AC 2007-859: A NEW REQUIRED SENIOR COURSE: THE ENGINEERING PROFESSION

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A New Required Senior Course: The Engineering Profession

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Abstract

This paper describes the development and implementation of a new required course called "The Engineering Profession" for senior mechanical and aerospace engineering students at Arizona State University. Based on the needs of industry and the ABET guidelines, this course provides a bridge between engineering coursework and industrial application. The course prepares students to be global leaders by emphasizing the skills of communications, teamwork, integrated product development, systems engineering, project management, business acumen, professional ethics and life-long learning.

Introduction

Industry demands graduating engineering students who have abilities in addition to traditional analytical and design skills. The current focus on meeting customer needs through the use of values-driven, multifunctional project teams has recruiters looking for graduates that possess "soft skills" such as communications, teamwork, project management, and professional ethics. Moreover, the rapid pace of technological innovation and changing markets requires graduating engineers to be skilled in the art of life long learning. As society becomes evermore driven by technology, there will be a growing need for articulate, team-oriented, socially-aware, and values-driven engineers to move into positions of global leadership. ABET 2000 challenges engineering schools to produce graduates with these skills. The Department of Mechanical and Aerospace Engineering (MAE) at Arizona State University (ASU) has integrated these skills into the various courses within the engineering curriculum. However, recent assessments of the Capstone Design Course indicate that seniors need even more opportunities to gain these skills. In addition, the Dean of the Engineering School directed departments to have a course primarily focused on engineering business practices such as ethics, finance, and entrepreneurship. As a result, MAE has created a new senior-level course called "The Engineering Profession".

This paper (1) discusses course development, (2) summarizes the course content, (3) describes initial implementation results, and (4) makes recommendations for course improvement.

Initial Course Planning

Previous and current department vice-chairs began planning discussions for the new course in 2002 by addressing the ABET (1997) criteria for "soft skills" as given in Table 1. In addition, these planners wanted the content to contain sufficient communications outcomes to qualify as a

University Literacy Course. This planning resulted in the course outcomes (and associated mastery levels) given in Table 2 where the outcomes are correlated to the ABET criteria.

Table 1. ABET Criterion 3 – Program Outcomes and Assessments

f) An understanding of professional and ethical responsibility
g) An ability to communicate effectively
h) The broad education necessary to understand the impact of engineering solutions in a global/societal content
i) A recognition of the need for and ability to engage in life-long learning
j) A knowledge of contemporary issues

Table 2. Course Outcomes vs. ABET Criterion 3

Course Outcomes	ABET (a-k)	Mastery Level[1]
• **Students will discuss expected ethical and professional standards of behavior and the consequences of deviations from these standards.**	**g, h, i, j**	**analysis**
• Students will demonstrate an ability to plan and develop a technical program (with its business case) through clear and concise written and oral communication.	**f, g, j**	**application**
• **Students will demonstrate teamwork skills in resolving technical and business issues.**	**g, i, j**	**application**
• **Students will be able to describe Engineering's critical contributions to, and interactions with, other key groups in an industrial enterprise and a global society.**	**g, i**	**comprehension**
• **Students will discuss some significant potential societal challenges in the next 25 years and their impact on the practice of engineering.**	**f, g, h, i, j**	**application**

[1] Mastery level uses Bloom's Taxonomy (Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation)

Course Development Approach

Two engineering leaders from industry with strong ties to the department, and who also have university teaching experience, volunteered to take these plans and design a course that would fit a 3-credit hour semester format featuring two 75-minute sessions per week. Their first decision was to give students ample opportunity to develop writing proficiency through the preparation of three papers and to become comfortable with public speaking by giving two oral presentations. The subjects for these major course assignments are as follows:

- Paper 1: What Does It Mean to be an Engineering Professional?
- Oral Presentation 1: Individual—My Professional Goals and What I've Done So Far
- Oral Presentation 2: Team—A Current Societal Challenge and What Engineers Can Do
- Paper 2: Ethics Study of the Gilbane Gold Case
- Paper 3: Proposal for the Development of a Microturbine

These communication activities were evenly spread throughout the semester. Further, a draft review cycle was incorporated into each paper preparation process. The instructors also added a teaching assistant from the English Department to emphasize proper writing mechanics.

Table 3 lists the planning steps followed by the instructors. As shown in Table 4, the development strategy had the following elements: (1) use industry leaders, (2) have a culminating course experience, (3) provide a unifying model, (4) feature industry speakers, and (5) encourage multiple ways of learning. The following paragraphs discuss the key elements of the course.

Table 3. Course Development Approach

1. Establish ABET and Literacy Course Requirements
2. Identify a Course Development Strategy
3. Develop Unifying Model and Culminating Course Experience
4. Refine Course Elements
5. Complete Syllabus and Schedule
6. Implement Course
7. Assess Course
8. Practice Continuous Improvement

Table 4. Course Development Strategy

- Use developers and instructors from industry
- Have a culminating course experience
- Present a Unifying Engineering Profession Model
- Integrate industry speakers into the lectures
- Encourage multiple ways of learning
    - Case Studies
    - Group Discussions
    - "Hands-On Contests"
    - Reflection
    - Papers
    - Oral Presentations

Culminating Experience: Team Microturbine Development Proposal

All the course lectures, speakers, exercises, readings, and homework are selected and tailored to prepare the students for their final project. In this project, a fictitious company's board of directors tasks the student teams to analyze the company's marketing and engineering data and then propose a microturbine (see Figure 1) development program including the business case. The proposal effort includes analyzing marketing data, conducting system trade studies, creating a work breakdown structure, estimating development and production costs, scheduling the program, and evaluating the business opportunity on an internal rate of return basis.

Figure 1. Typical Microturbine Powers (2000)

Unifying Model for the Engineering Profession

The instructors created the model shown in Figure 2 to relate the various elements of the course. The engineering professional is shown as a member of a business entity that is operating in society. Early in the course, readings, speakers, and discussions help the students to see that the role of business in society is to meet human needs and wants; and the reward for doing such is profit. The students then grasp the idea that engineers have a dual loyalty: (1) to their employer and (2) to their profession. Their primary role is to create products and services that meet society's needs while protecting the health and welfare of people within society.

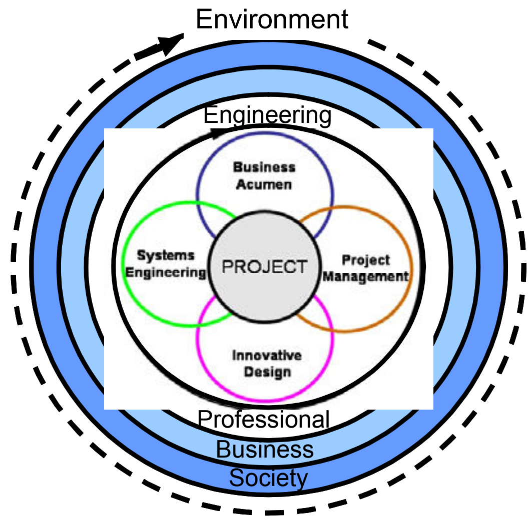

Figure 2. Unifying Model

Most engineering activities are now accomplished in project teams. Hence, the project resides in the center of the model. The following four key elements are shown interrelated within the project:

- Innovative Design
- Systems Engineering
- Project Management
- Business Acumen

These elements are discussed in more detail later in the paper. The dotted circle that surrounds society is the environment. This includes the socio, economic, political, and physical environments. The arrow on the circle indicates that the environment is constantly changing. This unifying model provides students with a simple and memorable method of organizing the various course elements into a cohesive approach for advancing their professional careers.

Industry Speakers

Table 5. Speaker Topics

Speaker 1: Role of Engineering in Business
Speaker 2: Project Management
Speaker 3: Ethics in the Corporation
Speaker 4: Renewable Energy Challenges
Speaker 5: Financial Planning for the New Graduate
Speaker 6: Systems Engineering in the Automotive Industry
Speaker 7: Lean Engineering in the Aerospace Industry

Students are eager to learn from practicing engineers. Likewise, many successful engineers want to "give back" to the profession by sharing their knowledge and experiences with those seeking to enter the profession. The use of guest industry speakers is a major element of the course. Table 5 summarizes the topics covered during the semester. Key tasks for the instructor are to locate the speakers and coordinate their availability with the organization of the course materials.

Textbooks Selection

The desire was to have one textbook that addresses all the elements of the course. Unfortunately such a textbook was not identified. The final solution was to have the students purchase three books with the following areas of emphasis: Voland (2004)—case studies, Fleddermann (2004)—ethics, and Woolever (2005)—communications. These books were supplemented with readings available on the Internet.

Course Elements: Communications Skills

The remaining course elements have been divided into four major themes: (1) Communications Skills, (2) Understanding the Engineer's Role, 3) Key Project Skills, and (4) Important Trends in the Engineering Profession. This section addresses the first theme with the following elements:

Writing Checklist and APA Guidelines. The first and second sessions of the course are dedicated to writing. The students participate in the compilation of a checklist to guide their writing mechanics. Thesis statements and the use of outlines are emphasized.

Paper 1 Example on Life-Long Learning. During the second class session, the instructor presents an example Paper 1. The paper has the dual purpose of covering APA writing mechanics and introducing the concept of life-long learning.

Effective Presentations. Prior to the first student talks, the instructor gives a PowerPoint lecture on effective presentations. In a similar fashion, prior to the team presentations, the instructor lectures on the proper use of graphics. The lecture draws from the article by Tufte (1997) on the confusing graphics used for the decision to launch the space shuttle Challenger.

Paper 2 Example of an Ethics Issue Analysis. Students are provided with an example paper that demonstrates proper writing mechanics and an effective method for evaluating an ethical situation.

Course Elements: Understanding the Engineer's Role

History of the Profession. This lecture traces the development of engineering from the Egyptian pyramids to the present. It emphasizes the efforts of the engineering societies to establish professional standing. The Order of the Engineer and its dedication to professional ethics is introduced.

Societal Challenges. Subjects such as global warming, health care, and energy are covered.

Role of Business in Society. It is posited that the fundamental goal of business is to satisfy human needs and wants. Further, the reward for doing this well is profit. These concepts are developed through the readings and in-class discussions.

Role of the Engineer in Business. Case studies are used to identify the potential conflict between the engineer's duty to the employer versus to the profession and its ethical standards. The various career paths available to engineering graduates within a business are also discussed.

Integrated Product Development. A six-phase IPD model is presented that features phase exit criteria and the ability to layer phases in order to achieve fast cycle time. Exercises based on case studies are used to increase the students' skills in planning IPD projects.

In addition to the textbooks selected for the course, the following sources are used for this theme: Trimble (2005), Sharke (2006), Kay (2006), and Schopfer (2002).

Course Elements: Key Project Skills

Teamwork. Student teams begin to form early in the semester through in-class exercises. The team spirit model, Heermann (2000), is used as a guide for students in determining what operating mode their team is in at the moment. Readings from the textbooks regarding team dynamics are also assigned. The instructor monitors the project teams for Presentation 2 and Paper 3 by having team reflections and Gantt chart progress reports due each week.

Innovative Design. Although this course is not primarily devoted to design, the importance of creativity in the engineering process is covered. In addition to a lecture on creative thinking, students learn about the various entrepreneurial opportunities at ASU including the school-level entrepreneurship course (FSE 394: Entrepreneurship for Engineers) and the ASU Technopolis program for start-up companies.

Systems Engineering. General systems theory, systems thinking, and systems engineering are presented and compared. The development of the Atlas rocket system is used to illustrate the need to design in the overall functional domain before going to the hardware domain. System requirements, trade studies, and validation approaches are presented along with the concept of life cycle analysis. The importance of developing a failure mode and effects analysis (FMEA) during the design process is emphasized.

Project Management. Students refine their skills in this area by creating team charters, work breakdown structures (WBS), Gantt charts, and mid-course correction plans first through homework exercises and in-class case studies and then as part of their team presentation and proposal activities. The concept of risk management is introduced including the ranking of risks relative to severity and probability of occurrence. A practical student exercise (see Figure 3) is the bridge building contest developed by VISTA Promotional Services (1999). In this exercise, teams estimate how long they will take to build a 2-dimensional bridge consisting of linkages and fasteners.

Numerous occurrences such as power outages, a flu epidemic, material shortages, and change orders are introduced to show the types of risks that can affect program schedule and budget.

Business Acumen. The demands of customers and the pressures of intense competition have forced businesses to develop products with more value in less time. Engineers must not only be aware but also engaged in the inner-workings of their employer's business if they are to arrive at new products that meet the customer's expectations and the company's bottom line needs. The typical 20th Century company model presented by Anderson (1998) is used as the launching point for a lecture on business structure and marketing. This is followed by balance sheet and income statement exercises. The concepts of time value of money are reviewed and problems utilizing return on investment and internal rate of return are covered.

Course Elements: Important Trends in the Engineering Profession

The demands on engineering professionals will intensify as the 21st Century progresses. Constant change will require constant learning. As global competition increases, the number of ethical situations and the drive to reduce costs will intensify. Engineers will be faced with meeting these challenges in the workplace while still having time and energy for a life beyond professional responsibilities. This course addresses these 21st Century trends as discussed below.

Work/Life Balance. Students are challenged to make conscious decisions regarding how they invest their time after graduation. The benefits and problems associated with moving up the corporate ladder are presented and then discussed in class.

Professional Ethics. This is a major portion of the course. The general subject of professional ethics is initially presented along with the codes of ethics from several engineering societies. The skill of actually resolving an ethical situation is addressed by studying the 9-step process provided by the Applied Ethics Case of the Month Club as reported on the National Institute for Engineering Ethics (NIEE) website. Following this introductory material, students are shown the DVD case study "Gilbane Gold" prepared by NIEE (1989). This case study is the subject of the students' second paper. Students are challenged to not only analyze the case, but actually decide what the engineer in the story should do to resolve the ethical dilemma.

Lean Engineering. The experience of the instructors in this area is used to present the fundamental concepts of lean as applied to the aerospace industry. This presentation is augmented by a guest speaker on the subject and an article from the magazine *Mechanical Engineering* (Thilmany, 2005).

Life-Long Learning. In addition to the sample paper on life long learning used early in the course, students are assigned readings on this subject. The readings are followed-up by an in-class discussion of specific steps to continue learning after graduation.

Global Leadership. Due to the expanding influence of technology on society, students are encouraged to assume leadership positions at work, inside the profession, and in society at large. The emphasis is leadership on a global scale. As such, the challenges of leading team members from other cultures are discussed. New leadership techniques such as contemplative leadership

(Trimble, 2004) and organizational learning (Senge, 1990) are explored. An important leadership case study presented is the development of the 1995 Lincoln Continental (Senge et. al., 1995 and Porter, 2001).

First Semester Implementation

The first semester for this new course was Fall of 2006. It was offered as an elective for seniors. (Next year, it will be a required course for graduation.) There were two sections. Section A had 29 students while Section B had 23 students. Each course developer taught a section. A teaching assistant from the English Department was used by both sections to grade the written papers relative to good writing principles. The papers were also reviewed by the instructors for content.

Figure 4. Team presentation on renewable energy

The students appeared to enjoy the course and there were several remarks that the emphasis on real world issues and approaches was appreciated. The course also turned out to be a forum for these senior-level students to discuss the "trials and tribulations" of interviewing for employment. Figure 4 shows one of the teams making their presentation on renewable energy.

Figure 5 provides the final schedule for the Fall 2006 course. There were 31 class sessions. Each session was divided into two 35-minute activities. The grading was conducted on the basis of 1000 points with the breakdown as shown in Table 6.

Table 6. Grading Points

	Points
Homework	100
Paper 1	100
Paper 2	150
Paper 3	200
Presentation 1	100
Presentation 2	150
Quizzes	50
Final Exam	150
Total	1000

First Semester Evaluations

Student evaluations and a lessons-learned session by the two instructors were used to evaluate the first semester of the course. These results are given in Tables 7 and 8 respectively.

Conclusions

Overall, the instructors and students both concluded that the course was successful in meeting its objectives. Key success factors were guest speakers, industry-experienced instructors, and engaging activities such as the team presentations, bridge building risk mitigation exercise, and ethics scenario on DVD. There was inadequate time to fully utilize the proposal activity, which is supposed to be the culminating activity for the course. With minor adjustments to the schedule and content, this course will be an effective required course for seniors to address the ABET Criterion 3 and new Dean's engineering business practice requirements that are not adequately covered elsewhere in the curriculum.

Activity 1	Activity 2	Key Student Deliverables	Session
Course Overview	Writing Lecture		1
History of Profession	Writing Lecture		2
Work/Life Balance	Life Long Learning		3
Course Models	Product Development		4
Role of Business	Art of Presentations	Paper 1	5
Lean Engineering	*~~Speaker 1~~*		6
Role of Engineering in Business		Presentation 1	7
Presentations	**Presentations**		8
Presentations	Societal Challenges		9
Systems Engineering	*~~Speaker 2~~*		10
Teamwork	Teams Meet		11
Program Managemen	PM Exercises		12
Professional Ethics	Discussion	Presentation 2	13
Ethics Case DVD	*~~Speaker 3~~*		14
Presentations	**Presentations**		15
Presentations	**Presentations**		16
Presentations	*~~Speaker 4~~*		17
Balance Sheets & Income Statements		Paper 2	18
Engineering Economics with Excercises			19
ROI & IRR Problems	Paper Questions		20
Proposal Writing	*~~Speaker 5~~*		21
Proposal Writing	Teams Meet		22
Work Breakdown Schedules and Tasks			23
Teams Meet	*~~Speaker 6~~*		24
Risk Management Game & Discussion		Paper 3	25
Paper 3 Review	*~~Speaker 7~~*		26
Teams Meet	Teams Meet		27
Leadership	Global Leadership		28
Course Review	Course Review		29
Paper 3 Returned	Course Review		30
FINAL EXAM			31

Figure 5. Final Schedule for Fall 2006

Table 7. Summary of Student Survey Results	
Survey Question	Summary of Results
1. How have you improved as a writer?	Better at using outlines; proposal writing was new and interesting
2. Have you improved as a team member?	I am now a better listener; learned the importance of diversity and scheduling; defining roles helps a lot; I learned how to help others carry their weight
3. Has your opinion changed about what it means to be an engineering professional?	4 students—not really; 14 students—yes; didn't realize that engineering is more than design and analysis; learned ethics, teamwork, and business are important
4. Do you think you are better prepared to handle ethical situations? Why?	All said yes; 9 step process helped
5. List five things you liked about the course.	Guest speakers (14); ethics (9); instructor/industry experience (7); topics not in other courses (7); bridge exercise (6); writing (6); proposal (5); teamwork (5); systems thinking (3); WBS (2); textbook cases (2); career lectures; classroom discussion
6. You have been asked to teach this course next semester. What would you change?	More time for proposal (6); have more essay on the final; change groups for proposal; more group projects in class; different textbook; tour an engineering-based company; tougher grading; less teamwork emphasis; more quizzes; more exercises like bridge building

Table 8. Instructors Assessment Prior to Reading Student Feedback

- Not enough time to fully develop the proposal activity
- Students are already able to make effective individual oral presentations
- There needs to be time for class discussion after the speaker leaves
- Students are able to analyze an ethical situation, from various points of view, but they don't want to personally decide on a course of action
- Students did not do reading unless they needed to study for a quiz
- Students liked the use of lists to help them remember key ideas on a topic
- Students responded well to the guest speakers and examples from the instructors' experience.
- Students were able to effectively prepare and present the course deliverables except for the proposal where the teamwork seemed to break down and this resulted in lower quality in the papers.

Recommendations

To increase the effectiveness of the course, the individual oral presentation should be deleted and the proposal activity should be expanded. The proposal problem statement should be given to students at the beginning of the course so they can see how the course material will help them prepare an effective proposal at the end of the course.

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