Engineering, Technology and Society: Increasing the Dialogue Between Liberal Arts Majors and Engineering Students

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Abstract

The EC2000 Criterion 3 a-k outcomes have increased engineering educators' awareness of the importance of contemporary and global issues in undergraduate engineering education. In an effort to increase college students' understanding of ethical, professional, and contemporary issues related to engineering, a senior-level discussion-based seminar has been offered at Mercer University for three years. The course, which has been designed and taught by an engineering professor, is part of the College of Liberal Arts' Senior Capstone program and is offered to students from any college in the university. The course structure encourages students to view contemporary issues from an organizational, personal and technical perspective. The presence of both engineering students and liberal arts students in the same class allows students to share knowledge and break down stereotypes as they study accomplishments in the fields of engineering and science.

Introduction

The practice of engineering is not conducted in a vacuum. Engineering accomplishments affect society and, conversely society affects what engineers can accomplish. As Wilson observes, "Engineers who understand how their profession influences society are in a better position to consider the policy implications of engineering creations." [1] Through the years, the practice of engineering has become more complex. This is true not only of the machinery, such as nuclear power plants and Mars orbiters; but also of the systems in which they operate. According to Jolly and Radcliffe, "The modern engineer is asked to deal with ambiguous and changing circumstances and in a social and environmental context."[2] Graduating engineers should be prepared to deal with such complex systems.

A strong foundation in the liberal arts can help give engineers the perspective they need to comprehend the social, ethical, and environmental implications of these ambiguous and changing situations. Since the 70s, certain engineering educators have been calling for inclusion of more humanities and social science courses in the required undergraduate engineering curriculum. As a result, some schools have strengthened the influence of the humanities and social science in the engineering curriculum by offering Science, Technology, and Society (STS) courses. STS courses, usually taught by liberal arts professors, have been developed in recognition of the interrelationships between technology and society. Lucena and Downey point out that, "Undergraduate STS courses for students tend to help students recognize that technological problems have multiple dimensions and that solving technical problems involves paying attention to the non-technical dimensions as well." [3] Other schools have strengthened the humanities/social science influence through service learning curricula. Programs such as EPICS[4] have shown how engineering undergraduates can demonstrate their social responsibility as they learn to apply engineering principles. Educators at the University of Virginia have shown how case studies can be used at the graduate level to integrate social and ethical dimensions of technology with engineering. [5]

Perhaps the biggest impetus to the greater influence of humanities and social science on the undergraduate engineering curriculum comes from the EC2000 Criteria. For many schools, wholesale adoption of the EC2000 philosophy will result in the incorporation of new attitudes, attitudes that reach the core of the engineering discipline. The observation that engineers need a broader education is not new; however, what is new is the degree to which the new criteria mandate a strong cultural change. This change requires educators to acknowledge that curricula based on the so-called "non-technical skills" included in EC2000 Criterion 3 deserve a place next to the more traditional engineering curricula. [6] As a result of EC2000 discussions, engineering educators are confronted with questions such as: 1) To what extent do our graduates incorporate social and ethical considerations in their design decisions? 2) How well will our students work in the global marketplace? 3) What do our students know about other cultures and how engineering is practiced in other cultures? or, 4) Where in the current four-year curriculum will engineering students learn about contemporary issues related to engineering?

A course titled "Engineering, Technology, and Society" has been offered at Mercer University for three years. The content of this course focuses on the above-mentioned questions. The course philosophy is fairly simple. It is hoped that students who complete this course will exhibit cognitive, behavioral, and attitudinal changes related to the role of engineering in society. The anticipated changes include the 'valuation' aspect of certain EC2000 outcomes (e.g. professional and ethical responsibilities, impact of engineering solutions in a global and societal context) as described by Besterfield-Sacre, et.al.[7] In addition, the course design gives students an opportunity to demonstrate accomplishment of cognitive and skill-based outcomes (multidisciplinary teamwork, effective communication, and knowledge of contemporary issues).

The Course Development

Although some would disagree, the "two cultures" atmosphere described by C. P. Snow is still present on the typical American campus. Although the original argument compared science and non-science, a similar argument could be made for engineering and non-engineering. Partially due to a highly prescriptive engineering curriculum, engineering students rarely enroll in classes with liberal arts students. Even though Mercer's campus is small, and students mix socially, our curriculum offers few courses in which students from both schools mix academically. In the summer of 1995, the deans of the School of Engineering (SoE) and the College of Liberal Arts (CLA) discussed ways in which they might encourage greater communication between engineering and liberal arts students at Mercer. They decided to offer support for a course that would help improve communication between the two groups of students. Early in the discussions, it was decided that the course would be targeted toward seniors because they had developed a certain level of competency in their respective disciplines.

During the five years I had been on the faculty of the SoE, I had been selected to serve on numerous university-wide committees. As a result, I had a good working relationship with many CLA faculty. In addition, I had earned a bachelor's degree in a liberal arts program prior to earning my engineering degrees. Therefore, the two deans asked me to design the course.

The Course Design

As described in the Mercer University Bulletin, Senior Capstone (SCP) courses are interdisciplinary seminars focused on significant questions or issues not regularly explored elsewhere in the standard Mercer liberal arts curriculum. Ideally, SCP courses encourage students' awareness of themselves as prospective workers and citizens. Seniors from different majors compare their perspectives and share their expertise. The emphasis is on using materials from a variety of disciplines. Ethical values are explored. The courses feature extensive writing and class size is kept small to allow participation in seminar discussions. College of Liberal Arts (CLA) students must successfully complete a Senior Capstone course prior to graduation. School of Engineering (SoE) students may apply credit in a Senior Capstone course towards their Humanities/Social Science requirement. The SCP course that most closely fit my vision for the new course was SCP 451 (Self and World: A Case Approach to Issues of Choice and Responsibility).

The director of the senior capstone program authorized me to develop SCP 451.003 as Science, Technology and Society. When Mercer switched to the semester system, the course was renamed Engineering, Technology and Society to better reflect the course content. The main mission of SCP 451.003 is to encourage effective intellectual communication between engineering and liberal arts majors. After successfully completing the course, the students should:

- Be able to state ways in which both technically and non-technically oriented individuals can affect the impact of technological changes

- Be aware of the viewpoints of creative writers and thinkers in a variety of disciplines concerning the social and cultural consequences of technological advancements

- Have an understanding of the necessity of trade-offs in business and government decision-making concerning the application of technology

- Recognize the need for, and develop proficiency in, the use of a multiple-perspective approach to the analysis of problems of a technical nature

- Have the ability to make rationally-defensible and personally-authentic decisions regarding the use of technology

I decided to build the course around five modules: 1) Science vs. Non-Science, 2) The Individual as a Producer of Science and Technology, 3) The Individual as a Consumer of Science and Technology, 4) Making Decisions in a Technological Environment, and 5) Preparing for the Future. The selection of a text for the course was somewhat problematic. The text needed to have the rigor associated with a 400-level course. However, because the students would have diverse academic backgrounds, the content of the text needed to be more general than specific. A highly technical text would probably alienate the non-science liberal arts majors. A non-technical text might not hold the interest of the science and engineering majors. As a compromise, I decided to use two texts. The first text[8] covered the topic of managing technology and was designed for seniors or graduate business students. The text was written by Harold Linstone and Ian Mitroff. Mitroff had a background in business and Linstone had a background in management and engineering. One of the most intriguing features of the text was its emphasis on a multiple perspective approach to case studies. The first half of the book discussed cases in terms of the technical, organizational, and personal perspectives. The second half of the text emphasized the development of models and the analysis of trends. Although there was a mathematical basis to the analysis, the verbal descriptions could be understood by persons with a limited mathematical background. The second text, Science and Technology Today: Readings for Writers, was written by Nancy MacKenzie[9]. As the name implies, the text is a compilation of readings related to science and technology. Articles were chosen for their provocative nature as well as their rhetorical style. The text includes both non-fiction and fiction entries written by a diverse group of authors. The text includes articles by well-known scientists as well as professional writers. Two of the articles were written by engineers: one by Samuel Florman, the other by Alvin Weinberg. The variety of articles would allow me to customize the course based on the mix of students for a given term. However, due to the paucity of writings by engineers, I would have to supplement the texts with references to additional articles.

Having chosen the main texts, I was able to develop the modules more thoroughly. I assigned required readings for each module. (These would be supplemented on a year to year basis with current readings on contemporary topics.) The basic readings were assigned as follows:

- Science vs. Non-Science (authors: George Orwell, Thomas Kuhn, Thomas Henry Huxley, C.P. Snow)
- The Individual as a Producer of Science and Technology (authors: Barbara Ehrenreich, Dorothy Nelkin, Ron Karpati, Ruth Cowan)
- The Individual as a Consumer of Science and Technology (authors: Ray Bradbury, Rachel Carson, Joy Williams)
- Making Decisions in a Technological Environment (authors: Linstone and Mitroff, George E. Brown, Joe Morganstern, Alvin Weinberg)
- Preparing for the Future (authors: Linstone and Mitroff)

The first module explores the nature of scientific endeavors. The idea of a scientific way of thinking is introduced. The existence or non-existence of the "two cultures" construct described by Snow is debated. The idea that business and government forces have shaped the path of scientific discovery and technological change[10] surfaces in the second module and persists throughout the course. The influence that society has on technology and the importance of viewing historical events with that concept in mind is an important part of modules two and three. As Cowan[11] observes, "A social history of technology, in short, assumes a mutual relationship between society and technology; it also assumes that changes in one can, and have, induced changes in the other." (1997, p. 3) Through its discussion of the Exxon Valdez incident from the vantage of the technical, organizational, and personal perspectives, the Linstone and

Mitroff text is a central component of the fourth module. We discuss the Manhattan Project and its consequences in this module also. The final module, Preparing for the Future, includes much of the information from the second half of the Linstone and Mitroff text. In addition, the influence of computers and the Internet is an essential component of discussions of future trends. I like to end the course with an acknowledgement of the positive actions of ethical engineers. The LeMessieur case (Citicorp Building) never fails to elicit positive comments from engineers and non-engineers alike.

The course shares a number of features with other Senior Capstone courses. All SCP courses include a minimum number of pages of required writing. Active participation in seminar discussions is essential. In addition, students must contribute from their respective disciplines. The course features two very different texts, written at two different levels. The MacKenzie text covers a wide range of topics. The writing style varies, but most articles are fairly easy to read. The text includes articles of fiction as well as excerpts from journals and popular magazines. The Linstone text is more advanced and is suited for upper level undergraduates or graduate students. However, its emphasis on the importance of multiple perspectives makes it very valuable for the course. This variation in subject matter and technical level gives each student, regardless of major, an opportunity to participate.

The class activities are designed to encourage the students to greet new experiences and ideas with an open mind, to reflect upon these experiences through the multiple perspective approach, and to build theories based on these reflections which will be the basis of rational decision making. The course atmosphere models the feedback loop described by Kolb and supports the development of the students' ever changing, growing philosophy of life. Students are required to continuously reflect on their feelings and beliefs, and to become aware of the basic assumptions behind those beliefs. Through the choice of controversial and provocative readings, and through the juxtaposition of scientific thinkers and non-scientific thinkers, the course atmosphere supports the development of new attitudes and beliefs. Students are able to understand the implication of engineering and business decisions, and to appreciate the role governmental regulations have in shaping our society.

I have taught the course three times. The breakdown of students by college is as follows: *Year 1* College of Liberal Arts-9, School of Engineering-7; *Year 2* College of Liberal Arts-10, School of Engineering-6; *Year 3* College of Liberal Arts-2, School of Engineering-6, School of Education-11. Each mix of students brings a new flavor to the class. During the first year, four of the CLA students were computer science or biology majors. Thus, the majority of students could be classified as having technical majors. During the second year, only two of the CLA students were science majors, and the discussions and presentations were markedly different. However, the greatest difference occurred in year three when the majority of students were elementary education majors. At first, they were intimidated by the discussion topics as well as some of the readings, but most students developed a certain "technology/technical issues comfort level" by the end of the course.

Communication Components

Biopoem During the first class, I concentrate on helping students get to know one another. I also want to help students feel comfortable expressing their opinions and feelings in front of others. The icebreaker I have used most successfully is the *Biopoem*. For the *Biopoem* exercise, each student is given a page of incomplete sentences. The students are instructed to complete the sentences in preparation for reciting their poem to the class. Typical lines in the *Biopoem* include:

______________________ (name)
graduate of _______________________,
gets angry when _____________________ ,
likes people who _______________________,
gets in trouble when ________________________,
would like to be remembered as _________________.

In spite of the name, I instruct students that it is not necessary that their poems rhyme. Also, it is important that the students know ahead of time that they will have to read their poems to the class. This principle of informing the students in advance how their submissions will be used is essential to the ethical conduct of the class.

Reflective Journal

I use the reflective journal to get the students accustomed to writing and thinking about their writing. Early in the course some students write journals that include mostly facts from the reading. They are reluctant to write down their own thoughts, reactions, and original ideas generated by the readings and discussions. By the end of the course all of the students write thoughtful journals and almost all of the students make frequent, thoughtful contributions to the class discussions. However, occasionally a student does not learn to trust the group enough to share original thoughts. This student loses some points in the course grade for participation.

Artificial Structured Controversy

At the beginning of the course I set the tone for the nature of the discussions. I commonly use a modified form of structured controversy[12,13] that I term Artificial Structured Controversy (ASC). I introduce an artificially black-and-white statement such as "Engineers should be required to take more liberal arts courses ". I assign half of the class to support the position; the other half of the class must develop arguments to refute the position. Each group goes to a separate room to develop their arguments. After fifteen minutes, they return to the classroom to present their arguments to the whole group. After the in-class discussion, each student is given a homework assignment to write a brief paper supporting one of the positions.

It is important to note that the ASC is not in the form of a debate; it is modeled as an interactive discussion. After returning from their breakout sessions, students are instructed to move their desks to form a circle so that the discussion can begin. I also place my desk in the circle. This seating arrangement reinforces the idea that the flow of the discussion should be between individuals, and that the instructor is one individual in the group. Early in the course, some students tend to direct their comments to the professor. Others frequently look to the professor for "the answers", but as the course progresses this behavior subsides.

Another concern from some students is that they cannot support the position they are assigned. For example, during the first ASC, some CLA students insist that they cannot support an argument that engineering students should take not take more humanities courses. However, I instruct the students that they must learn to take a position and support it with a well-thought-out argument. Sometimes it is the case, as Pearce[14] observes that, "the average engineering major knows more about the humanities than the average humanities major knows about science and engineering." However, by the end of the breakout sessions CLA students have new knowledge about the engineering curriculum and EGR students have new knowledge of the liberal arts curriculum. This ability to see a situation from a different viewpoint is an essential skill that students will apply to more substantive matters as the course progresses.

How-things-work Presentation

For the midterm presentation, individual students must describe the way something works and its affect on society. The first emphasis is on explaining the purpose, function and operation of a product or a process. The second emphasis is on explaining how that product or process has influenced our society. Regardless of the background of the presenter, the presentation must include a general description as opposed to a specific description as defined by VanAlstyne and Maddison[15]. The communication principle is that an engineering or science major will learn how to explain a complicated artifact in a non-complicated way. Specialized vocabulary must be clearly defined or omitted from the presentation. Even common terms may need to be explained. Obviously, this requirement is important for the students in the non-technical majors as well as the technical majors. In a multidisciplinary course such as Engineering, Technology and Society, the term *paradigm shift* is as foreign to some as *input-output device* is to others. In some ways, this assignment is more difficult for the engineering/science major than it is for the non-technical major. For those non-technical majors who are intimidated by the assignment, I recommend Macaulay's books[16,17] as a starting point. Since I last taught the course, the World Wide Web (WWW) has proliferated with easy to understand explanations of somewhat complex equipment. Although care must be taken to verify the credentials of the writer, the quality of many WWW sites is exceptional. During the next iteration of the course, I will make use of Web references as well.

Whistle-blowing Report

For the final report, students must write a paper about a whistle-blowing incident. The report must include 1) a review of the circumstances surround the situation, 2) the student's opinions concerning the ethics involved, and 3) the student's conclusions about the way in which the incident affected future decisions made by the company. Each student must have the topic approved in advance; no two students are allowed to write about the same incident.

Relationship to EC2000

Several course components can be used to support EC2000 Criterion 3 learning objectives, specifically those objectives related to global awareness, ethical and professional behavior, contemporary issues, and communication. Case studies of topics such as the Exxon-Valdez and Chernobyl raise students' awareness of global and environmental concerns. The final project on whistle-blowing deals directly with ethics, as do many of the assigned articles. Each year, I customized the course to include a discussion of contemporary issues in addition to those that were included in the texts. One year, the ValuJet crash occurred during the course. We were able to follow the story as it developed. The fact that initial theories of wrongdoing are often not supported during subsequent investigations was an important lesson. During another course, Dolly the sheep and the cloning issue was very much in the news. The religious and medical issues raised by this research were a significant part of the course. The ten-year anniversary of Chernobyl prompted a series of news articles during one of the courses. The students wrote papers about the global impact of technological disasters potentially far into the future. Government funding and government regulations were themes during all three offerings of the course. The influence/responsibility of agencies such as the EPA, NASA and NHTSA were topics of discussion. Finally, the Artificial Structured Controversy exercises, the oral presentations, the in-class journal requirements, and the written reports yielded evidence of the students' communication skills.

Student Comments

As may be expected, some engineering students complained about the amount of writing required. But almost all students enjoyed the roundtable discussions and Artificial Structured Controversy assignments. Some students expressed astonishment that they were allowed to express controversial beliefs openly and honestly. In a discussion-based class such as this, personal attacks are sometimes a problem, and the students need to be reminded to respect opinions that are quite different from their own. As mentioned earlier, most of the students developed a certain technology/technical discussion comfort level by the end of the course. However, course evaluations during year three indicated that two students wished that education majors would be allowed to take a senior capstone course offered exclusively for education students. This desire distressed me; I believe it would be a shame to eliminate education majors from this course. I was pleased with comments from two other elementary education students in that same class: 1) "This class has been a great learning experience", and 2) "The teacher was fair and stimulated a good learning environment."

Conclusion

In an effort to increase college students' understanding of ethical, professional, and contemporary issues related to engineering, a senior-level discussion-based seminar has been offered at Mercer University for three years. In this class, through a mix of writing, discussing, and presenting, students from diverse academic backgrounds learn to communicate with each other about science and engineering issues. The presence of both engineering students and liberal arts students in the same class allows students to share knowledge and break down stereotypes as they study accomplishments in the fields of engineering and science. As a professor, I learn new things each time I teach the course. I look forward to the next time I teach the course when I will meet a new diverse group of students and watch them learn to look at situations from each other's perspective.

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