AC 2012-4383: A COURSE ON ENGINEERING AND SOCIETY FOR FIRST-YEAR ENGINEERING STUDENTS AND NON-MAJORS

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

Abstract

A course designed for first-year engineering students and non-majors was conceived, piloted and taught over the course of two semesters. The course addresses the engineering design process, including a hands-on project, engineering ethics, and engineering and society content. This paper describes the course and the instructors' experience teaching it, and reports on an initial study of changes in student perceptions in the course using a single group, pre-test/post-test design.

Background and Introduction

Clarkson University is a small, technologically-focused, research university comprised of three schools – Engineering, Arts and Sciences, and Business. Total enrollment is approximately 3000 undergraduate and 500 graduate students, with engineering majors comprising over half of the undergraduate enrollment. A course was needed to meet the strategic needs of the School of Engineering as well as curricular requirements for majors of the other two schools. Specifically, the former can be summarized as enhanced engagement of first-year engineering students with engineering faculty and the field of engineering in general. Prior to the introduction of this course, 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 the School of Engineering faculty. The non-majors' needs consist of a *Technology (Tech)* course requirement having specific, defined outcomes associated with a common university curriculum.

A course was designed and taught for two semesters that addresses the aforementioned needs. The purpose of this paper is to describe this course, how it fits into the first-year engineering curriculum and to provide observations and results from the first semester pilot course and the subsequent semester roll-out of the course with multiple sections and instructors. A description of this course, preliminary assessment of related changes in student perceptions, and our experience teaching it will be provided. Direct assessment of learning outcomes is not presented in this paper, though a description of the intended outcomes is offered to provide context for the course design.

All engineering programs are faced with meeting the diverse and challenging outcomes of ABET Criterion 3.[*] Though it is not at present intended as a required course for engineering majors, the course described here at least partially addresses many (or most) of these outcomes in a course delivered to first-year engineering students. It does so in a multidisciplinary context in that it

[*] http://www.abet.org/eac-current-criteria/

does not focus on a single engineering discipline and non-engineering majors are enrolled. Because it addresses the role of engineering in society and the effect of societal forces on technology development, it might prove to be a good concept for a springboard course for engineering curricula. It may also be useful as a source of ideas to those teaching or contemplating delivering similar courses, or courses which intersect this course in some way in content, objectives, etc.

Course Outcomes, Content and Pedagogy

The common university curriculum, known as the *Clarkson Common Experience Curriculum*, requires all undergraduate majors of the university to complete courses in six *Knowledge Areas* and complete at least one *Tech* course along with other requirements relating to communications outcomes and professional experience. These curriculum requirements are outcomes-based, so that courses designated as satisfying any of the six *Knowledge Areas (KAs)*, or as a *Tech* course, must meet specified learning outcomes.[1] One of these *KAs* is *Science, Technology and Society (STS)* for which a student successfully completing a so-designated course should:

1. Analyze relationships among science, technology, and the health and welfare of humans and sustainability of the environment.
2. Gain an awareness of information technologies and their impact on society, culture, business, and education.
3. Understand the social and contextual nature of scientific research and technological developments
4. Analyze conflicting cultural values in scientific and technological research.
5. Analyze critically the sources of information about science and technology.

Courses receiving a *KA* designator should address a majority of the learning objectives for the *KA*. Courses receiving a *Tech* course designation should address the first of the learning outcomes listed below plus a majority of the remaining three learning outcomes.

1. Student work should demonstrate an understanding of the role of engineering in developing technological responses to human needs and desires.
2. Student work should demonstrate completion of progressively more complex problem-solving tasks showing competent information access, evaluation, and application.
3. Student work should demonstrate analysis of each task based on a clear, logical thought process well-grounded in the relevant underlying knowledge, and communication of an understanding of the significant characteristics of the problem.
4. Student work should demonstrate creativity by solving problems incorporating diverse considerations.

The clear possibility for intersection of Outcome 1 for a *Tech* course and all or most of the outcomes for an *STS* course can be noted, as can the correspondence of all the outcomes for a *Tech* course with expected outcomes from immersion in the engineering design process. As the engineering design process provides for unity among the engineering disciplines, a course incorporating this with a team design project addresses all engineering majors' needs as well as the needs of non-majors, the former in a formal sense with regard to ABET Criterion 3 and the latter with respect to the *Tech* course requirement. Furthermore, the outcomes for the *STS* course align in a general way with ABET Criterion 3, outcomes c, h and j,[†] and outcomes associated with engineering ethics intersect both ABET criterion 3, outcomes e and f and *STS* outcomes 1 and 4. Thus, a course was conceived that would meet approval from a university committee charged with that authority for both the *STS* and *Tech* designators, incorporating instruction in engineering ethics, the engineering design process and a design project, and content in how science, technology and engineering shape society and how society shapes science, technology and engineering. The only prerequisite for the course was an introductory college-level mathematics course. The course is not presently intended as a required course for engineering majors and it does not substitute for existing curricular content in any of the engineering programs. Instead, it attempts to address the KA outcomes of the common curriculum within an engineering context, providing for some engagement of first-year engineering students with engineering faculty while also meeting the *Tech* course needs of the non-engineering majors.

The basic goals of this course were:

1. To provide an introductory exposure to the engineering professions.
2. To engage teams of first-year engineering students and non-engineering majors in the engineering design process.
3. To introduce students to the role and impact of engineering in society.
4. To begin instilling a critical view of information sources impacting engineering analyses and decision making.
5. To begin developing an understanding of potential for conflicting personal, organizational and social values in engineering decision making.

As originally conceived, the course learning outcomes (referring to understanding and abilities appropriate for first-year, post-secondary students) were:

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.

[†] http://www.abet.org/eac-current-criteria/

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.

To achieve these objectives, the course as taught during both the first semester pilot (spring 2011) and the second semester (fall 2011) roll-out was structured as a lecture-discussion course augmented with a semester design-and-build project. Topical coverage can be summarized into the following categories: (i) Introduction and The Engineering Professions, (ii) The History of Engineering and Technology through the Early Twentieth Century, (iii) The Design Process, (iv) Value Systems and Engineering Ethics, and (v) Engineering and Society.

Topics (i), (iii) and (iv) used material published in a custom textbook created using selected chapters from the Pearson E Source texts by Horenstein[2] and Fleddermann[3] augmented with material from various sources. For topic (i) examples of such additional content would be discussion of the fundamental nature of science, mathematics, technology, sociotechnical systems, etc., and how engineering contrasts with and intersects with these. For topic (ii), no text was provided; all of the material was compiled from various texts with content on the sociology and history of engineering and technology.[e.g., 4-5] The coverage of these topics was 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. In the 3 credit semester, 15 week course, topics (i)-(iv) occupied one third of the semester with several periods devoted to either discussion of or activities in pursuit of the semester design project. The bulk of student work on the design project was done outside of regular class periods.

The remaining two thirds of the semester were primarily devoted to topic (v). This part of the course focused on reading and discussion of *Beyond Engineering: How Society Shapes Technology*[6] by Robert Pool. 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. Some historical cases, 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. The primary unifying case used throughout the book is the nuclear power industry, though there are multiple other examples illustrating thematic analyses. There is a chapter entitled ‘Choices’ that dovetails well with design process content. Writing for a general audience, Pool draws from history, economics, sociology, psychology, risk analysis, etc. to underpin discourse on the cultural and societal forces shaping technology. We feel that he provides enough technical detail to both provide engineering context and maintain interest from an engineering perspective for both students and faculty.

Students were prompted to read chapters prior to periods during which discussions of those chapters would be held. On-line quizzes, which were completed outside of class and administered through the university moodle[‡] site, were used to incentivize timely completion of the reading assignments. In-class discussions were facilitated by preparation of discussion questions about the reading created by the course instructors. Discussions centered on these questions. Students were allowed at times to discuss the questions in small groups, followed by sharing with the class as a whole. At other times, the discussions were led by the course instructor, soliciting answers and opinions from the class.

The design projects in this course had to be necessarily limited in scope, both in terms of the amount of time students were expected to spend on it as well as the resources needed to construct, test and demonstrate their prototypes. Immersion in the design process was the primary purpose. All of the engineering majors will complete additional design courses in their respective programs and this course is not intended to replace these. The design project for the pilot course was to design and construct a spill-proof table candle holder.[§] The design project for the subsequent multi-section course was to design a one-handed snow shovel for use by a person having functional capability of one arm/hand only. Materials for the prototypes in each case could include standard craft materials and throwaways or recyclables. Additional construction material purchases, including adhesives and fasteners were allowed as long as the total charges for any team did not exceed thirty dollars. In the case of the one-arm snow shovel, each team was provided with one standard snow shovel for modification. Construction of the prototype could employ typical hand tools used in crafting. Hand tools such as pliers, wire cutters, saw, and screwdrivers were allowed; hot glue guns were allowed. Power tools and machine tools were not allowed, though a difficult cut or hole drilling operation could be performed by the machine shop staff if warranted. Small tool kits were provided for the teams on a check-out basis. The students were allowed to self-select their design teams of 3-5 students per team. Using a brief survey, we found during both the pilot course and the subsequent roll-out semester that non-majors were as likely to self-report an aptitude for creativity, innovation and hands-on activities as the engineering majors enrolled in the course. Roughly five class periods were given over to in-class design project work, team-building, etc.

Design project teams were required to submit four progress reports, deliver an in-class presentation and prototype demonstration and submit a final report. The four progress reports were broken down according to: (a) Specifications, (b) Results of Brainstorming; Identification and Evaluation of Possible Design Strategies; Preferred Approach, (c) Design of Prototype, and

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[‡] http://moodle.org/

[§] This project idea was taken from Horenstein's text[2] (Chapter 2, Problem 7)

(d) Build and Test Prototype. These team assignments were used to assess a team grade for the design project.

Assessments for grading the lecture-discussion content of the course consisted of homework assignments, the on-line quizzes, in-class questions, homework portfolio, two in-class examinations and a final exam. Homework, quizzes, and in-class questions were considered to be largely formative and, consequently were not weighted heavily in the final grade. Homework assignments consisted of written answers to questions about the reading/in-class presentations/discussions. These assignments were all graded by the course instructors who provided written feedback on the answers. On-line quizzes were short answer (e.g. multiple choice and true/false); answers to in-class questions were graded largely based on effort; the purpose of the homework portfolio was to instill the habit of keeping and organizing course work and, as such, credit was assigned on the basis of completing and turning it in. Examinations (in-class and final) were comprised of a mix of multiple choice, true/false, and discussion questions, with substantial weighting on the discussion questions.

Instructor and Student Cohort Characteristics

The four instructors for the multi-section roll-out of this course are all faculty in the School of Engineering, with advanced degrees in engineering disciplines (two Ph.D., one M.S., one M.S. and M.B.A.); three are female. The pilot course was taught by the Associate Dean of the School (who also taught a section of the multi-section version), assisted by one of the other three faculty.

The pilot course enrollment consisted of second-semester, first-year engineering (1stYE) students and non-majors (NMs), with 22 1stYE students and 13 NMs. Twelve of the NMs were School of Business Juniors and one was an Engineering and Management major who was a freshman. The subsequent multi-section roll-out was taught in six sections with a total enrollment of 190 (163 1stYE, 27 NM), broken down as 29 (24 1stYE, 5 NM), 37 (25 1stYE, 12 NM), 35(29 1stYE, 6 NM), 31(27 1stYE, 4 NM), 28 (27 1stYE, 1 NM) and 30 (29 1stYE, 1 NM). In contrast to the pilot course, which was taught in the spring semester, the 1stYE students in the fall semester roll-out were first-semester students. In addition, the bulk of these first-semester, 1stYEs (approximately 140-150) were students who were 'tracked' into the course in lieu of Physics I by virtue of their scores on previously validated math-readiness exams[7] administered pre-enrollment. This was part of a related but distinct initiative with the intention of de-coupling Calculus I/Physics I co-enrollment for this group of students. These students would take Physics I in their second semester rather than taking it at the same time as Physics I. In depth discussion of this initiative is beyond the scope of this paper. It is mentioned here since it relates to the academic preparedness of this group of 1stYEs, who were identified as less well prepared in mathematics. The remaining 1stYE students (approximately 10-15) in this cohort were students having incoming college transfer credit or advanced placement (AP) credit such that this was a logical course for them to take during the first semester in lieu of courses for which they already had credit. All preliminary assessment of student perceptions and attitudes presented in this paper pertains to the cohort in the fall semester roll-out.

Assessment of Student Perceptions and Attitudes

Methodology

In addition to the aforementioned content-related course outcomes and learning objectives, 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 that end, a simple study has been designed and implemented in the fall 2011 course roll-out that uses a single-group pre-test/post-test design with the pretest acting as the control group.[8] Students completed written questionnaires on the first day of class, and again near the end of the semester. The questionnaires were anonymous, although students entered codes to enable matching of their pre- and post-survey responses. All components of the survey procedures have been approved by Clarkson University's Institutional Review Board (IRB) and were conducted in a manner that protects the rights and welfare of the human participants.

The questionnaire we used was developed as part of this project. Most of the attitude items were adapted from existing instruments,[**] while original items were created to measure course objectives related to students' understanding of the breadth of engineering and interactions with society. The questionnaire contains 27 items that use a Likert-type format with five options ranging from strongly disagree (1) to strongly agree (5). The first 13 items are intended for all students (ALL), followed by nine items intended for 1stYE and five items for NM students. The items are specifically intended to measure students':

1. (ALL) Self-confidence, including general student performance as well as confidence with engineering problem solving and design, and team work;
2. (1stYE) Confidence in engineering curriculum;
3. (1stYE) Satisfaction with decision to study engineering;
4. (ALL) Comfort level or "fit" in an engineering company;
5. (NM) Interest and confidence in engineering curriculum; and
6. (ALL) Understanding of the broad nature of engineering and engineering problem solving, including creativity, teamwork, ethics, and societal context.

Additionally, one open response question was included on the post survey requesting students to briefly describe which aspects of this course were most valuable to them.

[**] Existing instruments include (references 9-10);[9-10] as well as the APPLES (Academic Pathways of People Learning Engineering Survey), created by the CAEE (Center for the Advancement of Engineering Education) project and available online at http://caee-aps.stanford.edu/phpESP/admin/manage.php; and the LAESE (Longitudinal Assessment of Engineering Self-Efficacy) survey versions 3.0 (copyright 2006) and 3.1 (copyright 2007), which are products of AWE (Assessing Women and Men in Engineering), available online at www.aweonline.org.

Student responses to each item were entered into a Microsoft Excel spreadsheet for analysis. Likert-type responses were converted to a numerical score ranging from 1 (least desirable) to 5 (most desirable). With the exception of the post-survey open-ended response question, only those surveys for which both pre and post data were collected were used, and blank responses to individual questions were omitted case-wise from the analysis. All open-ended post-survey response questions were retained for analysis.

Student responses on the pre and post surveys were compared using students' matched pre/post scores on individual items as well as their mean scores for each of the six categories described above, which were calculated as simple means based on their responses to each item in the category. Pre and post item and category mean scores, ranging from 1-5, were compared using the Wilcoxin signed rank test, a nonparametric statistical procedure equivalent to the paired-sample Student t-test. All analyses were performed for the entire group of students, and separately for the 1stYE and NM students. Analyses were performed with *Statistical Package for Social Sciences* (SPSS) Statistics Version 17. Students' open-ended responses to the post survey question were reviewed for the presence of conceptual threads or patterns,[11-13] with subsequent tallying of the particular threads or themes that emerged. The narratives were also used to provide more depth to our understanding of the impact of the course on student attitudes toward and understanding of engineering.

Results

The pre/post matching procedure resulted in a 73% overall response rate (n=136 total; 122 1stYE and 14 NM student surveys). Results are summarized in Table 1 and Figures 1 and 2 (with full details in the appendix). Table 1 presents mean student responses on the post survey (ranging from 1 to 5), and the post-pre differences, for all six of the above categories and for a few selected items within each category. Results are shown for the 1stYE and NM students, separately. Bold values in the table indicate a significant difference between the pre and post survey mean response, as calculated with a Wilcoxin signed rank test. Pre/post mean student responses are shown for each of the six item categories for 1stYE students (Figure 1) and for NM students (Figure 2).

In general, there were significant pre-post improvements in student responses to items relating to students' self-confidence (post score 4.2 1stYE; 4.0 NM), particularly with respect to their problem solving capabilities (post score 4.2 and 4.3, 1stYE; 3.9 and 4.3, NM). 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 (post score 4.4, 1stYE and NM students) and the role of ethics in engineering design (post score 4.4, 1stYE and NM). They also better understood the role of creativity in the engineering design process (post score 4.6, 1stYE; 4.5, NM). When asked about their sense of "fit" within the engineering profession (1stYE) or with an engineering company (NM), there was

Table 1: Student post mean response and pre/post gains on selected items				
	1stYE		**NM**	
	Mean response Post	**Post-pre Gain[b]**	**Mean response Post**	**Post-pre Gain[b]**
Self-Confidence	**4.24**	**0.15*****	**4.03**	**0.31***
On the whole, I am pleased with my performance as a student.	3.97	-0.05	3.86	0.14
I feel confident about applying a systematic design process to an unfamiliar problem.	**4.15**	**0.57*****	**3.86**	**0.64***
I have almost no understanding of how to approach solving a new problem or challenge.[a]	**4.31**	**0.25****	4.50	0.07
Confidence in Engineering Curriculum	**(3.76)**	**(-0.35***)**		
I can succeed in an engineering curriculum	(4.24)	(-0.13)		
I will succeed (earn an A or B) in my math/physics courses (2 items combined)	**(3.36)**	**(-0.57***)**		
Satisfied with decision to study engineering	**(4.17)**	**(-0.15**)**		
At the present time I am satisfied with my decision to study engineering.	**(4.20)**	**(-0.20*)**		
At the present time I am exploring other non-engineering majors at Clarkson University.[a]	**(3.98)**	**(-0.36**)**		
A degree in engineering will allow me to get a job where I can use my talents and creativity.	**(4.38)**	**(-0.17**)**		
"Fit" with engineering profession	3.90	0.13	**3.62**	**0.33***
I will/would feel "part of the group" if I get a job in engineering/in an engineering company.[b]	3.90	0.13	**3.62**	**0.33***
Interest and confidence in engineering curriculum			2.97	0.17
I could succeed in an engineering curriculum			**3.79**	**0.57***
At the present time, I would consider changing my major to engineering or an engineering-related field.			1.85	0.06
Understand the broad nature of engineering	**4.30**	**0.30*****	**4.22**	**0.36***
Ethical problem solving is an important part of engineering design.	**4.39**	**0.37*****	4.36	0.29
Engineering design is influenced by the societal context in which it takes place.	**4.36**	**0.39*****	**4.43**	**0.86***
I understand how engineering decisions are made.	**4.21**	**1.02*****	**3.93**	**1.29****
I understand the relationship between engineering and the society in which it is practiced.	**4.37**	**1.04*****	**4.36**	**1.21****

[a]These negatively worded items have been reverse-scored for analysis.

[b]This question was worded slightly differently for 1stYE and NM students.

[c]**Bold** values indicate that pre/post gains for this student group are significant. Probability calculated with a Wilcoxin signed rank test. Parenthetical values () indicate a negative pre/post change. **Bold** values are significant:
*α=0.05
**α=0.01
***α= 0.001

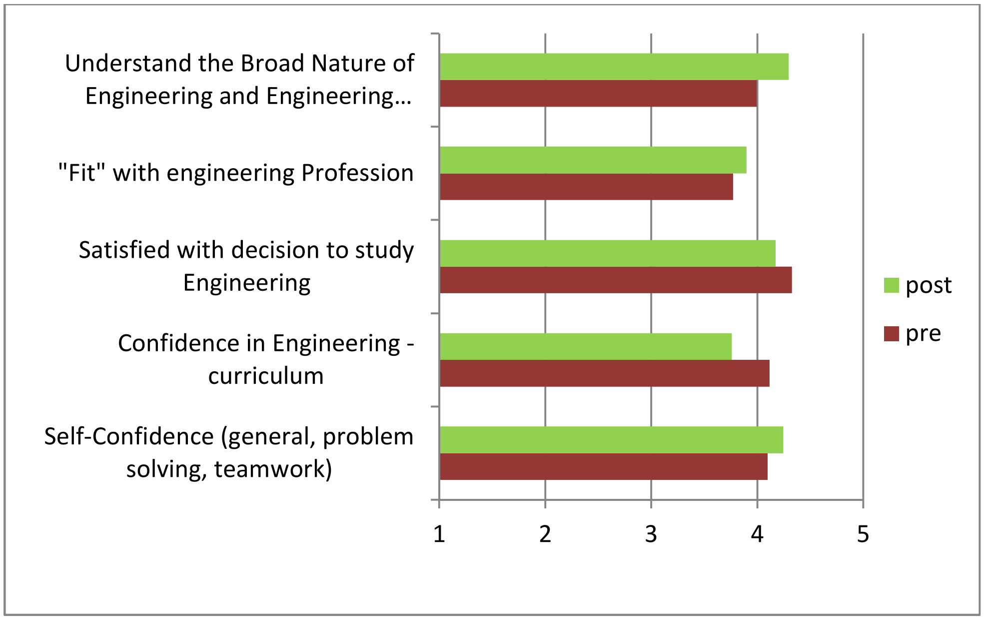

Figure 1. Attitude Survey Results, 1stYE students (n=122). Results show significantly *positive* pre-post changes in students' understanding of the broad nature of engineering and engineering design and their self-confidence with respect to problem solving, and significantly negative pre-post changes in students' confidence and satisfaction with their decision to study engineering.

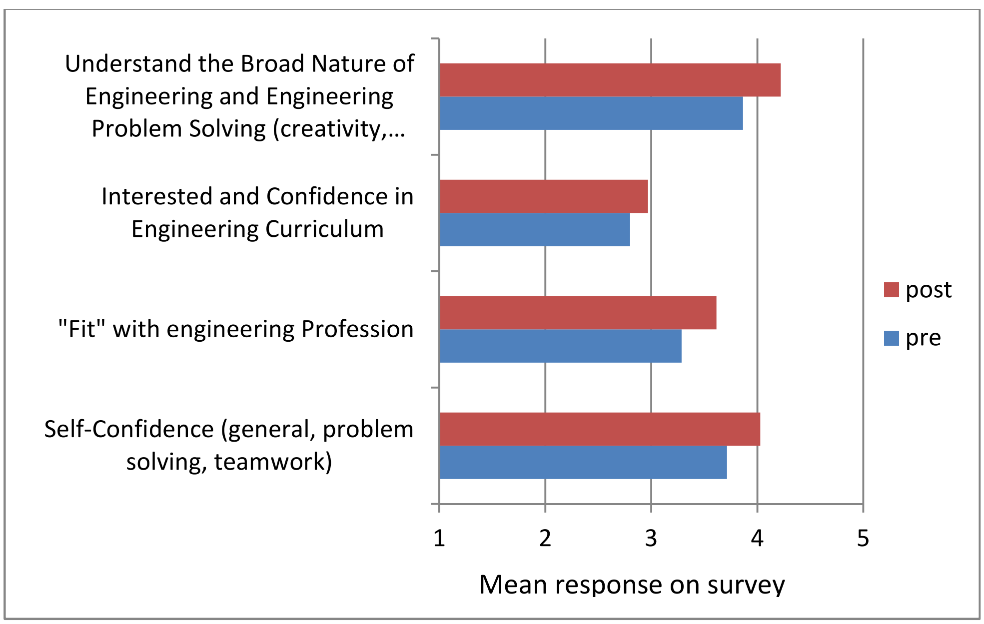

Figure 2. Attitude Survey Results, NM students (n=14). Results show significantly *positive* pre-post changes in students' understanding of the broad nature of engineering and engineering design and their self-confidence with respect to problem solving, and also with their sense of "fit" with an engineering company.

a significantly positive pre-post change for the NM students and a slight but insignificant positive change for the 1stYE students. As might be expected, post scores for the 1stYE students were quite high relative to NM students (3.9 vs. 3.6).

NM students showed a positive pre-post change in their confidence in being able to succeed in an engineering curriculum (post score 3.8). On the other hand, when 1stYE students responded to items related to their confidence at succeeding in the engineering curriculum, there was a significant drop in the category mean (post score 3.8) and several of the item mean scores. Students indicated lowest levels of confidence about succeeding in their math courses (post score 3.3) and highest levels of confidence regarding success in their engineering courses and engineering curriculum (post scores 4.0 and 4.2, respectively). As discussed below, these negative changes for 1stYE students follow pre-mean values that are in fact quite high - with a category average of 4.1 and individual responses ranging from 3.9 (I will succeed in physics) to 4.4 (I will succeed in math).

A total of 101 students (78 1stYE, 23NM) provided qualitative feedback regarding the most valuable aspects of the course. Among these responses, the most frequent theme that emerged was the students' participation in the design project (mentioned by 29 students), and their exposure to teamwork (14 students), for example: "The group project was most important for me because it was a real-life example of how engineering can be," and "Working with a team to create a tangible product."

Also prevalent was the students' recognition of societal influence on engineering and technology (mentioned by 24 students). Students also reported that they appreciated learning about the relationship between ethics and engineering (14 students), the breadth of the engineering profession (9 students), and several simply enjoyed the course (18 students). In the words of one student: "People usually describe how technology shapes society, but in this course I also learned how society shapes technology and how technical and nontechnical factors affect the outcome and fate of certain technology. Furthermore, improves teamwork skills and interactivity with people of different backgrounds and ideas of how to make the project."

Discussion

The experience of the instructors over two semesters teaching the course has been that the enrollment of NMs along with the 1stYEs in this course has provided net benefits. The NMs have overwhelmingly been sophomore or above and their presence in the course has tended to elevate the maturity level of the entire cohort. This was more apparent in the pilot semester when they made up more than a third of the class. The grade point average of the NMs was higher than the 1stYEs in both semesters, though only slightly, probably reflecting a higher level of maturity and more fully developed verbal/communication skills. Unfortunately, the much lower fraction of approximately one NM/seven 1stYEs in the fall semester roll-out is likely to continue to prevail as it represents more closely the steady state demand. Nevertheless, enrollment of

Business School and Arts and Science School majors adds a multidisciplinary element to the course through the student cohort that goes beyond the fact that multiple engineering disciplines are represented. This is desirable as it mimics in some sense the world of work that graduates will encounter.

It has already been noted that the course meets graduation requirements for the NMs. That the NMs had a positive experience in the course can be inferred from the positive changes in all of the categories of the pre-post survey for the NM cohort. Positive feedback in the open-response post survey question supports this assertion as well. For example, NM students indicated that they benefited from exposure to the engineering design process and working with a team of engineering students, as well as learning the multitude of ways in which engineering has influenced major critical events in history. Being a technologically focused university with majority engineering enrollment, institutional culture is such that taking an engineering-like course is not abnormal in any sense for NMs. Indeed, there is considerable overlap among the companies employing larger numbers of both NM and engineering graduates of the university. In this sense, it can be said that the course meets the needs of NMs in ways that go beyond simply satisfying graduation requirements.

Positive changes in perceptions/attitudes were achieved in all categories except 1stYEs confidence in succeeding in their engineering curriculum and satisfaction with their decision to study engineering, where it must be noted that the negative pre-post changes occurred relative to very high (>4.0) pre-values. The largest negative changes occurred in their confidence about succeeding in their math/physics courses. This most likely reflects a combination of their overconfidence when first arriving on campus (pre scores on the survey were on the order 3.9-4.0 for these questions) followed by their realization, after the first semester, of the difficulty level of these courses. Recall that this cohort of 1stYEs 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,[7] i.e. these were the 1stYEs 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. It must be noted that even though there are negative changes in these categories, the post-response average for satisfaction with their decision to study engineering remains relatively high (4.17/5.0), probably reflecting a high determination to succeed in the engineering curriculum among incoming students that is an institutional characteristic. Comparison of aggregated pre and post survey responses from this 1stYE cohort with a 1stYE cohort consisting largely of 2nd semester students who were tracked differently by virtue of higher scores on the pre-enrollment tests, i.e. into Physics I concurrently with Calculus I in the first semester, will be possible in future semesters and should provide additional insight. A future cohort comprised of first semester 1stYE students who enroll in the traditional

Calculus/Physics/Chemistry sequence will provide a broader baseline for comparison purposes, and is intended for future years. The information provided by these two additional cohorts will provide a better perspective for examining the noted changes in confidence among this particular group of students.

Focusing on the positive changes, it can be inferred that students' perceptions of their understanding of engineering problem solving and the broad nature of the engineering profession increased. Since this course was the only 'engineering' course taken by these students over the course of the semester (with a few exceptions at most), it can be concluded that the course experience was largely responsible for these changes. This is supportive of the broad goal of enhancing 1stYEs' engagement with the field of engineering in general. Engagement with engineering faculty was at least marginally enhanced relative to the situation prevailing before the introduction of the course by virtue of the fact that School of Engineering faculty taught the course. The positive change in perception of their ability to apply a systematic design process to an unfamiliar problem might also be said to support the former goal, but it certainly aligns with learning outcomes. Positive change in the self-confidence category in general is encouraging and, taken together with the negative change in perception of their ability for success in math/physics and given the nature of the student cohort, is probably due mostly to their experience in this course. Student written comments are consistent with these findings.

The overall approach to the course was a combination of descriptive and participative. Though there was certainly conceptual content, sociological theory with respect to science, technology and society was not emphasized. Nor was the course proscriptive with respect to contemporary technology and society issues. Rather, it can be described as emphasizing the design process and societal context for the practice or profession of engineering. This was the intent, given the combined goals (exposure to engineering, *STS* and *Tech* outcomes) dictated for the design of the course, and the practical orientation and relative academic maturity of the target student population. The reading selected for a large portion of the course[6] reflects this orientation. This book by Pool is written for a general audience, though his style and the density of material does tend to strain the reading comprehension of some 1stYEs. While this challenge is not without benefit, this particular text may not suit all student populations. The course outcomes could be achieved with a variety of resources and approaches. As an example, there could be a sustained focus on a significant contemporary issue, such as sustainable energy technology, with appropriate selection/provision of texts, online resources, etc., that would provide the basis for exploration of the important concepts and issues. Depending on instructor orientation, use of appropriately selected fiction as the basis for reading and reflection can be envisioned as well. In short, the concept of combining design process immersion with engineering and society concepts and outcomes could be achieved in a variety of ways. We feel there is an opportunity for closer coupling of the design project with major themes of the reading than we have achieved so far, and this is an area for focusing future efforts.

Conclusions and Future work

A course has been successfully piloted and rolled-out for multiple sections and instructors that:

1. Exposes students to the engineering design process with a hands-on component;
2. Enrolls and addresses the needs of both first-year engineering students and non-majors; and
3. Positively affects students' confidence in approaching design problems/new problems or challenges, students' perceptions of their understanding of the broad nature of engineering, and non-majors' perceptions' of their "fit" with the engineering profession.

Future work will include a comparison of student perceptions and attitudes between cohorts of first semester students determined to be less well prepared in mathematics with different, second semester students determined to be better prepared in mathematics. This should shed some light on negative changes in student confidence in math/physics courses. Comparison with first semester students determined to be better prepared in mathematics may also be possible in the future by administering appropriate parts of the survey to first semester students in Physics I. Future work also needs to be focused on obtaining conclusions about the degree to which intended course learning outcomes are attained. Since the pre-post surveys administered constitute an indirect assessment which is, additionally, not targeted at assessing course learning outcomes *per se*, direct assessment of student work for outcomes assessment needs to be more fully developed and implemented.

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Appendix: Student post mean response and pre/post gains, ES110 Attitude Survey

	All Students		1stYE		NM	
	Mean response Post	Post-pre Gain[b]	Mean response Post	Post-pre Gain[b]	Mean response Post	Post-pre Gain[b]
Self Confidence	**4.22**	**0.16*****	**4.24**	**0.15*****	**4.03**	**0.31***
On the whole, I am pleased with my performance as a student.	(3.96)	(-0.03	(3.97)	(-0.05)	3.86	0.14
I feel confident about applying a systematic design process to an unfamiliar problem.	**4.12**	**0.58*****	**4.15**	**0.57*****	**3.86**	**0.64***
I am capable of becoming an engineer.	(4.34)	(-0.01	(4.42)	(-0.07)	**3.64**	**0.57***
I have almost no understanding of how to approach solving a new problem or challenge.[a]	**4.33**	**0.24****	**4.31**	**0.25****	4.50	0.07
I feel confident working as a member of a team.	4.37	0.04	4.38	0.03	4.29	0.14
Confidence in Engineering Curriculum			**(3.76)**	**(-0.35***)**		
I can succeed in an engineering curriculum.			(4.24)	(-0.13)		
I will succeed (earn an A or B) in my math courses.			**(3.32)**	**(-0.66***)**		
I will succeed (earn an A or B) in my physics courses.			**(3.40)**	**(-0.49***)**		
I will succeed (earn an A or B) in my engineering courses.			(4.00)	(-0.12)		
Satisfied with decision to study engineering			**(4.17)**	**(-0.15**)**		
At the present time I am satisfied with my decision to study engineering.			**(4.20)**	**(-0.20*)**		
At the present time, I feel confident that I will keep my chosen engineering major throughout college.			**(4.03)**	**(0.06)**		
At the present time I am exploring other non-engineering majors at Clarkson University.[a]			**(3.98)**	**(-0.36**)**		
A degree in engineering will allow me to get a job where I can use my talents and creativity.			**(4.38)**	**(-0.17**)**		
"Fit" with engineering profession	3.87	0.15	3.90	0.13	**3.62**	**0.33***
I will/would feel "part of the group" if I get a job in engineering/in an engineering company.[b]	3.87	0.15	3.90	0.13	**3.62**	**0.33***
Interest and confidence in engineering curriculum					2.97	0.17
I could succeed in an engineering curriculum.					**3.79**	**0.57***
I would find an engineering curriculum interesting.					(3.31)	(-0.23)
At the present time, I would consider changing my major to engineering or an engineering-related field.					1.85	0.06

Appendix cont.

Understand the broad nature of engineering and engineering problem solving	**4.29**	**0.31*****	**4.30**	**0.30*****	**4.22**	**0.36***
Creativity is important to the engineering process.	**4.59**	**0.12***	**4.59**	**0.14***	(4.54)	(-0.03)
The role of engineers is limited to technical problem solving.[a]	**(3.87)**	**(-0.18*)**	(3.89)	(-0.18)	(3.64)	(-0.21)
Collaboration and teamwork are essential components of the engineering process.	(4.55)	(-0.02)	(4.57)	(-0.01)	(4.36)	(-0.14)
Ethical problem solving is an important part of engineering design.	**4.39**	**0.36*****	**4.39**	**0.37*****	4.36	0.29
Engineering design is influenced by the societal context in which it takes place.	**4.37**	**0.44*****	**4.36**	**0.39*****	**4.43**	**0.86***
I understand how engineering decisions are made.	**4.18**	**1.04*****	**4.21**	**1.02*****	**3.93**	**1.29****
I understand the relationship between engineering and the society in which it is practiced.	**4.37**	**1.06*****	**4.37**	**1.04*****	**4.36**	**1.21****
Engineers are responsible for solving technical problems with little or no collaboration with other professionals.[a]	**(3.93)**	**(-0.35**)**	**(3.92)**	**(-0.34**)**	(4.00)	(-0.43)
I understand how business professionals, technicians, and scientists work together with engineers to solve problems.	4.31	0.38			4.31	0.38

[a]These negatively worded items have been reverse-scored for analysis.
[b]This question was worded slightly differently for 1stYE and NM students.
[c]**Bold** values indicate that pre/post gains for this student group are significant. Probability calculated with a Wilcoxin signed rank test. Parenthetical () values indicate a negative pre/post change. **Bold** values are significant at:
$^{*}\alpha=0.05$
$^{**}\alpha=0.01$
$^{***}\alpha= 0.001$