Beyond Their Technical Capabilities: Providing Student Exposure to Professional, Communication, and Leadership Skills

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Abstract

Beyond their technical capabilities, future engineers will require strong leadership, communication, and professional skills to navigate an ever-changing field that is increasingly influenced by issues associated with globalization and environmental sustainability. A new course on these "soft" skills has been developed at Tufts University. The course, recently taught to civil and environmental engineering majors, was designed to introduce professional issues associated with the practice of engineering. The course also examines the economic, political and social issues that frame the project delivery process. Professionalism, ethics, communications, and leadership skill development were threaded throughout the course. Though specifically developed and aimed for civil and environmental engineers, course materials are applicable to most areas of engineering and science.

This paper presents an overview of the course and provides specific examples of different pedagogical methods and tools used for topic and course delivery. In addition to exams and assignments, a number of term projects were completed, allowing students to actively apply the skills discussed. Some of the pedagogical methods used during the course included "before and after" questionnaires in order to gauge the effectiveness of a discussion, as well as the use of psychological evaluation techniques to gauge leadership traits and skills. In addition, various assessment techniques including surveys, course evaluations, and student and faculty reflections were used to gauge how well course results met course objectives. Based on these assessments, the course could be considered as a success, but additional efforts to improve course content and its delivery in some areas are warranted.

Introduction

From books such as Thomas Friedman's *The World is Flat*[1], to the NAE's *Rising Above the Gathering Storm*[2], it is clear that the way engineering is practiced has changed over the last 50 years. Considering transformations such as the rapid development of China and India as technological powers, the off-shoring and outsourcing of engineering jobs, the globalization of goods and services, and the need for more sustainable products, infrastructure, and development; it is clear that the challenges of engineering in the 21st century are great and require re-evaluating the way engineers do their work and how they are prepared to do this work. Unfortunately, change in engineering education is in some ways not moving at a pace as rapid as that of the profession. Though in the past few years, a number of innovations in delivery and assessment of engineering education have been developed and implemented, the institution of engineering education has been similar to that of three to four decades ago.

One of the more recent, substantial changes in engineering education was the implementation of what is commonly referred to as "ABET 2000", which moved ABET from a "bean counting" mentality in what constitutes a good engineering program, to a structure where programs must demonstrate, via appropriate assessment, that desired program objectives and outcomes are being achieved.[3]

Specifically, ABET program outcomes include the development of student's value of professionalism and ethics and the ability to effectively communicate. ABET does not stipulate the methods for achieving these or other outcomes, rather it requires a demonstration that they are being achieved, normally via direct measurement (e.g., examples of student work).

Given this freedom, a program may chose to achieve ABET outcomes related to professionalism, ethics, communications, and leadership by dispersing these themes throughout the undergraduate technical curriculum; alternatively, a course or series of courses can be used to present these outcomes directly. In the fall of 2007, the Civil and Environmental Engineering department at Tufts University implemented a new course entitled "Issues in Professional Engineering Practice." This course addressed the issues of professionalism, communication, and leadership both via explicit and implicit efforts. This paper presents an overview of the course and provides specific examples of different pedagogical methods and tools used for topic and course execution.

Course Description

The course's main objective is to introduce professional issues associated with the practice of engineering. Professionalism and ethics, communications, and leadership skill development are key features of the course. In addition, the course also examines the economic, political and social issues which constitute the non-technical framework in which practitioners navigate project delivery. Though specifically developed and aimed for seniors in civil and environmental engineering, course materials are applicable to most areas of engineering and science.

Specific topics covered in the course include:

a. Economics of engineering practice: the organization of engineering companies, the need for marketing and business development, project procurement, and project financing
b. Legal aspects of engineering: contracts and agreements, terms and conditions of engineering services, legal adjudication including Alternate Dispute Resolution
c. Professional risk management techniques: insurance requirements for design professionals, peer review processes, and product quality management
d. Personnel/career management including professional licensure and society participation

Additionally, the course presented an overview of future trends and challenges to the engineering profession, focusing mainly on globalization and sustainable design and development. The course format consisted of three, 50-minute class meetings per week for the 13-week semester (39 total class meetings). Class meeting times were used for lectures, workshops, and term project presentations. The first offering of the course was to a class of 16 engineering seniors.

Course Topics

Course topics and the number of lectures, assignments, workshops, and in-class exercises dedicated to them are presented in Table 1. Most topics involved traditional, stand-up presentations. Often these presentations included in-class exercises that forced students to consider and respond to the subject matter instantaneously. At other times, take-home mini-assignments were used to reinforce lecture content.

Table 1 – List of Course Topics and Lecture Presentations

Topic	Number of Lectures	Assignment	Workshop	In-class Exercise
Project Delivery	2			
Professionalism and Ethics	1		✓	✓
Communication	1			
Leadership	2		✓	✓
Project Delivery Case Study – Sophia Gordon Hall	3	✓		✓
Project Documents – Overview	1			
Project Procurement – Proposal Writing	1	✓		
Documents - Bid Phase	1	✓		✓
Documents - Construction Phase	1			
Business Entities	1			✓
Project Financing	1			✓
Risk Management	1			✓
Legal Issues	3		✓	
Licensure	1			
Sustainability	2	✓	✓	✓
Globalization	1			✓
Lifelong Learning	1			✓
Term Project-Related Presentations	4			
Guest Presentations	3			
Totals	31	4	4	10

Required Texts

The course textbook was *The Entrepreneurial Engineer* by David Goldberg (2006)[4]. This textbook provides only an overview of the issues faced and necessary skills that engineers should develop in order to be successful in practice. The book was supplemented by articles on subjects ranging from ethics, leadership, project delivery systems, globalization, sustainability, bid and project agreement documents, and risk management.

Grading

Elements included in grading of the course included assignments (15%), three exams (30%), workshop participation (15%), class participation (15%), and a term project (25%). Assignments ranged from developing a response to a Request for Qualifications (RFQ) to evaluating if Leadership in Energy and Environmental Design (LEED®) credits could be obtained for an existing building on campus. Class participation was based on student attendance and performance in in-class exercises. Workshops and the term projects are discussed in detail below.

WORKSHOPS

Four course workshops, each occurring over 2 to 3 consecutive class periods, included a review of professionalism and ethics, leadership styles and skills, legal aspects in engineering design and construction, and the LEED® process and its influence on design. This paper will not present an in-depth description of each workshop; however, the effort in the professionalism and ethics workshop is described below.

Professionalism and Ethics Workshop

This workshop focused on attitudes and beliefs regarding professionalism and ethics. For this course, professionalism was defined as the way a professional acts (timeliness, dress, attitude, etc.); ethics was defined as adherence to appropriate or accepted norms of ethical behavior. Furthermore, it was clarified that while acting ethically constitutes good professionalism, not all un-professional actions constitute ethical misconduct. Part of the workshop consisted of a pre- and post-discussion survey of student views on professionalism and ethics; students were asked to evaluate several situations as to whether the engineer demonstrated poor conduct or judgment (PC) OR demonstrated inappropriate ethical behavior (IEB).

Discussion between the pre- and post-surveys focused on the various Canons of Ethics by the American Society of Civil Engineering (ASCE), National Society of Professional Engineers (NSPE), and the Accreditation Board of Engineering and Technology (ABET). Case studies of ethical dilemmas faced by engineers, such as those found on the Center for the Study of Ethics in the Professions at IIT [5] were also presented and discussed. The survey questions and results of the pre- and post-discussion surveys are summarized in Table 2.

Projects

The most significant component of the course was the term project. The benefits of project-based learning have been well established, especially the ability to encounter and address both technical and non-technical issues and constraints [6, 7]. In this course, students worked in four-member teams on one of four projects. Projects included both technical and non-technical challenges for teams to address. These projects are briefly described below.

<u>Green Technology for Low-Income Housing</u>

The overall goal of the project was to create a guidance document for selecting and implementing appropriate green engineering practices into low-income residential housing. Green engineering can occur in both the construction, and operation and maintenance of the home; thus, the decision to incorporate green components, materials, fixtures, methodologies, and/or practices in a new residence requires a more holistic approach to home design and construction than current standards. During the project, the team addressed the feasibility of incorporating various green engineering techniques and technologies into the building of simple, affordable homes. Ultimately, the team created decision-matrices that addressed when, where, and how to use green technologies in residential housing. In order to complete their work, the team had to become familiar with residential housing design and construction.

Table 2 Professionalism and Ethics Survey and Pre- and Post-Discussion Results

1. The engineer forgets to have someone check his/her design calculations.

Results	PC	IEB
Pre-discussion	11	2
Post-discussion	11.5	1.5

2. The engineer, while checking the design calculations of a co-worker, ignores errors in the calculations so that the project can be sent out to the client on time.

Results	PC	IEB
Pre-discussion	1	12
Post-discussion	0	13

3. The engineer consistently arrives one to two hours late to his/her field job.

Results	PC	IEB
Pre-discussion	12.5	0.5
Post-discussion	10	3

4. The engineer attends meetings with clients completely un-prepared.

Results	PC	IEB
Pre-discussion	12	1
Post-discussion	11	2

5. The engineer knowingly provides false information to the architect so that the architect will not win the bid for a project.

Results	PC	IEB
Pre-discussion	0.5	12.5
Post-discussion	0	13

6. A water supply system fails based on a poor design. The engineer changes his/her calculations on design documents after investigation of the failure is underway.

Results	PC	IEB
Pre-discussion	1	12
Post-discussion	0	13

7. An engineer purposely fails to make a public meeting where possible wrong-doing by his/her client is being investigated.

Results	PC	IEB	No Decision
Pre-discussion	5	6	2
Post-discussion	4.5	8.5	0

Water Resources in Juampas, Haiti

This project's ultimate goal was to assess the feasibility of a water management and distribution system using existing, and potentially new, water resources in the rural Haitian community of Juampas. The project was to be implemented over the next few years. The final design needed to provide a sustainable potable water supply with methods that are easy to create and replicate. During the project, the team had to address the feasibility of developing a water collection and distribution system using existing local water resources, as well as consider the development of new water resources. Potential methodologies considered included wells, roof-top collection systems, long-term storage systems, and water filtration systems. The team became intimately familiar with the engineering and construction processes in rural Haiti and its influence on the project.

Bio-Digester Unit in Rural Vermont

This ongoing project required the design and development a bio-digester unit for a 100+ cow dairy farm located in central Vermont. The project's ultimate goal was to complete the design and development of a rational process to implement the bio-digester installation, with a goal of construction to begin as early as Summer 2008. The team had to address the design of the bio-digester within the physical, operational, and economic constraints of the farm. During the project, the team became familiar with the construction process in the rural Vermont area and how it pertains to this project. For the team, the learning objectives included designing the various components of the bio-digester unit, evaluating input alternatives to optimize methane production, and developing an implementation plan for the digester considering a new KISS principle (Knowledge + Innovation = Sustainable Systems).

Public Communication of Longfellow Bridge Rehabilitation

This project required developing an effective communication method for the Longfellow Bridge Restoration Project. The Longfellow Bridge, one of the most architecturally distinguished bridges in Massachusetts, connects Boston and Cambridge, carrying a Massachusetts Bay Transportation Authority (MBTA) subway line and two-way vehicular traffic across the Charles River. Currently, an extensive restoration of the bridge is underway and is entering the final design phases with anticipated completion in 2013. For the course, the project team's overall goal was to provide a fact sheet (or series of fact sheets) that described, in laymen terms, the engineering aspects of the restoration projects. The team expanded this scope of work to also include an animation of the restoration process. The animation and fact sheets were developed for possible use in public presentations by the lead engineering firm. The team developed a strong understanding of the project, its engineering aspects, and its benefits to the public. The team also became intimately familiar with the engineering and construction processes used in long-running projects.

PROJECT IMPLEMENTATION PROCESS

All projects ran for approximately 9 weeks. First, students were presented all project scopes and allowed to individually select (rank) their top three projects. Based on these rankings, the instructor created project teams. All students worked on one of their top two preferred projects. Once teams were in place, groups would meet weekly with the course instructor to present the project's progress (oral communication required) and plan subsequent tasks (teamwork and leadership skills). All except the Green Technology for Low-Income Housing project had external parties or "clients" who periodically communicated with the team during the project.

PROJECT DELIVERABLES

In additional to weekly meetings, each group had a series of communication-based deliverables to provide, including:

- A proposal for services to their "client"
- A mid-project progress memorandum as well as a 50% oral presentation which was videotaped and subsequently reviewed by the team
- A final report and oral presentation, again videotaped

Assessments and Evaluations

Since this was the first time that this course was being taught, significant effort went into gathering information on how the course was progressing. The university-wide course evaluation, traditionally conducted only at course's end, was also conducted at the mid-point of the course. In addition, a supplemental evaluation that gauges how the course meets ABET program outcomes was also performed. Pertinent results of this supplemental evaluation are presented in Figure 1. As can be seen in the figure, ABET program outcomes related to professionalism and ethics, communications, and leadership, were viewed by the students to represent moderate-to-major components covered in the course.

At various times throughout the course, attempts to assess course content areas occurred via self-reflective evaluations. For example:

1. an initial survey asked students to reflect upon the relative importance of all the skills involved in an engineering career
2. the DiSC and Myers-Briggs assessment methodologies were used so students could assess their own leadership traits or skills as well as those exhibited by others;
3. questionnaires were routinely used during team projects, both having individuals assess intra-team efforts as well as students evaluate the performance of other team's oral presentations

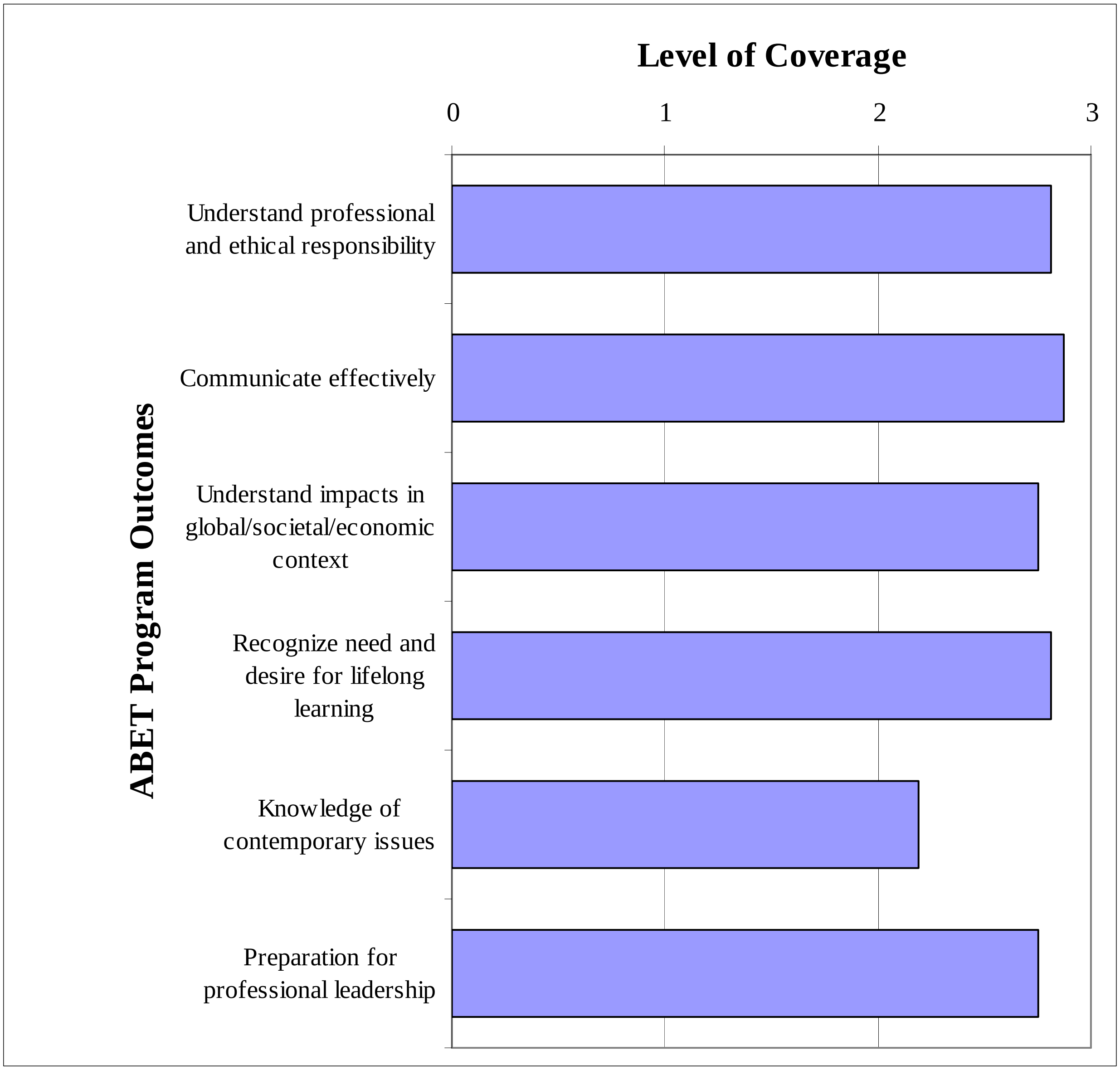
An example of the assessment of individual team members' performance during the term project is presented below.

Final Term Project Evaluation

At the completion of the term project, each student was asked to assess the effort of their team members in three areas – overall effort, leadership, and professionalism. Specifically, students were asked:

- Question 1: If you had $100, how would it be divided amongst the team (including you) for their overall effort in the project?
- Question 2: If you had $100, how would it be divided amongst the team (including you) for their leadership efforts in the project?
- Question 3: If you had $100, how would it be divided amongst the team (including you) for their professionalism (e.g., showing up for meetings, doing their work on-time, etc.) displayed during the project?

Figure 1 Results of ABET Supplemental Evaluation of a Course



Legend:

<u>Level of Coverage</u>

3 = Major	1 = Minor
2 = Moderate	0 = None

Table 3 summarizes the average and standard deviation of the results for these questions for the four term projects. [Note: Project and student names are removed to retain confidentiality.] The results of this evaluation can be interpreted in a number of ways, but in this case, the rationale for asking the questions was to provide to the instructor some insight into team dynamics that the instructor could not observe. For example, identical individual results (i.e., an average of 25 and standard deviation of zero) for all members of a project team indicate that all team members were equally satisfied with the work of themselves and their peers on the project for overall, leadership, and/or professional efforts. The results in Table 3 clearly show that Teams 3 and 4 thought this way for most of their scores.

Varying scores (average and/or standard deviation) indicate that team members did not work well together (e.g., Team 1). However, for some cases, varying scores could indicate that one team member gave extensively and noticeably more effort than other members [defined as the average – one standard deviation >> 25]; e.g., Student 3 on Team 2 for leadership. Alternatively, a lower score, defined as the average + one standard deviation << 25, indicates a poor effort, as illustrated by Student 1 on Teams 1 and 2.

Table 3 Results of Final Project Evaluations: Student-to-Student Assessments

Team No.	Student	Overall Effort Score		Leadership Score		Professionalism Score	
		Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Team 1	Student 1	17.5	5.5	20.125	5.6	20	4.1
	Student 2	28.75	3.8	32.875	5.3	32	4.8
	Student 3	29	6.7	24.625	5.0	24	6.3
	Student 4	24.75	4.1	23.625	5.3	27.5	6.5
Team 2	Student 1	19.75	4.1	18.75	2.5	21.25	7.5
	Student 2	26.75	2.4	21.25	2.5	26.25	2.5
	Student 3	28	2.4	38.75	6.3	26.25	2.5
	Student 4	25.5	1	21.25	2.5	26.25	2.5
Team 3	Student 1	25	0	22	2.4	25	0
	Student 2	25	0	25.5	4.2	25	0
	Student 3	25	0	28	2.4	25	0
	Student 4	25	0	24.5	4.2	25	0
Team 4	Student 1	25	0	23.75	2.5	24.75	0.5
	Student 2	25	0	25	0	25	0
	Student 3	25	0	25	0	25	0
	Student 4	25	0	26.25	2.5	25	0

Conclusions and Recommendations

This paper presented a new course that was developed with an overall goal to present many of the non-technical skills desirable in the engineer of the 21st century, namely effective communication, knowledge of leadership skills, and an appreciation of professionalism and ethics. Through lecture, assignments, workshops, and a term project, students are exposed to these and other issues engineers face in professional practice. The term projects have both technical and non-technical challenges, thus providing direct experience in how these skills are combined to execute and deliver real-world engineering projects.

Shortcomings of the course included insufficient time to delve deeply into the theoretical foundations of many of the course subjects. An increase in time would also allow for more reflection on in-class activities. For example, while the results of the Myers-Briggs personality test were used for an in-class exercise, there was no evaluation or full discussion of the DiSC evaluation. New and/or improved methods of evaluation need to be developed so that they can better inform the course both during and after the discussion of a topic or event.

Already scheduled for the Fall 2008 semester, the course will now include a 150-minute “lab” section to be used for longer workshops, site and company visits, and guest presentations.

The course is also expected to have 40 students, significantly increasing the number of term projects. It is therefore imperative that the course material and assessment methods be sufficiently enhanced in order to efficiently realize the goals of the course.

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