AC 2012-3526: INTEGRATION OF SCIENCE, TECHNOLOGY, AND SOCIETY (STS) COURSES INTO THE ENGINEERING CURRICULUM

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Integration of Science, Technology, and Society (STS) Courses into the Engineering Curriculum

Abstract

The Accreditation Board for Engineering and Technology (ABET) requires core classes in the humanities and social sciences for accredited engineering programs. A unique set of course offerings at the University of Colorado Denver speaks to these requirements by addressing race, gender, and cultural differences in the context of societal change, contemporary issues, and technology. Professional engineers are responsible for the design of safe and reliable infrastructure, public health and safety, and the environment. As a result, it is critical that engineering graduates understand the impacts that technology has on individuals, society, and the environment. This paper discusses two Science, Technology, and Society (STS) courses in the area of cultural diversity and international perspectives. This paper briefly overviews science, technology, and society (STS) as an emerging field, describes the content and purpose of the two STS courses at the University of Colorado Denver, discusses the research that has emerged from these courses, explains how the courses have been used to satisfy ABET criteria for accrediting engineering colleges and schools, and considers the effectiveness of these courses in broadening the education of engineers.

Introduction

This paper highlights two Science, Technology, and Society (STS) courses in the College of Engineering and Applied Sciences at the University of Colorado Denver and how they were initially integrated into the engineering college curriculum and later University-wide as part of the University's core curriculum in the area of cultural diversity and international perspectives. STS can be described as the study of how social, political, and cultural values affect scientific research and technological innovations, and in turn, how these issues impact society, politics, and culture in various ways. Issues related to the ever-increasing influence of science and technology on all aspects of culture and society, and vice versa, have become essential elements of the undergraduate education at the University of Colorado Denver. As these STS courses were integrated into the curriculum, the dearth of such courses previously became even more apparent. One example is the way that these courses encourage students to analyze critically and systematically complex technical and human interactions through a looking glass that uniquely focuses on technological and scientific contexts that have become global in nature. The first part of this paper describes two such upper division courses, ENGR 3400: Culture and Technology and ENGR 3600: International Dimensions of Culture and Technology. The next section discusses the rationale for taking what were initially courses designed for engineering undergraduate students and opening them up to students across the university. This is followed by an exploration into some of the research emerging from these course offerings while the last section describes how the courses have been used to satisfy ABET accreditation criteria. This includes an overview of course effectiveness and assessment with respect to student learning.

Science, Technology and Society Course Overview

Under a grant from the National Science Foundation, the College of Engineering and Applied Science at the University of Colorado at Denver established one Science, Technology and Society Course (STS) entitled *Technology and Culture*, or ENGR 3400, that was initially intended to broaden the educational context of engineering majors. A second STS course, *International Dimensions of Technology and Culture*, was subsequently added. Both courses eventually were integrated as possible courses into the University of Colorado Denver's Cultural Diversity Core Curriculum and International Perspectives requirements.

Science, Technology and Society (STS) as an Emerging Field

The Science, Technology, and Society (STS) field includes the study of how social, political, and cultural values impact scientific research and technological innovation and how these, in turn, affect society, politics, and culture. As STS courses have become more commonplace in a world where science and technology is endogenous in all aspects of culture and society, their indispensability to the undergraduate education has become more and more apparent (Tang and Johnson 1996). STS courses allow students to think critically and systematically while analyzing complex technical and human interactions in an increasingly

technological, competitive, and even global context. Specifically, students learn to identify and understand how to develop the knowledge and skills necessary to take leadership roles in increasingly complex and multifaceted environments, including international arenas, to analyze ethical problems, explore impacts of technology and science, and to engage productively with diverse groups of people in the contexts of technical and health science professions (Fuller and Collier 2004; Bauchspies, Croissant et al. 2005; Hess 2007).

STS, as a field of study, has been steadily growing over the last thirty years. This is evident, to some extent, by a bibliometric analysis of hits on Google Scholar using the following keywords: "science, technology and society," "engineering," and "society." Figure 1 depicts the results. The graph also shows that scholarly work in engineering is rapidly accelerating while general research in the social sciences (i.e. "society") remains relatively flat.
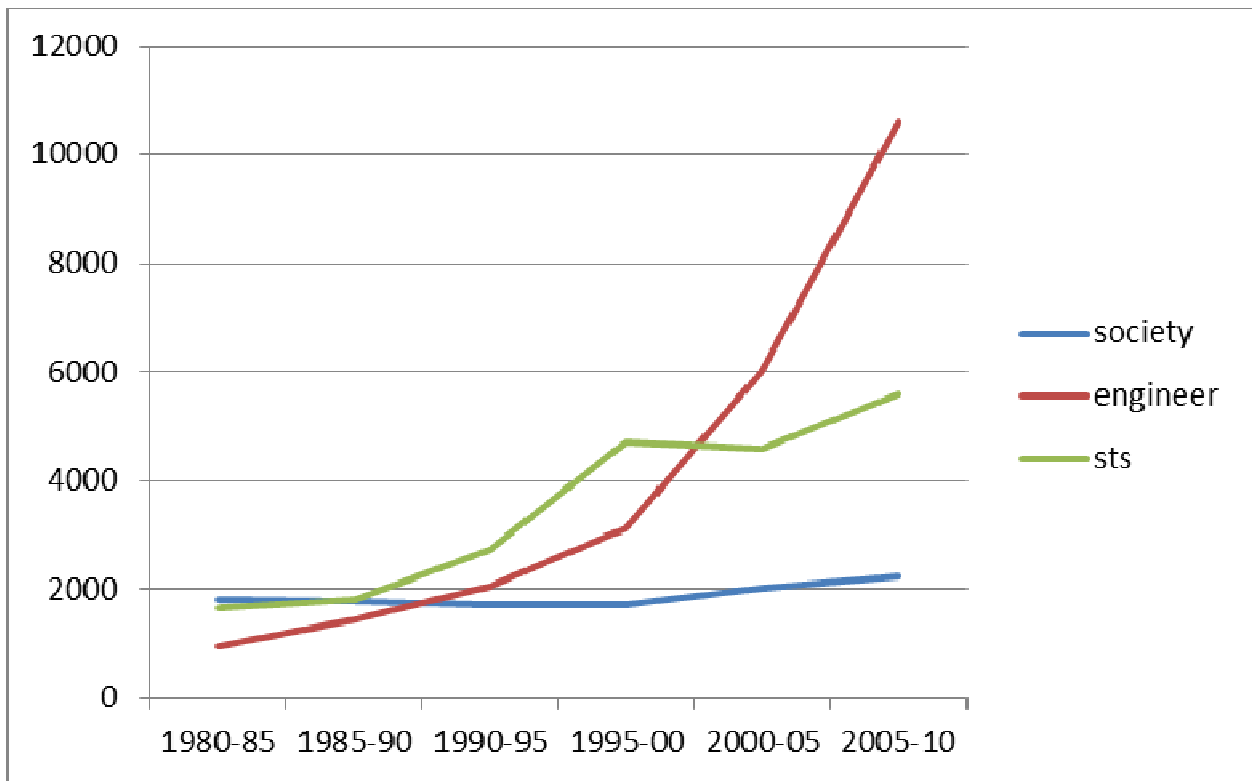

Figure 1 – Relative Growth of Scholarly Work in Various Fields.

STS Courses at the University of Colorado Denver
So far, two STS courses have been developed in the College of Engineering and Applied Science at the University of Colorado Denver. The first course, "Science, Technology and Culture" or ENGR 3400, is offered as an interdisciplinary course that integrates the history, sociology, and philosophy of science and technology from an American perspective. To

paraphrase Marshall McLuhan: when you're immersed in technology, it's like a fish being immersed in water; you don't know it's there. While it is difficult to fully comprehend this paradigm shift, it is important for students to acknowledge and attempt to understand such cultural dimensions of science and technology. Students self-examine themselves and their relationship with technology by asking questions such as: what does technology do; and how does technology impact you and the world? Through related readings, coursework, and deliberations, students can begin to make the decision for themselves as to whether a technology is good or not. Students then step into questions of how we transition from a very abstract, linear, literate type of medium to the medium that we are dealing with today, which is interactive, multimedia, and multisensory. For example, how is the message of multimedia different that the message of a printed book? The course was also developed to highlight multicultural diversity in order to help satisfy the core curriculum and ethics requirements of many engineering majors. This component of the course directs student focus and inquiry into timely issues such as:

- How do diversity, science, and technology interrelate;
- How do gender, science, and technology interrelate; and
- How do science, technology, and creativity interrelate?

The second course, "International Dimensions of Science, Technology and Culture" or ENGR 3600, challenges students to start understanding other cultures, and the influence that they have had on the development of science and technology in order to better identify issues concerning how science, technology, and international issues interrelate in a global context that has become more interconnected and interdependent. For example, in attempting to better understand other cultures, students consider questions such as: why did they not have a scientific revolution or why did they not have an industrial revolution? This course also seeks to explore technical, organizational, and cultural aspects of technologies while emphasizing impacts on third-world countries by directing students to question the impact of technologies on society and the future on a global scale and on different countries, populations, and groups, such as women and environmental groups. Student questions about the impacts of technology are further explored and analyzed in ways that help students understand interrelations with, for example third-world countries or feminism. This is accomplished by delving into topics such as the scientific revolution, ethnoscience, resistance to western technologies, globalization, and the environment.

Students are required to take exams in both courses that consist of multiple choice questions and short essay answers. The exams are open book and open notes, meaning that the questions focus more on concepts than specific content such as dates and places where an event occurred. In addition, they use visual learning maps, which are described in greater detail later in this paper.

Rationale for Offering Courses University-Wide

Although the two courses in technology and culture were originally developed due to the perceived need for engineering majors to better understand engineering practice in a greater context, it became clear that the same need existed for other science majors as well as those in the social sciences and humanities. Science, engineering, and technology have become – according to the economist Paul Romer of Stanford University – endogenous in society and any academic discipline must take into account the omnipresence and ubiquity of science and technology to be able to make sense and apply their training in the real world (Romer 1990).

As a result of this conviction that a fundamental understanding of the role of science and engineering in society is essential in the education of today's undergraduate students, the College of Engineering applied to have the two courses included in the University's core curriculum, also called the University Core. The philosophy of the University Core is to provide undergraduate students with a better capacity to understand and analyze, based upon critical thinking, with the hope that these analytical skills will empower them to make informed decisions and provide them with the ability to adapt to future environments and act independently on acquired knowledge. University Core courses expose students to multiple literacies, technologies, and sensitivity to diversity, as reflected in the particular course content. Another goal of the University Core is to engage students in developing a sense of their place in our urban environment and in the greater global environment. Thus, when submitting ENGR 3400 and 3600 to the Core Committee, the reasoning was that goals and objectives of these engineering courses would fit well within the mission of the University's General Education Core Requirements and satisfy core curriculum requirements at the University level. The courses were then approved as interdisciplinary general studies course options that satisfy university core curriculum requirements in the areas of: gender and multi-culture diversity (ENGR 3400); and international perspectives in an increasing global environment (ENGR 3600).

Since becoming a part of the University-wide core curriculum, the two courses have attracted considerable attention across majors and academic colleges. Students typically take these courses to satisfy their general education requirements, and the courses are offered every fall and spring semester in two formats: in the regular classroom as a blended course or strictly online during the summer months. Table 1 is a projection of next year's enrollments based on average enrollment from the last two years and totals over 800 students. Roughly one-quarter of the students are engineering or pre-engineering majors and another one-quarter are from the College of Liberal Arts and Sciences, mainly from the sciences, including pre-med majors. The remaining students are approximately evenly divided between College of Business majors and students from the College of Media Arts.

Table 1 – Projected Enrollments in STS courses at the University of Colorado Denver for 2012-2013

Course	Section	Fall	Spring	Summer
ENGR 3400	Online	60	59	92
	Regular	53	60	
ENGR 3600	Online	110	92	120
	Regular	97	95	
Total Enrollment		**320**	**306**	**212**

Research Related to the Courses

A third and largely unexpected development of these courses, due in part to the large number of students in each, is that the courses provide an ideal laboratory for quantitative research as to their effectiveness. This includes the study of online course delivery in comparison to more traditional teaching methods with respect to the impact of such technologies on higher education pedagogy.

Results of this research have been published in peer review journals on the following topics:

1) A comparison of student satisfaction of course delivery among online, blended, and regular students (Byrne and Tang 2006);
2) A gender study of the perception of the learning effectiveness of instructional tools used in online and blended learning (Byrne and Tang 2007); and
3) A study as to whether or not online students cheat more than regular students and a demographic profile of students who plagiarize or collaborate on exams (Tang, Byrne et al. 2007).

One of the studies suggests that both students and faculty generally prefer face-to-face lecturing and individual tutoring (Byrne and Tang 2006). However, while students prefer face-to-face lectures over videos and posted lecture slides in sampled courses, a second study indicated that online students who do not attend lectures in-person performed better on exams than students who attend class in-person regularly (Byrne and Tang 2007). At the same time, a third study suggested that online students do not seem to cheat more than students in regular classrooms (Tang, Byrne et al. 2007). Moreover in online course delivery, it was interesting to find that women tended to value new online and other educational technologies more than men (Byrne and Tang 2007).

Overall, these empirical studies led to developing educational software to enhance the delivery of the courses, whether online or in a blended format, such as the development of a suite

of applications called eTutor © at the University. The eTutor software, based on cognitive linguistics research, proposes to increase the study and learning skills of high school and undergraduate STEM student (Knaus, Tang et al. 2011; Knaus, Tang et al. 2012). Although the authors may not share their political views, much of this research was inspired by the works of the late iconoclastic historian of science and STS professor David F. Noble (Noble 1977; Noble 1997; Noble 2001).

Research into the impact of new technologies on teaching has also led to research in how these technologies are changing the process of teaching and how students learn. For example, the Internet, according to Nicolas Carr, is radically changing not only the way we learn, but also the way we think. Carr argues that the Internet is causing information overload, and technology is conditioning us to think superficially and without serious sustained attention. As argued in his much discussed 2008 article in *the Atlantic*, the very existence of the Internet and accompanying new technologies such as the smart phones and tablet computers world has made it much harder to engage with difficult texts and complex ideas, the very stuff of all academic endeavors (Carr 2008). *"Once I was a scuba diver in a sea of words,"* Carr writes, with typical eloquence, but *"now I zip along the surface like a guy on a Jet Ski."* Accordingly, these courses seek to find new ways to counter-act the superficiality of learning that is a possible consequence of the new technologies.

For example, one of the most original and creative contributions to the advancement of education in the area of pedagogy is the use of a restricted set of visual learning maps. One of the authors of this paper along with another colleague are experimenting with the use of visual learning maps, or mind maps, in the presenting and acquiring of textual information. Mind maps are used to generate, visualize, structure, and classify ideas, and as an aid to studying and organizing information, solving problems, and writing. The elements of a given mind map are arranged intuitively according to criteria such as importance and connections related to the concepts, and are classified into branches, areas or groups to represent semantic or other relationships found in the subject being analyzed (Budda 2004). Visual Learning Maps (vLms) represent a limited subset of mind maps, or diagrams that represent words, ideas, tasks, or other items linked to and arranged around a central key word or idea. The vLms can also be distinguished from mind maps in that the main elements of the vLms are arranged in very specific spatial patterns and the different arrangements of the map elements denote different meanings or logical relations. The vLms are spatial, as well as visual, in that where and how elements are located in a map, relates to the kind of logical relations being represented. For example, vertical placement of elements in a tree form represents genus-species relationship while horizontal placement of terms would represents a structural relationship (Tang, Hyerle et al. 2012). Figure 2 depicts examples of vLms templates generated from Microsoft's Smart Art.
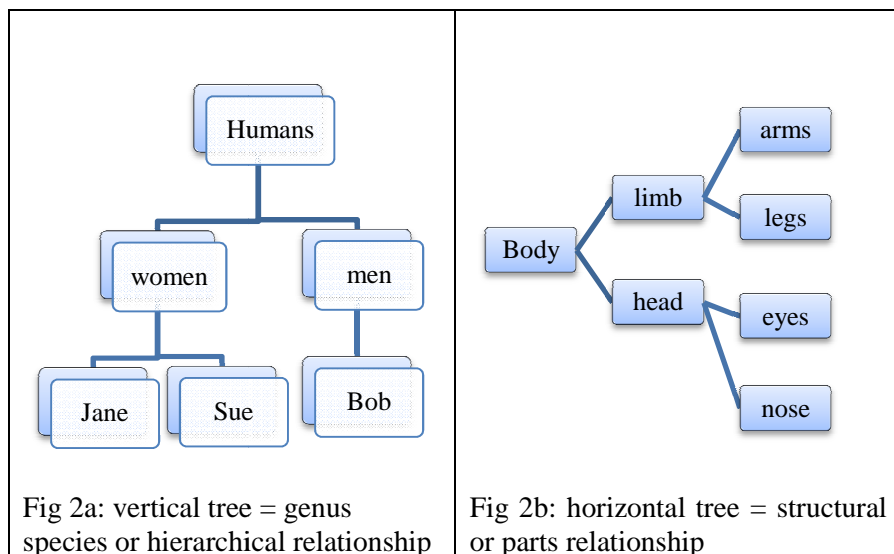
Figure 2 – Examples of Visual Learning Maps

While such vLms are being used in these STS courses, one of the authors of this paper has been collaborating with another faculty member in the University's chemistry department on these visual learning maps in introduction to inorganic chemistry and chemistry for engineering courses. The intent is to help students develop study and thinking skills for effectively reading and learning from college level textbooks. These maps are integrated into the lesson plans as useful aids to help students simplify complex textual information, solve problems and improve their reading and writing skills. The instructor of these courses, Knaus (2012), has shown that using the vLms improved the thinking skills of college chemistry students, especially those whose previous achievement in the discipline have been on the lower end of the bell curve (Knaus, Tang et al. 2012).

The preliminary results suggest the maps work best with students at the "lower" end of the bell curve describing academic achievement and understanding is encouraging because the maps can therefore be used most effectively for students who are in the greatest need for such intervention tools. When pre- to post-student performance score are broken down into tritiles, we can see that a greater proportion of students initially in the low ability level made transitions into either the middle or high ability level for the experimental condition (maps class) in comparison to the control condition. Figure 3 depicts pre- and post-student performance and net learning gain in content areas for students using mind maps as a function of student ability.
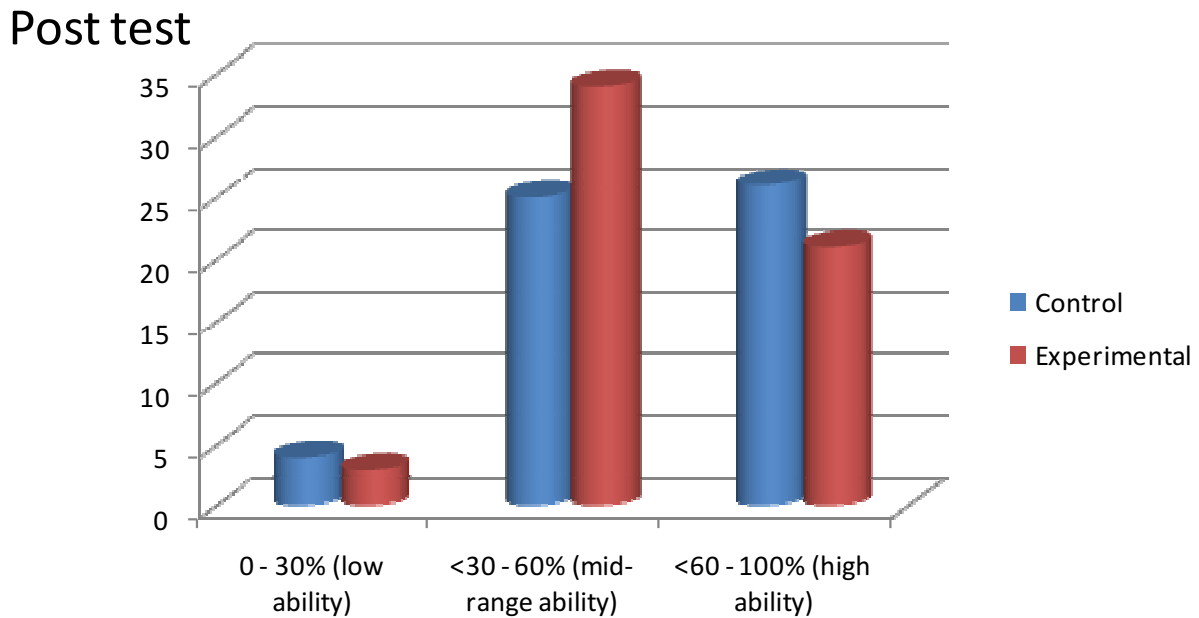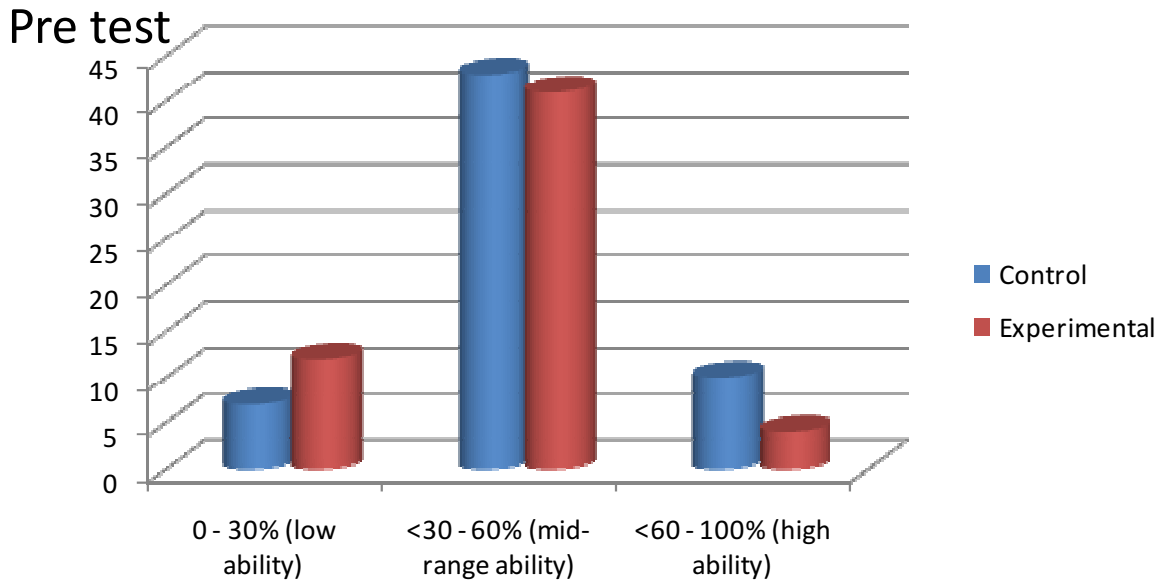
Pre test

Post test

**Figure 3 – Pre-post student performance and net learning gain
in content areas as a function of student ability**

Overall, the propagation of research emanating from these two STS courses suggests that ENGR 3400 and Engineering 3600 are making a considerable impact in the Engineering College, the University, and beyond in the world of education research on the impact of new technologies in higher education (Tang, Hyerle et al. 2012).

Satisfying ABET Criteria

After numerous course offerings over several semesters, it became clear that aside from fulfilling Core Curriculum and general liberal education requirements of the university, the two courses also address contained content and learning goals that fit well into ABET accreditation such as:

- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; and
- a knowledge of contemporary issues

This portion of the paper describes how the courses fit into specific ABET requirements and how the authors measure these rubrics for ABET purposes. After each rubric, the authors briefly describe how well the courses are satisfying specific ABET outcomes.

A. An ability to design a system component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability:
ENGR 3400 or ENGR 3600 do not have a strong design component; however, these courses do teach systems as a sociological methodology, which can be applied to economic, environmental, social, political, and ethical issues relating science and engineering practice. ENGR3400 focuses one-third of the course on ethical and value issues as they relate to science and engineering.

B. An understanding of professional and ethical responsibility:
One of three units in ENGR 3400 is dedicated to ethics as they relate to entrepreneurs involved in the development of the Internet. The course looks at ethics as part of a new business value system as well as the "hacker ethic," which some speculate may be emerging in engineering practice.

C. An ability to communicate effectively:
In both ENGR 3400 and 3600, students are assessed in the understanding of the reading material and the ability of the students to express that understanding with in-class writing as well as threaded discussion board posts for online sections.

D. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context:
One of the goals of both ENGR 3400 and ENGR 3600 is to give Engineering and pre-Engineering majors a broad and interdisciplinary perspective and an educated framework

to better understand the impact of engineering solutions in a global, economic, environmental, and societal context.

E. A knowledge of contemporary issues:
    While the two courses are interdisciplinary in content and methodology, they do emphasize the sociology of science and technology as well as the contemporary issues relating the scientific and engineering practice.

F. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:
    Both courses examine the techniques, skills, and modern tools necessary for contemporary engineering practice. For example, in ENGR 3400, Technology and Culture, we examine the empirical history of the Internet to the present. In addition to learning about how the Internet works from a technical perspective, such as requisite operating systems and technical requirements, the course covers how these technologies impact other aspects of society, such as business and education.

In the Spring/Fall Semester of 2010, the authors attempted to evaluate the ABET outcomes in the courses in a more quantitative method by including questions associated with the ABET criteria to Faculty Course Questionnaires (FCQ) with the results displayed in Table 2 on a five-point Likert scale:

Table 2 – FCQ Data Comparing Student Appreciation and Evaluation of General Course Objectives with ABET Content and Issues Criteria

n=179	Avg.	Median	SD
(a) **Instructor Compared to others**	3.7	4	1.7
(b) **Course as Learning Experience**	3.8	4.5	1.7
(c) **Course Compared to All others**	3.7	3.5	1.7
(d) **Appreciation of Global aspects of STS**	4.2	5	1.6
(e) **Understanding of Ethics and Values**	3.8	4	1.6
(f) **Appreciation of STS Contemporary issues**	4.2	5	1.4
(g) **Understanding of cultural aspects of STS**	3.8	5	0.5

While Table 2 does not directly illustrate how well students understand the ABET concepts and rubrics, the numbers do indicate that they appreciate certain ABET learning outcomes as much as they do the other general ideas of the course as they relate to the interactions between society, science, and engineering. From these numbers, it can be seen that students generally were more satisfied with the ABET rubric content of the course than they

were with other aspects of the course such as (a) the instructor compared to others, (b) course as a learning experience, and (c) course compared to all others.

Conclusion

The integration of two STS courses – ENGR 3400: Culture and Technology and ENGR 3600: the International Dimensions of Culture and Technology – initially into the engineering curriculum and later university-wide has been achieved with considerable success. With respect to the original goal of adding breadth to the undergraduate engineering curriculum so that our future engineers will better understand the context of their work in society, these two courses have provided a forum for engineering students to critically and systematically analyze complex technical and human interactions through a looking glass that uniquely focuses on technological and scientific context that have become global in nature. As general studies courses in the areas of cultural diversity and gender (ENGR 3400) and international perspectives (ENGR 3600), the courses have also attracted considerable enrollment across majors and academic divisions, with most non-engineering students coming from the sciences and the colleges of business and media arts.

While the high enrollment numbers may be related to a general increase of STS studies throughout the country and Europe, there is also the accelerating trend of technology and technological practice becoming endogenous to all aspects of culture and society (Romer, 1990). One benefit of the high enrollment and different teaching formats is that these courses have provided an ideal environment to study an STS theme and the impact of new technologies on education. This research has also led to development of new software applications to improve the teaching of the courses and STEM courses in general

In addition to helping students understand technological practices such as engineering in a broader context and systems perspective as well as providing the course instructors with empirical research opportunities on the impact of new technologies on higher education, these two STS courses have also fostered a new and unique way to satisfy specific ABET accreditation requirements. Currently, the data used to determine if the students achieved understanding of engineering practice in a broader context simply measured student opinion instead of whether they truly achieved this understanding; accordingly, we are developing another assessment method to help better measure how well the students actually acquired this understanding.

Overall, these courses are a template by which other professors and universities can begin to establish their own curriculum for subjects such as technology as it relates to globalization, multiculturalism, informational technologies, world politics and culture, diversity, as well as alternate paradigms. Such an understanding will only help improve the ability of our next generation of engineers, as well as those from other disciplines, in solving many of the complex, global problems that the 21st century will face.

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