issues through an inquiry project. Additionally, students work on different assignments that teach them to use community and university resources in research.

E&S 2Y03 – Case Studies in the History of Technology – Year 2
This course brings in guest lecturers each week for the purpose of exploring different topics in the history and philosophy of technology. Students are exposed to a number of different readings that emphasize the impact of technology on culture. At the end of the term, each student conducts a paper and presentation that focuses on a topic in the history of technology.

E&S 3Y03 – The Culture of Technology – Year 3
This course explores the nature of culture, the nature of technology and the role of groups in a culture dominated by technology. Students are exposed to many great 19th and 20th century thinkers such as Popper, Wittgenstein, Marx and Ellul.

E&S 3X03 – Inquiry in an Engineering Context II – Year 4
This course focuses on issues concerning the role of engineering and technology in society. Topics include international development, healthy work, sustainable development and appropriate technology.

E&S 3Z03 – Preventive engineering: Environmental Perspectives – Year 4
This course teaches the concept of preventive engineering (to be described later) and applies the concept to specific case studies. Students then use tools such as Life-Cycle Analysis to conduct a project on a particular engineering area.

E&S 4X03 – Inquiry in an Engineering Context III – Year 5
In this course, students conduct an independent inquiry project on the topic of their choice. Students select a supervisor and work with him/her to develop the project and to write up a thesis.

E&S 4Z03 THE SOCIAL CONTROL OF TECHNOLOGY - Year 5
This course examines the engineering profession with a focus on engineering ethics.

Overall, the core courses expose students to many new ideas and a unique way of considering the broader context of engineering education and practice. As a result, some E&S students end up pursuing careers with an environmental focus or continue their education in fields related to public policy. In terms of the individual courses, in theory, they are very useful; in practice, only a few of them manage to accomplish the goals they set. The main problem is that the program is under-funded and, as a result, under-staffed. Thus, very few of the core courses have regular instructors to teach the course for more than one or two years. Because of this some of the courses lack the required focus to leave a lasting impact with students.

The bigger issue is that, in my experience, it is difficult to connect the complementary studies (both the focus electives and the E&S core courses) with the technical core of the engineering program. As a student, I felt as though I was participating in two different academic worlds with very few avenues of integration. If the purpose of the program is to train engineers to become more responsible professionals, it can only be somewhat successful in doing so as long as these two worlds remain completely separated. For example, if in a chemical engineering course, students learn plant design with no mention of the implications these designs have for the workers or for the biosphere, then as professionals they will be less likely to make such considerations. Although such considerations are mentioned in the E&S core courses, they are not linked up with the actual engineering knowledge that students are learning in their technical core. As a result, it is difficult for these students to use their understanding of the interaction between technology, society and the biosphere in a negative feedback mode to adjust engineering approaches. In other words, the incompatibility between technological decisions and the context in which these decisions are made remains an issue.

Preventive Engineering

After completing my undergraduate years at McMaster, I began graduate studies at the University of Toronto. I am currently doing a PhD under the supervision of W.H. Vanderburg, the lead author of the above study on engineering education. When completing my course work, I took two graduate level courses, both dealing with the interaction of technology, science, society and the biosphere. These courses are JEI1901 – Technology, Society, and the Environment I, and JEI1902 – Technology, Society, and the Environment II. JEI1901 develops a conceptual framework for understanding technology-society-biosphere interactions. This understanding is then applied to the development of preventive approaches for the engineering, management and regulation of modern technology in order to reduce the burdens imposed on society and the environment[3]. Topics include: society as a cultural system, industrialization as a process that simultaneously transforms technology, society and the biosphere; technology as knowledge; the modern corporation; underdevelopment and technology transfer; and sustainable development. JEI1902 continues the development of this conceptual framework and extends the analysis to include the impact of more complex technology, in particular computer-based technologies. Topics include: the rationalization of intellectual work; technology as life-milieu, social force and system; feedback in the technological system and its response to values[3].

These courses provide a more rigorous and academic framework for analyzing the reciprocal relationship between technology and society. The reading material is challenging and quite dense, but the result is a deeper understanding of the history of culture and the impact of industrialization on its development. The central purpose of these courses is to teach students about preventive approaches to engineering, an idea recognized in 2002 by the Canadian Foundation for Innovation as one of 25 recent Canadian innovations. Preventive approaches for design and decision-making focus considering the context in which engineering problems are embedded and making a diagnosis that will enable the achievement of the desired results while simultaneously reducing or greatly minimizing any potential harmful side-effects. Thus, the knowledge of how technology influences human life, society and the biosphere is used to steadily improve the ratio of desired to undesired effects. This approach encourages the constant verification that any new technology is not a compensation for problems created by earlier technologies. Responsible design and decision-making involves going to the root of a problem, hence a distinction must be made between compensatory technologies/services and ones corresponding to real needs.

Both courses attempt to teach students that any critical evaluation of a technology depends on a frame of reference; what one group may deem to be a good technological solution may not be seen as such by others. Furthermore, because our lives are so intertwined with technology, we approach technology-related issues and problems with certain pre-judgments. Thus, we must constantly use negative feedback to ensure that as engineers, we are acting responsibly.

While these courses are more rigorous than those taught in the E&S program, they lack the elements of interaction. This is in part due to the fact that E&S extends the engineering curriculum by one year and thereby has more opportunity to incorporate different types of projects that involve different skills. Ideally, a combination of the two types of approaches would provide the most beneficial educational experience. For example, if the E&S courses adopted the more rigorous framework of the Centre for Technology and Social Development, the ideas of technology-society-biosphere interaction, sustainable development and engineering ethics could be pushed further.

Conclusion

The development of a preventive orientation in undergraduate engineering education depends on the creation of a synergistic relationship between the technical core and the complementary studies components of the curriculum. While the E&S program attempts to create a curriculum that is more balanced and well-rounded, it lacks this synergy and thus, in my experience, cannot adequately teach students to approach engineering problems preventively. At present, the engineering intellectual realm is full of technology and little else, while the complementary studies are full of context that is not linked adequately to the technology. This dualism makes it difficult for students to understand how their technical design and decision-making contributes to the creation of functional technology, and how this technology influences all aspects of society, from its economy to its art.

To overcome the above difficulties, courses in the undergraduate curriculum should attempt to establish a bridgehead from which economic, social and environmental considerations can be internalized into all engineering disciplines and specialties to create a preventive orientation. This can be done and has been done successfully with subjects such as economics. In many engineering courses, economics has been internalized and incorporated as a key consideration when problem-solving. Similarly, social and environmental considerations could follow the same path and become an important part of each course in the engineering curriculum. Without this kind of evolution in engineering education, the status of engineering as a self-regulating profession will be increasingly weakened. Our profession must learn to approach design and decision-making with more than just technical tools. Only then can we hope to play a more decisive role in transforming our present situation and to play a seminal role in creating ways of life that are more economic, socially viable and environmentally sustainable.

References

1. Vanderburg, W.H. and Khan, N., “How Well is Engineering Education Incorporating Society Issues?”, *Journal of Engineering Educaiton*, Vol.83, No.4, Oct.1994, pp. 357-361

2. Vanderburg, W.H., *The Labyrinth of Technology*. Toronto: University of Toronto Press, 2000, pp.89-732.

3. Vanderburg, W.H. Centre for Technology and Social Development: Course Descriptions. [online].http://ctsd.utoronto.ca/courses.html, October 1, 2007.

Rei Marzoughi is a second year PhD student in the Department of Civil Engineering at the University of Toronto. Her research focuses on the relationship between urban form and travel behavior and the influence of built form on the mobility patterns of those who cannot drive.