Engineering and Society: A Course for First-Year Engineering Students and Non-Majors

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***Abstract* – Engineering and Society is a course designed for first-year engineering students and non-majors. The goals for the design and implementation of this course, as well as course learning outcomes and content are discussed. Preliminary assessment of changes in student perceptions and attitudes after taking the course is reported. Preliminary outcomes assessment for the course is also reported. In general, the course is achieving the goals and outcomes it was intended for.**

Index Terms – Engineering and Society, First-Year Engineering, Engineering for Non-Majors

INTRODUCTION AND BACKGROUND

A course designed for first-year engineering (FYE) students and non-majors (NM) has been conceived, piloted one semester, and taught four semesters in multiple sections at Clarkson University, a small, technologically-focused research university comprised of three schools – Engineering, Arts and Sciences, and Business. *Engineering and Society*, ES110, was designed to meet the strategic needs of the Wallace H. Coulter School of Engineering as well as curricular requirements for majors of the other two schools. Briefly, the course engages FYE students with engineering faculty and the field of engineering in general, but course content is focused on societal aspects of engineering and technology more than traditional engineering topics. The purpose of this extended abstract is primarily to report on the conception and design of this course and our experience teaching it over a few semesters. Some data indicating course impact on student perceptions and attitudes and partial assessment of student learning outcomes are also reported.

Prior to its introduction the first-year curriculum for all engineering majors consisted of two-course sequences in Calculus, Physics and Chemistry, two humanities/social science/writing courses and a two-credit computing course, which was the sole course taught by School of Engineering faculty. One of these social science/humanities courses would satisfy a "knowledge-area" (or KA) requirement of the Clarkson Common Experience (CCE) [1], broadly analogous to an outcomes-based general education curriculum. ES110 was designed to meet the outcomes of one of the KAs of the CCE requirement, namely the Science Technology and Society (STS) KA. Non-majors who enroll in this course receive credit toward the Technology course requirement of the CCE which also has specific, defined outcomes. These latter outcomes are often obtained in an engineering design experience, so engineering majors satisfy this requirement naturally in their required curricula.

COURSE CONTENT AND PEDAGOGY

The core learning objectives of the course are:

1. Students will demonstrate an understanding of and an ability to use the engineering design process.
2. Students will demonstrate an understanding of value systems and ethics and be able to relate these concepts to professional problems.
3. Students will demonstrate the ability to recognize and analyze environmental, social, political, ethical, health and safety, and sustainability considerations and impacts of engineering design.
4. Students will demonstrate an appreciation of the need for critical assessment of the sources of information, including computational tools, used to solve engineering design problems.
5. Students will demonstrate an understanding of the major engineering disciplines and be able to identify the core scientific disciplines underlying these. They will demonstrate an understanding of how the engineering profession intersects with the sciences and mathematics.
6. Students will demonstrate the ability to effectively communicate their ideas in written and oral formats.

These map with various degrees of intersection to ABET General Criteria (3), outcomes a,b,c,d,f,g,h and j, but especially to c, f, h and j which associate to design, ethics, societal context, and contemporary issues, respectively. They also map to the STS KA and Technology course outcomes mentioned earlier.

Instead of the more common first year engineering course consisting of design, engineering ethics, engineering problem solving and engineering topics, the course fuses a scaled-back version of such content (excluding most of the engineering problem solving) with content addressing concepts and knowledge associated with engineering, technology and society. When synthesized in this manner, engineering ethics and engineering design content/ experience dovetail with the technology and society content. Our approach is supported by the work of Geselowitz and

Vardalas [2], and our experience has been that this combination works well. It is a way (among many) to address societal context and contemporary issues (ABET 3 h & j) alongside engineering topics in a manner that emphasizes the former. In particular the role of societal forces in shaping technology is emphasized. While most students broadly accept the notion that our society is shaped by technology, the converse relationship is less apparent.

Course content is summarized broadly in Table I, where topical areas are listed along with the approximate number of periods dedicated to that topical area, based on a 15 week semester with three 1-hour class periods per week. Also listed in Table I are the reading and reference materials that support the topical areas listed. The custom textbook referred to in Table I was created using the Pearson E Source texts by Horenstein [3] and Fleddermann [4]. For the first topical area, additional content is drawn from various sources on the fundamental nature of science, mathematics, technology, sociotechnical systems, etc., and how engineering contrasts with and intersects with these. For the second topical area all of the material has been compiled from various texts with content on the sociology and history of engineering and technology such as [5-6], for example. The coverage of these topics is necessarily brief. In particular, coverage of the history of engineering and technology from pre-history to the early twentieth century was intended primarily to set the stage for discussion of modern engineering and emphasized the scientific and industrial revolution periods. The bulk of student work on the design project is done outside of regular class periods.

TABLE I
BROAD TOPICAL DISTRIBUTION

Topical Area	Number of Class Periods	Reading and References
Introduction and The Engineering Professions	2	Custom Textbook and Supplemental Material
The History of Engineering and Technology through the Early Twentieth Century	3	Supplemental Material
The Design Process and Design Project	8	Custom Textbook
Value Systems and Engineering Ethics	5	Custom Textbook
Engineering and Society	22	*Beyond Engineering: How Society Shapes Technology* by Robert Pool [7]
Exams	5	

The largest amount of time is devoted to the topical area sharing the course name. This part of the course focuses on reading and discussion of the text listed [7]. This volume addresses the following concepts: positivism and social construction, technological momentum, complexity, uncertainty and risk, control of technology, and business and economic forces with respect to the evolution and management of technology. It does so by describing historical cases, primarily from the early 20th century on, such as the electric power industry, gas turbines, personal computers, etc. The development of nuclear power serves as a consistent theme throughout the book. Some historical cases described, such as the development of steam power, the Challenger launch decision and the Bhopal, India pesticide plant disaster, overlap with cases addressed in earlier sections on the history of technology and engineering ethics. There is a chapter entitled 'Choices' that dovetails well with design process content. Writing for a general audience, the author draws from history, economics, sociology, psychology, risk analysis, etc. to underpin discourse on the cultural and societal forces shaping technology. Enough technical detail to provide engineering context as well as to maintain interest from an engineering perspective is included.

Substantial reading outside of class is expected of students with class periods devoted mostly to interactive class discussions and activities, though some presentations by the instructor are required. As an example of class period activities, when engaging them in the study of engineering ethics, students practice role play and value conflict resolution, approaching problems through the lens of different ethical theories, and applying ethical problem solving techniques to analyze ethical decisions associated with a number of historical case studies and hypothetical examples. Students are assessed on their ability to engage in course activities and to successfully demonstrate their understanding of concepts orally and in writing.

PRELIMINARY ASSESSMENTS AND RESULTS

We have completed partial assessments of two types, conducted during different semesters: (I) we assessed opinions and attitudes of students enrolled in each semester of the course to date, and, (II) we conducted course level outcomes assessment in Spring 2013. Analysis of student attitude data is currently underway; results reported here include those 'in progress' only.

I. Opinion and Attitude Survey

A supplemental goal of this course is to clarify students' perceptions of the broad or holistic nature of engineering problem solving and design, and in fact, of engineering careers in general, as well as to positively impact their attitudes toward studies and careers in engineering. To assess the degree to which we are achieving this goal, we have conducted a relatively simple pre-test/post-test study each semester using a single-group pre-test/post-test design with the pretest acting as the control group [8]. Students complete written questionnaires on the first day of class, and again near the end of the semester. During one semester (Fall 2012) a true control group was obtained by administering questionnaires at similar times to engineering students in all sections of freshman Physics I who, by virtue of their schedules, were not enrolled in ES110. We plan to utilize a similar approach for subsequent fall semester assessment protocol. The questionnaire we use was developed as part of this project. Most of the attitude items were adapted from existing questionnaires [9-12]. The questionnaire contains 27 items that use a Likert-type format with five options ranging from strongly disagree (1) to strongly agree (5). Some items are intended for all students (ALL), while others are intended for FYEs or for NMs only.

Likert-type rating scales were converted to numerical values (1 to 5) according to a predetermined preferred direction of response in order to calculate summated rating totals for each item. Items were subsequently grouped into six topics or categories, and average mean responses for each student were calculated as simple means based on their responses to each item in the category. Results were analyzed by comparing students' matched pre/post average mean scores using the Wilcoxin signed rank test, a nonparametric statistical procedure equivalent to the paired-sample Student t-test.

Students were grouped into three categories for analysis: FYE (n=435), NM (n=77), and Control Group (n=253). Results are displayed in Figures 1-3, where error bars represent ±1SD, S+ and S- denote statistically significant positive and negative changes, respectively (α=0.05).

In general, for all students enrolled in the course there were significant pre-post improvements in student responses to items relating to students' self-confidence, particularly with respect to their problem solving capabilities. Differences were significant for both groups of students for the category average, and for several items within the category. Likewise, there was a positive change in students' understanding of the broad nature of engineering and engineering problem solving, including the relationship between engineering and society and the role of ethics in engineering design. They also better understood the role of creativity in the engineering design process. Similar increases in positive response were noted for all students when asked about their sense of "fit" within the engineering profession. As might be expected, post scores for the FYE students were quite high relative to NM students. On the other hand, when asked about confidence in an engineering curriculum NM students showed no pre/post change in response and the average response was quite low (2.8), while FYE students demonstrated a significant drop in the category mean and several of the item mean scores, yet post scores were much higher than for the NM students (e.g. 3.9 category average mean score for FYEs). Students indicated lowest levels of confidence about succeeding in their math courses and highest levels of confidence regarding success in their engineering courses and engineering curriculum. The negative changes for FYE students follow pre-mean values that are in fact quite high. Interestingly, when FYE students were analyzed in separate cohorts for fall and spring enrollments, both groups demonstrated this same behavior although post average scores for the spring cohort were slightly higher than for the fall (4.1 vs. 3.9, respectively).

Although no statistical comparisons have been made as of yet, there appear to be great differences between the pre/post changes in student opinions and attitudes toward engineering among the Physics control group vs. the students enrolled in this course. Average student responses to 4 categories of items dropped significantly between the

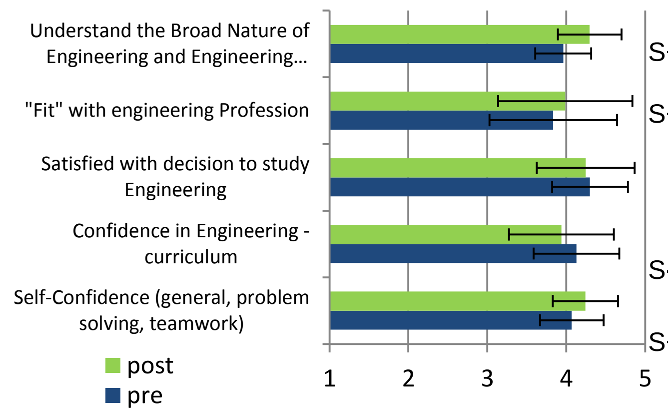

FIGURE 1
MEAN RESPONSES FOR QUESTION CATEGORIES, FYES

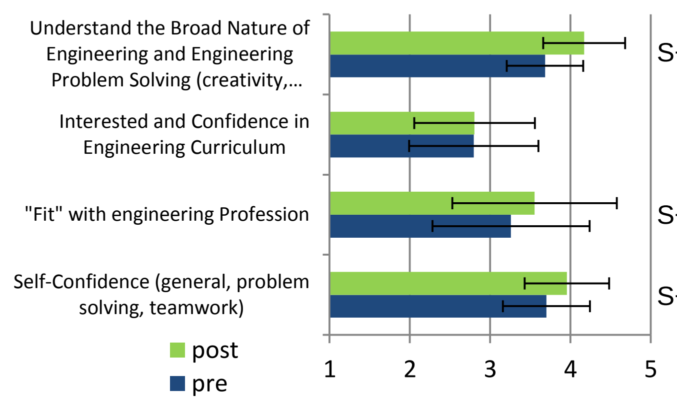

FIGURE 2
MEAN RESPONSES FOR QUESTION CATEGORIES, NMS

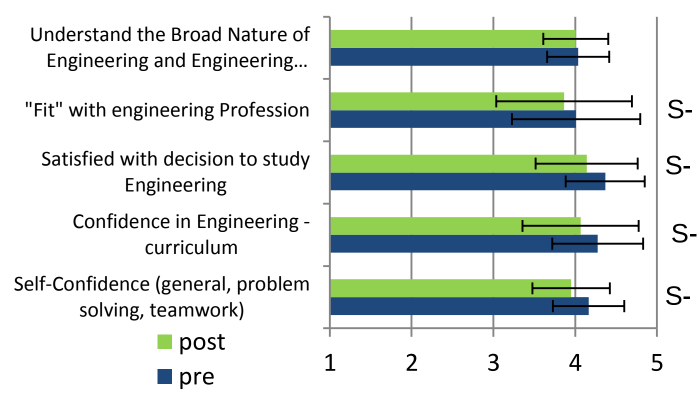

FIGURE 3
MEAN RESPONSES FOR QUESTION CATEGORIES, CONTROL GROUP

pre and post survey, with significant negative changes in 18 of the 23 questions asked. Student post scores were higher than pre-scores for only one item, their degree of understanding regarding how engineering decisions are made. Relative to the FYE students enrolled in the course, the control group had lower post scores on most survey items, and lower averages in all categories except for one: control students exhibited a higher confidence in their ability to succeed in the engineering curriculum (4.1, control; vs. 3.9, FYE). This most likely reflects differences primarily between the control group and the fall cohort of FYE students enrolled in the course. This cohort of FYEs was overwhelmingly composed of those who were tracked into this course by virtue of their scores on pre-enrollment exams, with emphasis on the math readiness, i.e. these FYEs were identified as less well prepared in mathematics. There is no content in this course aimed at improving their confidence in math/physics *per se*, so their experience in Calculus I over the course of the semester and, in particular, their perception of their likely grade in Calculus I at the particular time they completed the post-survey is probably a more important factor influencing these responses than their experience in this course. Differences between the control group and the spring FYE cohort were negligible, and for all groups of students there was a negative pre/post change in their confidence in this area.

Despite the drop in student confidence regarding the engineering curriculum, the post-response average for satisfaction with their decision to study engineering remains relatively high for all the FYE students (4.25 post for all FYEs). This probably reflects a high determination to succeed in the engineering curriculum among incoming students that is an institutional characteristic.

II. Course-Level Outcomes Assessment

Outcomes assessment was performed for the Spring 2013 semester version of the course focusing on ABET General Criteria 3(c), (f), and (h). Summative assessments were conducted using their design project deliverables [ABET 3(c)] and specific exam questions that targeted 3(f) and (h). Scoring rubrics were used for the design projects and specific criteria were used to grade the exam questions. For outcome 3(c)-design, 98.0% of students met and 65.7% exceeded expectations. For outcome 3(f)-ethics, 86.3% met and 44.1% exceeded expectations. For outcome 3(h)-societal context, 85.3% met and 41.2% exceeded expectations.

For this semester, student work met expectations for ABET General Criteria 3 outcomes assessed and, by extension, the overlapping STS and Technology course outcomes. More data are needed, however, to form firmer conclusions. Additionally, the spring semester student cohort in this class is potentially quite different than the fall cohort. Future work will involve use of the same questions in Fall 2013 for course-level assessment and then re-evaluation with respect to course content and pedagogy.

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