AC 2009-2456: IMPACT OF ENGINEERING: DESIGNING A CLASS FOR TECHNOLOGICAL LITERACY DISCIPLINES

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Impact of Engineering:
Designing a Class for Technological Literacy Disciplines

This paper addresses some of the important challenges faced when designing a class for technological literacy programs; specifically, we discuss our experience in designing a class called *Impact of Engineering* for nonengineering students. We explore the meaning of "impact of engineering," from a technological literacy standpoint through a discussion of the material, focus, and emphasis of the lectures, classroom discussions, and projects of the course. Attention is given to the process of creating the class: identifying material to cover, possible textbooks, available resources, and ideas for student projects. The paper also provides various valid options (with examples) for creating syllabi, class material, class discussion topics (including invited lecturers), and the use of Internet resources. Of particular importance is how, and if, the class is to be differentiated from, or complementary to, similar classes offered in liberal arts, history, political science, and philosophy programs. Student input is also considered: their reflections concerning the experience and their contributions to the discussions, design, and implementation of the class.

Introduction

The quality of life and economic prosperity of the over 300 million residents of the United States are critically dependent on making wise choices on the use and further development of technology. Addressing technological issues, ranging from formulation and implementation of energy policies to telecommunications, is the mission of our 1.5 million engineers. To educate the public in technological literacy and provide them with essential information about technology requires a new look at our efforts in undergraduate education. As engineering programs at all levels are responsible for educating nonengineers about technology,[1–10] we, as engineers, have a duty to provide effective technological literacy for the other 99.5% of U.S. citizens. Most of the country's leadership usually comes from this larger group of citizens and generally has only a vague understanding of engineering and the use of technology for the national interest. Engineering concepts are pervasive in decision making within industry, government, education, and health care, and yet people make most decisions in these sectors with little or no formal engineering education. It is thus apparent that there is a national need for programs that train nonengineers to understand technological issues and possibilities and to be ready to address international-level challenges by working with politicians and technical people. In short, we need a national-level technological literacy program. Our school hopes to contribute to this effort by creating a new minor program (Engineering Studies) for nonengineering students that provides training to create a new, more technologically informed frame of mind for future leaders.

The structure of institutions of higher education has made it difficult for nonengineers to develop any depth of understanding about engineering and technology. An engineering major has an elaborate curriculum, requires substantial prerequisite courses, and is difficult to pursue in combination with another field of study. Science courses emphasize knowledge of the natural world but provide little practical understanding of our complex human-built technological infrastructure. Nonengineers who complete a university natural science requirement are hardly prepared to lead the world's largest economy through its present turmoil if not able to make

technically informed decisions about such topics as supporting the automotive industry, developing fossil fuel alternatives, or appropriate regulation of nanotechnology.

A minor in engineering studies should prove an efficient and credible way for nonengineering majors to obtain a practical and meaningful degree of technological literacy. Crucially, the minor is not intended to develop design-level engineering knowledge, but rather is based on the general competencies advocated by the National Academy of Engineering in such documents as *Technically Speaking* and *Tech Tally*.[7,8] The minor combines several courses, achieving a balance of depth and breadth that is not possible in a one- or two-course distribution requirement. In addition, the minor also provides a formal credential that students can use when entering the job market—a strong incentive and motivating factor for many students. In our program, there are three core classes: Introduction to Engineering, Impact of Engineering, and How Things Work.[5,6] In this paper, we address some of the challenges and thoughts on developing the second class, Impact of Engineering.

Motivation

In the national drive to infuse technological literacy, as laid out above, university programs play, or must play, an important leadership in identifying key issues and approaches through the implementation of key educational objectives. The role of engineers and their relationship to technology is one of the most interesting and least-addressed aspects of technological literacy programs. That is why a class that explores the often-overlooked fact that engineering is usually subservient to the whims of larger forces—namely, industry and society—could be especially fruitful in considering technological literacy—by examining engineering as a social process, we can impart a richer understanding of how technology is created and to what ends.

We believe that there are two main challenges when engineering colleges teach this class. First and foremost, a well-balanced course must not only discuss technology but relevant historical, societal, and even philosophical aspects of development, as well. The second challenge is how to identify the technologies that are interesting to the students, are pivotal for human development, and would lead to a better understanding of modern technology and the challenges facing modern technological development. This is an important part of technological literacy programs, since the goal of the programs is to enhance technological appreciation and understanding among nontechnical people by addressing national and international needs for more technological education for the public in general and those who may be in decision-making positions and/or are working with engineers specifically.

Perhaps the most challenging issues of such a class are the material to be covered, the approach, and the focus of discussions and presentations. In order to truly address the impact of technology, it is necessary to have a historical perspective of both societal and technological development. Due to the fact that much of the technological development that has brought about the modern era has been influenced and led by Western countries, this class will have a heavy emphasis on Western civilization and historical development of this civilization. It should be noted that by considering the modern scientific and engineering traditions as having originated in ancient Greece and Rome, this approach would also include the examination of parts of the world now considered “Middle Eastern.” The extent of such study must be necessarily

abbreviated, as to offer a class based on philosophical, historical, and societal development of Western civilization can be demanding and time consuming and can leave little space for discussion of the role and development of technology and its impact on civilizations and development.

Finally, with the new perspective of the "flat world" and the understandable need to focus on the revolutionary developments of technology in the last 50 years, one can only examine key technologies and how they reshaped the fabric of some modern societies, as well as developing ones, without any regard for the historical, political, and societal aspect of the development.

Studying the Impact of Engineering

A practical approach adopted by many courses is to review the impact of engineering from historical, social, economical, and philosophical perspectives in conjunction with technological development. A central theme of the impact of an engineering course should be a focus on the need to assess the impact of technology. This topic can be addressed from a societal, as well as engineering, perspective. In particular, an emphasis should be placed on the duality of intellectual/cultural history and engineering on the progression of civilizations by focusing on a few revolutionary technological advances and studying how they were influenced by culture and in turn influenced culture to ultimately produce new technology. While there can be many approaches to such a class, the idea of understanding and introducing the historical, cultural, and social impact of technology remains the most important component of technological literacy programs. There are many such classes in history, journalism, and philosophy departments that offer such studies, and all provide unique, interesting, and valid perspectives; however, the engineering college's viewpoint must also be considered as part of a broader technological literacy effort. For example, our school offers a minor in engineering studies (MES) to nonengineering students, and though the Impact of Engineering class is offered by the engineering college, efforts are made to compliment similar classes offered by other departments and programs across campus. While we accept students' credit for similar classes offered by different colleges, we do suggest that students take our class due to a different perspective offered by the class—namely, one that approaches and explicates technology from a science and engineering standpoint.

Finding a Working Theme

There are definite distinctions that exist between philosophical, historical, sociological, and technological aspects of engineering and their impact on society. A class on the impact of technology should identify and discuss these perspectives; however, it is imperative to include the engineering perspective in all these classes. Many existing classes on technology include a societal perspective and address important issues, though few address and discuss the role or views of an engineer. It should also be noted that, from an engineering standpoint, many classes engineers take would also benefit by incorporating other views and should, in fact, have an understanding of all such views. One of the interesting by-products of conducting technological literacy by engineering colleges, and one that has informed this opinion, is that we have found that students who take these classes and work with engineering students, as well as the faculty

that are involved with technological literacy classes, all agree that engineering classes should incorporate some of the historical and societal aspects of technological development.

A natural tendency, and one that must be avoided, when teaching these types of classes is to focus too much on the scientific perspective of technological development. Historically, most technological developments have been introduced by scientists of the more practical, or applied, kind, rather than traditional engineers. To address this, such classes need to address the differing perspectives, goals, and constraints of "engineers" and "scientists." On the whole, classes would benefit from discussing the limitations of professional perspectives (such as the fact that an engineer will tend to focus on an area of knowledge) and ways to surmount them.

The General Approach

Regardless of the discipline of specific approaches for classes on the impact of engineering, there are some important items that are common to all. The best result will be achieved in each instance if we identify:

1. The overall approach assumed for the class: long view of technological development, case studies of specific technologies, or a combination wherein the objective is to focus on over-arching themes
2. Focus of the class: academics, practicing engineers/scientists, or outsider/insider

Once the general approach and the objectives for the class are identified, there are various resources that can be used. A rich set of videos is available that includes pop-culture items such as HowStuffWorks.com, technologically inclined series from The History Channel or PBS—both of which produce infotainment and documentaries on various technological developments with great historical perspectives—or academic publications.

How to Be Effective

The authors' experience is based on offering technological literacy to nonengineering students. This means having a variety of disciplines (students have been from many diverse fields of study including music, education, economics, architecture, journalism, entrepreneurial studies, environmental studies, and industrial technology) with differing backgrounds and interests. These students enrolled in an impact of technology class from the College of Engineering and wanted a more technologically inclined perspective than similar classes offered in history, philosophy, and other fields. One of the challenges of such a class is to incorporate the students' unique interests and perspectives, while at the same time meeting objective and planning requirements, to enrich the class through a synergistic sharing of viewpoints. This is perhaps the most important component of an effective and successful class.

As students with various backgrounds, interests, and discipline-specific biases take the class, it can often be difficult to maintain the students' interest in, or make them understand the importance of, a particular technology; however, by tailoring available material to their backgrounds it is possible to satisfy their particular curiosities while informing them of the relevance of technology in not only their own field but society in general. One way to identify

interest and track responses is to have students submit material and ideas and then share it with the class. This type of input tends to evolve the more they learn about a particular subject, which allows the class to chart and follow student ideas. In addition to providing information on their own interests, students need to reflect and share their critiques of the covered subjects. This can be achieved by using commonly available software, with differing amounts of user control and interaction, that allows for the free sharing of ideas and posting of media. A wiki, for example, can be used for assessment and interaction, posting of notes and homework, presentations, discussions, and identification of individual interests.

The Role of the Instructor

The lecturer plays an important, unique, and nontraditional role in a class that sees the professor less as someone that lectures and more as a facilitator that guides an exploration of student-inspired topics fitting within an underlying framework. While typical duties, such as clarification of course structure and goals and identifying the right resources and reference materials for the class, are retained, the lecturer is also pivotal in bringing a collective harmony, collaboration, and creative interaction to the class. This can be accomplished both by identifying specific topics to cover and by encouraging students to suggest new topics and then discussing them to come up with a general consensus among the students—it is always more interesting if the instructor offers a number of topics and basics to cover and then asks the students to identify a few areas to investigate. Of course, it is inevitable that students will make suggestions that the lecturer may find difficult to cover. In these cases, guest lectures and invited speakers are the best approach. During these sessions, the lecturer can guide the discussions in order to provide an overall perspective and suggest connections between the subject and class goals. Finally, the instructor will have to aid in identifying, discussing, and elaborating on student ideas for final projects.

Impact of Technology, an Example: Engineering Studies 265

To a greater or lesser extent, we were able to incorporate the above into a course on the impact of engineering taught at Iowa State University in the fall of 2008. Our experience indicates that it is possible, with a bit of priming (mainly through the selection of initial texts for discussion) from the lecturers, to engage nontechnical students in a thoughtful examination of technology and its place in their own fields and society in general. By requiring students to place their notes and any accompanying material on a class wiki, we were able not only to identify interests, distribute multimedia materials, evaluate the students, and adapt the focus of the course, but also to indicate to the students that they had a hand in the direction and development of the class. Future work should be undertaken in this area to better help students understand that they can be an active part of the class, and not just passive agents.

Thomas P. Hughes' *Human-Built World*[11] was used to introduce students to a long view of technology and its interaction with, and place within, Western civilization; the first few chapters were especially useful in exposing students to the interplay of religion/philosophy and attitudes toward technological development. By providing a general historical, religious, and philosophical overview of technology and then moving to specific topics such as complexity, industrial design, urban planning, and environmentalism, students discovered the dynamics of

technology in society that led them to reconsider how technology shapes their lives—beyond mere gadgetry—and specific disciplines.

Case studies of military aircraft design projects, the introduction of fluorescent lighting, and handling of radioactive waste, all found in Bijker and Laws' *Shaping Technology/Building Society*, were used to demonstrate the link between engineers and the government, emphasize how engineering works in practice, and show how engineering can be overtaken by larger forces. Discussions of these topics by the students tended to focus on the inherent complexity and multifaceted nature of social-technological dynamics.

In the beginning, most topics were selected, and discussions led, by the lecturer; however, once it became apparent to the students that they could influence material selection, student suggestions began to be heard. After one student showed an interest in the technology of computing, for example, the lecturers brought in documentaries and short videos to explain the history of computing in general as well as popular articles by Jack Kilby and on Robert Noyce to demonstrate the historical importance of the modern invention and evolution of logic devices and their construction.[12] Beyond student suggestions for topics, we were also able to initiate student-led discussions of instructor-selected texts. For this purpose, Richard Rhodes' *Visions of Technology*[13]—a collection of reminiscences and commentaries by engineers, inventors, industrialists, politicians, and scientists—provided a rich and diverse set of writings for analysis and discussion. Having summarized a given selection from the book, students were asked to explore its meaning in allegorical terms, after which the entire class offered a critique of the individual student's commentary.

A key component of the class, which the students were apprised of early in the semester, was a student-selected project consisting of a paper and presentation that required the students to apply classroom knowledge to their own discipline. We saw a cost-benefit analysis of windmill installation on Iowa farms (agronomy major), a discussion of green architecture (architecture major), viewpoints on video game usage in the media (journalism major), and the affects of technology on management practices (business major), which indicates to us that technological literacy courses have something to offer for nearly everyone.

Following the presentations, students were asked to post reflections of their experience and ways to improve the course on the class wiki. Students generally seemed to appreciate the wiki approach (after overcoming some initial difficulties with the syntax) and especially liked that it allowed for the posting of homework and multimedia material. We also received suggestions for new course topics (different technologies to consider, negative aspects of technology, re-emerging technologies, and failed ideas), the impact of technology on specific areas of culture (language, communication, and lifestyle changes), questions the students would like answered (what does the term technology mean in different fields, and where does technology begin), and a desire to see guest lectures (in the areas of psychology, history, and environmental science).

In Conclusion

This paper discussed some of what we feel are the most important challenges in designing and implementing classes for nonengineering students to learn about the impact of engineering. Such

classes have been successfully offered by history, philosophy, political science, and related fields. We pointed out the importance of the engineer's perspective in such classes, and gave an example of a technological literacy class—differentiated from similar classes in other disciplines—designed and taught by an engineering college. Finally, some details about the particular class offered at our college were presented.

Bibliography

1. Committee on Science and Technology in Foreign, U.S. Agency for International Development (USAID) and National Research Council (NRC). 2003. *The Fundamental Role of Science and Technology in International Development: An Imperative for the U.S. Agency for International Development*. Report.
2. Bugliarello, G. 1998. Technological literacy (editorial). *The Bridge* (National Academy of Engineering) 28 (2, Summer).
3. Jones, R. C., and T. Kumar. 1991. Technological literacy for non-engineers. In *Frontiers in Education, Proceedings Twenty-First Annual Conference: Engineering Education in a New World Order*, 179–84. 21–24 September.
4. Krupczak, J. J., Jr., D. Ollis, R. Pimmel, R. Seals, G. Pearson, and N. Fortenberry. 2005. The technological literacy of undergraduates: Identifying the research issues. Panel member, in *Frontiers in Education, T3B-1-2, FIE '05, Proceedings 35th Annual Conference*. 19–22 October.
5. Mina, M. 2007. Work in Progress—Minor in Engineering Studies: Teaching Technology to Non-Engineering Students. In *Frontiers in Education, FIE '07, Proceedings 37th Annual Conference*, S1J-36-7. 21–25 October.
6. Mina, M. 2008. Work in Progress—The Role of Engineering Colleges in Providing Technological Literacy. In *Frontiers in Education, FIE '08, Proceedings 38th Annual Conference*, S1J-36-7. 22–25 October.
7. Pearson G., and A. T. Young, eds. 2002. *Technically Speaking: Why All Americans Need to Know More about Technology*. National Academies Press.
8. Pearson G., and E. Garmire, eds. 2006. *Tech Tally: Approaches to Assessing Technological Literacy*. National Academies Press.
9. http://www.history.com/
10. http://www.pbs.org/
11. Huge, T. 2004. *Human-Built World: How to Think about Technology and Culture*. Chicago, Illinois: The University of Chicago Press.
12. Nye, D. 2006. *Technology Matters: Questions to Live With*. Massachusetts Institute of Technology Press.
13. Smith, M. R., and L. Marx. 1998. *Does Technology Drive History? The Dilemma of Technological Determinism*. Massachusetts Institute of Technology Press.