2006-1556: ENGINEERING ETHICS INSTRUCTION AS AN INTEGRATED PROFESSIONAL COMPONENT

Kevin Schmaltz, Western Kentucky University

Kevin Schmaltz teaches thermo-fluid and professional component courses in Mechanical Engineering, including the Freshman Experience course, Sophomore Design, Junior Design and the Senior Project Design course sequence. Prior to teaching at WKU, he was a project engineer for Shell Oil, designing and building oil and gas production facilities for offshore platforms in the Gulf of Mexico.

Engineering Ethics Instruction as an Integrated Professional Component

Abstract

The Mechanical Engineering faculty at Western Kentucky University have developed and implemented a Professional Plan to assure that graduates of the program have experienced key areas of the engineering profession and demonstrated their abilities to perform in a professional manner. This Professional Component includes Engineering Design, Professional Communications, Professional Tools, and Engineering Ethics, with students receiving instruction and practice in each area at least once per academic year.

This paper will detail the Engineering Ethics component, which has been created to provide students with a framework for understanding professional expectations, techniques for clarifying the ambiguity of ethical dilemmas, and familiarity with both classic and typical ethical cases. The delivery of ethics within the team-based Professional Component classes provides an appropriate forum for group discussion and resolution of ethical situations. We believe that inclusion of Engineering Ethics on an equal footing with the other professional skills is appropriate and required.

The philosophy that motivates the four-year ethics instruction is to expose freshmen to ethical cases and published codes to provide expected behavior. Sophomores perform more in-depth analyses of cases to develop judgment. Juniors not only analyze cases, but also clarify the circumstances of cases. During the senior project sequence, seniors again demonstrate problem definition and resolution through case studies as well as their own project activities.

To improve ethics instruction, two phases of assessment are implemented. Overall course assessment is performed for all courses using a collective Peer Evaluation of Course Effectiveness at the end of the semester. In addition, ethics-specific assessment is incorporated into the Program Outcome: ME graduates can judge appropriate professional and ethical conduct. Program Outcomes are measured using several methods and are reviewed on an annual basis.

The integrated Professional Component structure provides a framework for building upon previous coursework, assessing student progress, and adjusting course coverage based on prior assessments to assure that departing graduates do not experience a wide gap between their campus experiences and professional practices.

Introduction

The ME faculty at Western Kentucky University (WKU) have developed and implemented a sequence of professional experiences for students pursuing a baccalaureate ME degree that is consistent with overall mission of the engineering department [1]:

> *…to produce, as its graduates, competent engineering practitioners. An engineering practitioner is one who has a foundation of basic science, mathematics, and engineering knowledge, combined with practical knowledge and experience in applying existing technology to contemporary problems. … Program curricula will be project-based. Students will have sufficient opportunity to*

engage in project activities to support development of a clear understanding of engineering practice. ... Projects that provide opportunity to accomplish design, development, and implementation should be available.

To achieve this outcome, the ME curriculum delivery involves a structured Professional Component that defines and organizes how students acquire design tools and skills, competency in mathematical and technical analysis, the ability to communicate effectively, and experiences and methods to make professionally ethical decisions. The four areas defining, quantifying and assessing the Professional Component are:

- Engineering Design (teaching and practicing design skills)
- Professional Communications (conveying designs and interacting with peers)
- Professional Skills (teaching and implementing design tools)
- Professional Ethics (evaluating and practicing appropriate professional behavior)

The WKU Professional Component also provides mechanisms for satisfying the Criterion 4 requirements EAC of ABET: "Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints" [2].

Formal plans for the four areas define the attributes and goals of each area, organize the implementation across the four years of the curriculum, and coordinate the assessment activities monitoring student outcomes. The plans are necessary to coordinate efforts of multiple faculty members across the curriculum to assure student success in developing these skills and because no desired student professional outcomes are completed within individual courses. Using previously agreed-upon descriptions and measurement tools also helps the difficult assessment of students' results and progress through the curriculum. Lastly, more timely corrections are possible along the students' development path, instead of merely observing professional shortcomings at the senior level. The result has been a capstone course that is an integrative experience instead of a last minute attempt to introduce the necessary professional skills.

The overall details of the entire WKU ME Professional Component Plans have been discussed previously [3]. This paper is intended to focus on the Engineering Ethics plan, describe the ethics instruction across the Professional Component courses, and discuss the assessment and evolution of the activity.

The Professional Ethics Component

While determining and implementing coverage of engineering design and professional communication skills is a considerable challenge, the concept of teaching professional behavior and the agreement for appropriate content for ethics instruction is even more difficult to determine. Unlike technical skills that are more clearly defined, if not always agreed upon by all, ethics material is more often considered only as an afterthought. An unfortunate possibility is that ethics coverage is provided because ABET requires it. Hopefully this is rarely the case. The means of implementing ethics instruction range from first year instruction [4] to senior capstone coverage [5] to embedding the material throughout [6].

The system that WKU ME faculty developed for implementing the Professional Component originally did not include Professional Ethics. However the success of the earlier method led us to implement the same strategy for ethics instruction. As an initial step before formalizing the content and execution of the Professional Ethics Plan, the following desirable outcomes were agreed to [7]:

- increased ethical sensitivity
- increased knowledge of relevant standards of conduct
- improved ethical judgment
- improved ethical will-power (ability to act ethically when one wants to)

A second step is to decide when to teach the ethics component material. Providing ethics instruction in a single required course offers the opportunity to get the material covered in one (painful?) experience. However it can be difficult to find faculty willing to invest the effort to properly teach the course. It is also difficult to fit an additional course into an already crowded engineering curriculum. Most importantly, this approach can marginalize ethics as side-topic, and not an integral or important part of engineering study from the students' view.

The ME faculty have chosen to spread ethics instruction throughout curriculum, taking advantage of the existing Professional Component sequence. With this approach the students will hopefully perceive ethics as a common attribute of good engineering practice. In addition, instruction and student expectations can rise with progress through curriculum.

The rising expectations can follow Benjamin Bloom's taxonomy for categorizing levels of student learning [8]:

Knowledge:	The student is capable of recalling words, facts, and principles.
Comprehension:	The student is capable of interpreting and extrapolating
Application:	The student is capable of remembering knowledge to solve a problem
Analysis:	The student is capable of identifying elements, relationships and principles.
Synthesis:	The student is capable of devising a plan to accomplish a task
Evaluation:	The student is capable of making critical judgments based on internal and external criteria.

These learning levels guide the material presented to the students, the instruments used to measure student performance, and the assessment of this performance.

The Professional Ethics Plan developed by the ME faculty addresses the need to convey professional behavior expectations to the students as a continuous process consistent with their level in the curriculum. The primary components of ethics covered are [9, 10]:

- Profession and Nature of Engineering

- Ethical Theories
- Assessing Safety and Risk
- Implications of Responsibilities
- Problem Solving Techniques

Four Professional Component courses in the four-year plan of study have ethics components, where the students receive instruction and are required to demonstrate an appreciation of ethical circumstances and to apply problem solving techniques. The students' awareness of professional ethics is expected to evolve from an understanding of professionalism and knowledge of standards of behavior, to the learning and application of ethical dilemma resolving methods. Table 1 lists courses with a Professional Ethics component.

Table 1: Professional Component Courses with Ethics Content

Professional Component Course	**Credits**
ME175 Freshman Experience	2
ME200 Sophomore Design	2
ME300 Junior Design	2
ME400 Mechanical Engineering Design	2

The following section details the structure of the delivery of professional ethics topics across the curriculum, and the opportunities to integrate ethics with other professional components such as design and communications.

Delivery of Ethics Material

A variety of traditional ethics material is provided to the students in the four Professional Component classes, including investigations of existing frameworks for understanding the expectations for professional behavior. This includes discussions of the meaning of being professional, and researching professional codes of ethics. Students are exposed to case studies ranging from major disasters to moderate dilemmas to every day issues in order to elevate their awareness of ethics situations. Developing the ability to evaluate the merits of existing cases is stressed, in order to implement effective strategies to make ethical decisions as the ultimate goal.

In freshman class (ME175) the ethics instruction takes approximately 15% of the course. Students are introduced to the profession of engineering, are asked to research existing Professional Codes of Ethics and critically compare them, and then discuss both disaster and dilemma ethical cases such as the Ford Pinto Case and the Gilbane Gold Material [11].

An advantage of delivering ethics within Professional Component classes is that the material can be related to other professional activities. The ethics material follows the initial instruction in engineering design, and so the discussion of the Ford Pinto can focus on design decision-making

patterned after some in-class experiences, as well as cost-benefit analysis. For this class the desired student learning outcomes are increased ethical sensitivity and increased knowledge of relevant standards of conduct; the desired Learning Levels are Knowledge and Comprehension.

In the sophomore class (ME200) increased discussion of Engineering Responsibility and the Implicit Social Contract between professionals and society becomes the focus. Ethics instruction again takes approximately 15% of the course. The students are expected to include existing frameworks from the freshman year and develop ethical analysis techniques for making decisions. A Line Drawing Technique [10] is covered to attempt to clarify ethically gray areas by placing hypothetical situations between clearly negative and positive extremes. Students can then locate the existing situation within this spectrum, and discuss where they would find an acceptable compromise.

Sophomores also investigate whistle blowing cases, which provide a forum for elevating the observation of situations to the level of taking action to make others aware of illegal, unjust, or harmful practices. In ME200, increasing emphasis is placed on professional communications, clearly conveying and evaluating information, and particularly defining the obligation of the writer to focus on the needs of the reader [12]. All ethics situations need this careful communication of information, since the facts are often subject to interpretation, and with whistle blowing cases it is most important to recognize the severity of one's decisions. For this class the desired student learning outcomes are the same as the freshman class, but also include improved ethical judgment. The desired Learning Levels similarly follow the freshman levels, but include Application and Analysis.

In the junior class (ME300) the previous concepts of engineering responsibility are repeated and students are expected to demonstrate the concepts. The more mature audience can better assimilate Risk Assessment and Management concepts now, and is asked to use analysis techniques in team settings to present disaster cases such as: the DC-10 crash in Paris, 1974; Three Mile Island, 1979; Kansas City Hyatt Regency Hotel, 1981; Union Carbide, Bhopal India, 1984; Chernobyl, 1986; Valuejet Flight 592, 1996.

For the juniors there is a focus on professional communications together with the ethics instruction. Student teams must investigate and summarize the events for presentation to a defined audience – their classmates. They identify the parties impacted, describe the ethical dilemmas and implications. Finally they must discuss how risk and consent were considered, and how they think that it should have been considered.

In ME300, the desired student learning outcomes build on the sophomore class, but are essentially the same three (sensitivity, knowledge of standards, judgment). The desired Learning Levels are also the same as the sophomore classes, with higher expectations within the categories.

In the senior class (ME400) the students demonstrate prior concepts, with all activities undertaken in the students' senior design teams. This links their most significant design experience during their education to the final ethical deliverables. Typically a major disaster case (often the Challenger case) and more immediate personal ethical issues are covered. For the disaster case the seniors analysis is expected to include engineering design, technical and statistical considerations (if possible) to assess risk, and ties to Codes of Ethics.

Personal ethical issues have more relevance for the seniors nearing completion of their studies. We have also been including efforts to create a WKU Student Code of Ethics to emphasize the more common ethical decision-making that will be necessary.

For the senior class, the desired student learning outcomes include the final individual behavior outcome, and the Learning Levels cover the entire list from Knowledge through Evaluation.

Program Outcomes and Assessment

The ME faculty members have developed and are measuring and assessing thirteen Program Outcomes that encompass ABET outcomes a-k, as well as particular program expectations. The four Professional Component plans focus on five of the thirteen Program Outcomes. For Engineering Ethics, the Engineering Professionalism outcome that is applicable is:

ME graduates can judge appropriate professional and ethical conduct.

The assessment of each outcome is achieved using a variety of measures, including evaluation of selected student work, performance of students in extra-curricular activities and nationally normed exams, student exit interviews and composite student grades in appropriate courses.

Faculty evaluation of outcomes takes place in two forms. Each semester, faculty members hold a Peer Review of Course Effectiveness session to review every engineering course taught in the program. The primary function of the Peer Review is to improve course outcome delivery; however the integration of the courses across the curriculum is also discussed. The second review is performed annually, where the faculty reports and discusses the data gathered for each Program Outcome.

Table 2: Rubric to Assess Professional Ethics Student Work

Attributes	Absent (0)	**Novice (1):** some of the elements are present.	**Intermediate (2):** most of the elements are present.	**Proficient (3):** all elements are present.
Organization/Coherence: Statement of ideas is gramatically correct, professionally formatted. Authors intent is clear.				
Identify consitutents: Clear indication of the parties impacted by the ethical dilemma.				
Describe purpose/dilemma: Ethical dilemma described, implications are conveyed.				
Develop resolution/solution: Methods for resolution are presented, comparisons made between solutions, and alternatives discussed.				
Total Score: Expect 6 for Sophomore class, 8 for Junior Class and 10 for Senior Class				

The primary measure of student performance related to Program Outcomes is through the evaluation of collected student work using assessment rubrics. The rubric for the program's ethics outcome is shown in Table 2. The rubric is used for all years of student evaluation, allowing the comparison of varied levels of professional competence as students advance through the curriculum. The expected Total Score indicated at the bottom of the rubric changes,

reflecting the increasing expectation for student performance as they move through the elements of the integrated Professional Component.

The Table 2 Rubric is applied to a representative sample of student work in the freshman, sophomore, junior and senior design classes, and the results of this analysis supports the Engineering Ethics component of the Professional Plan. The student work is independently evaluated by several ME faculty members and then discussed together. For each sample of student work, faculty members independently assign scores of 0 (absent) to 3 (proficient) for each attribute component in the rubric. The sum of these scores for all attribute components becomes the total score. Freshmen and sophomores are expected to attain a novice to intermediate level, while seniors are expected to attain an intermediate to proficient level. The average values of student performance, assessed by several faculty members provide the basis for the student work evaluation used in the Professional Plan reports.

Student work has been evaluated from each of these courses for the past two years. The freshman level was assessed at an average Total Score of 4, the sophomores at a Total Score of 5 ½, the juniors at a Total Score of 7 ½, and the senior level was 9. This indicates an improving level from the students, but below target values. Since this is the early phases of application of the rubric, the ME faculty are cautious about over-interpreting these early results.

Graduating senior performance on the ethics questions on the FE Exam have also been monitored. For the April 2005 FE Exam, WKU ME students averaged 73% on the ethics questions, compared to a 65% national average.

Conclusions

Early in the 2005 spring semester, Roger Boisjoly was invited to speak to all engineering students at WKU. Mr. Boisjoly was a key player in the Challenger Space Shuttle Challenger Disaster in 1986, as a knowledgeable engineer for the NASA contractor providing the component that failed, causing the destruction of the Challenger. Mr. Boisjoly participated in several classes during his day at WKU and gave an excellent talk in the evening. The students reacted favorably to the experience ("visitor was a big influence"; "Boisjoly's speech was really good"), but also with some caution to the terrible events ("All I learned about Engineering Ethics is don't open my mouth…").

My reaction to Mr. Boisjoly echoed the students as being a positive educational experience, but I also found him troubling. His conclusions seemed to indicate that the corporate culture at NASA was so flawed that acting ethically was fundamentally impossible. His voice was so fatally pessimistic that I did not want to ask him the question "what would/should you have done differently?" This is contrary to the fourth desired outcome of ethics: improved ethical will-power (ability to act ethically when one wants to).

Based on this experience, the WKU ME program approach to teaching professional ethics that includes all four outcomes seems to be on the right track. Over a four-year period students are exposed to situations that provide a framework for understanding professional expectations. They are provided with both techniques for and experience in clarifying ambiguous ethical cases. And most importantly, they are challenged to develop and defend professional "solutions" – resolutions to ethical dilemmas. By linking ethics instruction to the other Professional

Component topics, an appropriate forum for group discussion and resolution exists, and Engineering Ethics is given an equal footing with the other professional skills.

Overall student appreciation for ethical considerations is good, and performance by juniors and sophomores has been rising compared to earlier cohorts for the past two years. The quality of ethics assignments has been increasing. However there is work to do. Engineering Design and Professional Tools component skills are more accepted and better developed by the students. Professional Communication skills need work – which is evident in ethics analysis papers. Professional Ethics is still the least important of the four components in students' opinions.

The future plans include continuing with the ME175 – ME200 – ME300 – ME400 sequence with some increase in faculty development of ethical pedagogical competence and greater faculty participation. Continuation of the Professional Plans is expected to create rising performances of students and rising expectations of faculty. The WKU ME faculty members are confident that the Professional Plan is in place to monitor activities and make corrections.

References

[1] http://www.wku.edu/ engineering/depmiss.php

[2] 2004-05 Engineering Criteria, Accreditation Board for Engineering and Technology, Baltimore. (http://www.abet.org/criteria.html)

[3] Schmaltz, K.S., Byrne, C., Choate, R. and Lenoir, J., "Integrated Professional Component Plan from Freshmen Experience to Senior Project," Proc. 2004 ASEE Annual Conference, Salt Lake City, UT.

[4] Lau, Andrew, "Teaching Engineering Ethics to First-Year College Students," Science and Engineering Ethics, Volume 10, Issue 2, 2004

[5] Catalano, George, "Senior Capstone Design and Ethics: A Bridge to the Professional World," Science and Engineering Ethics, Volume 10, Issue 2, 2004

[6] Fleischmann, Shirley, "Essential Ethics – Embedding Ethics into an Engineering Curriculum," Science and Engineering Ethics, Volume 10, Issue 2, 2004

[7] Davis, M. 1999, "Teaching ethics across the engineering curriculum." Online Proceedings of International Conference on Ethics in Engineering and Computer Science.

[8] Bloom, Benjamin. Taxonomy of Educational Objectives, Pearson Education, Boston, MA 1984.

[9] Schinzinger, R. and Martin, M.W., Introducing Engineering Ethics, New York: McGraw-Hill, 2000.

[10] Fleddermann, C.B., Engineering Ethics, Upper Saddle River, NJ: Prentice Hall, 1999.

[11] http://www.nspe.org/ethics/eh1-gold.asp

[12] Carvill, C., S. Smith, A. Watt, and J. Williams. "Integrating Writing into Technical Courses: Steps toward Incorporating Communication Into the Engineering Classroom." Proc. 2002 ASEE Annual Conference, Montreal, Quebec.