Using the Engineering Method To Research and Write about Corporate Practice: A Model for Teaching Engineering Ethics

O. Christene Moore, Senior Lecturer
Billy Vaughn Koen, Professor
The University of Texas at Austin

Introduction

The pressure to include, if not emphasize, the importance of ethics in the engineering curriculum is one of the most perplexing challenges facing engineering educators today. For one thing, it is difficult to decide where exactly to put ethics in the curriculum. With course requirements that are already bursting at the seams, it's hard, as Michael Davis suggests in his article "Teaching Ethics Across the Engineering Curruiculum"[1] to fit a free-standing course in ethics into the curriculum or to "make what it teaches seem a routine part of engineering." And unless we are able to make it "seem a routine part of engineering" students will resist our best efforts. One strategy that Davis recommends is a pervasive approach to ethics infusing a discussion of ethics in existing courses at all levels.

The problem then becomes discovering the best pedagogical approach to ethics instructions in individual courses. Many feel caught between two possibilities: either tackling traditional texts, such as Plato or Kant or Mill, or skirting the difficult scholarship involved in teaching those philosophies by using case studies and scenarios that prepare students for the complexity of ethical decision-making. While the value of classical philosophy is undeniable, those systems of thought may not be the best strategy for solving engineering problems. And although there is no disputing the complexity of decision-making in engineering practice, understanding complexity does not necessarily make for a principled engineer.

In this article, we argue that the best resource available for discussing engineering ethics with undergraduates is the Engineering Method -- a problem-solving method that is unique to engineering. It is a method which, though widely overlooked, accommodates the complexity of engineering problems, allows students to feel that ethical decision-making is a "routine part of engineering" [1] and even contributes to the field of philosophy. In the summer of 2004 we began a pilot study in the Department of Mechanical Engineering's required Engineering Communication course that required students to research corporate practice and evaluate professional standards of behavior using the Engineering Method as an analytical tool.

[1] Davis, Michael, "Teaching Ethics Across the Engineering Curriculum," *The Online Ethics Center for Engineering and Science* Case Western Reserve University: 2004.

Caroline Whitbeck in her article "Undergraduate Education in Practical Ethics"[2] suggests that whatever method we use, the important thing to accomplish is a "'practice-oriented,'" . . . or 'active-learning' approach to ethics education." Our goal in the pilot study we undertook was to use an "active-learning" approach that would integrate ethics more seamlessly into the course content and allow students to feel that the topic was a "routine part" of the course and the engineering profession. In this article we will describe and evaluate that pilot study beginning with a definition of the Engineering Method. We will explain the assignment we used in Engineering Communication, describe students' performance on the assignment, evaluate the effectiveness of the assignment, and discuss our plans for the future.

The Engineering Method

The *engineering method* (or engineering design as it is sometimes called) may be defined as the use of heuristics to cause the best change in a poorly understood situation within the available resources.[3] In this definition the word *heuristic* refers to anything that is helpful, useful, and based on experience, but in the final analysis is unjustified, unjustifiable, and potentially fallible. Engineering heuristics include all of the graphs, mathematical equations, and empirical correlations used by the engineer, of course; but, they also include the strategies the engineer uses to reduce risk, to allocate resources, and to establish the attitude or approach used in solving engineering problems. A single heuristic is seldom used in isolation, but most often used in groups that may conveniently be called the *state-of-the-art* (sota). A *sota* is the set of heuristics used in a specific situation at a specific time. The term *best engineering practice* refers to the best collective sota of the engineering community. For example, when we say we have a "state-of-the-art stereo system" we mean that it is consistent with the best set of heuristics known to the engineering community at the time it was designed. With these definitions in place, we can now define ethical behavior for the engineer. The fundamental *rule of ethical judgment* is to evaluate an engineer and his or her engineering design against the sota that represents best engineering practice at the time the design was made.[4] A parallel *rule of implementation* to guide the engineer in every ethical judgment follows immediately: In every instance choose the heuristic for use from what your personal sota takes to be the sota representing best engineering practice at the time you are required to choose.[5]

Interestingly enough a variant of this same rule is used in the most profound ethical decisions in the American judicial system and another has recently been mandated to correct some of the ethical indiscretions seen in business. For example, the American jury system impanels 12 carefully chosen individuals to represent the current state-of-the-art of the community and to pronounce the guilt or innocence of the defendant—even in the ultimate ethical decision as to whether to sentence someone to death. And in the Sarbanes Oxley bill [6] the

---

[2] Whitbeck, Caroline, "Undergraduate Education in Practical Ethics," *The Online Ethics Center for Engineering and Science* Case Western Reserve University: 2003.
[3] Koen, Billy Vaughn, *Discussion of The Method: conducting the engineer's approach to problem solving,* NY: Oxford University Press, 2003.
[4] Koen, Billy Vaughn, "Engineering Method," entry in *Encyclopedia of Science, Technology, and Ethics*, NY: Macmillan Reference U.S.A. June 1, 2005.
[5] Koen, Billy Vaughn, "Engineering Method," entry in *Encyclopedia of Science, Technology, and Ethics*, NY: Macmillan Reference U.S.A. June 1, 2005.
[6] Bumiller, Elisabeth, "Corporate Conduct: Bush Signs Bill Aimed at Fraud in Corporations," *New York Times*, July 31, 2002.

Congress has mandated that the business community establish the state-of-the-art for good business practice in the wake of the Enron debacle.

The final rule for ethically implementing the engineering method just given does not, of course, imply that an engineer will always act ethically. At times his or her sota may not be congruent with the sota that represents best engineering practice. It is for this reason that it is incumbent on the engineering community to articulate what represents best engineering practice and on the professoriate to develop strategies to teach what this is.[7][8]

Believing that the best strategy for teaching engineering ethics may be to let students research and analyze the heuristics or sota that professional engineers use to make decisions, we piloted a new research assignment in our Engineering Communication course in the summer of 2005. The assignment challenges students to research and write about how professional engineers and corporate leaders face challenges. Simply put, students are required to pursue a semester-long research project focusing on a corporation that employs engineers and that has faced a crisis. Because the assignment requires students to investigate the practices and policies that companies use to address the challenges they face, it obliges students to examine the state of the art in corporate practice and evaluate the ways professionals respond to problems. This article describes the research project students were assigned and evaluates its effectiveness in engaging students in a discussion of ethical dilemmas.

The Assignment: Researching Corporate Responses to Crisis

Engineering Communication or ME 333T is a required junior-level course in the Department of Mechanical Engineering. Typically, in semesters past, students have worked on research projects involving a topic in engineering. The course has sought to engage students in some reflection on the ethical dimensions and social impact of engineering design, but much of the research and writing has been focused more on reporting data rather than evaluating it. The new assignment was first used in the summer of 2004 with the goal of integrating a discussion of engineering ethics and professional responsibility more seamlessly into the content of the course. The project students worked on was a semester-long, research project and involved several intertconnected assignments which are listed below:

a memo suggesting a company to research,
a formal proposal for a research project,
an executive summary of an article in the research,
an annotated bibliography,
a formal presentation, and
a formal report.

Figure 1 is an excerpt from the first assignment in the project, the memo, and describes the parameters students must consider in defining a topic. For instance, the assignment requires

[7]Koen, Billy Vaughn, "On Defining Engineering Ethics: A Challenge to the Engineering Community," Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition.
[8] Koen, Billy Vaughn, "On Teaching Engineering Ethics: A Challenge to the Engineering Professoriate," Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition.

that students choose a corporation or agency that employs engineers and evaluate the practices and policies the companies used to address the crisis they faced.

Subsequent assignments build on this theme and require students to investigate the behavior of individuals and groups of individuals in response to the professional challenges they face. The goal of the whole project is to encourage students to recognize the complexity of the variables engineers must weigh and give them some criteria, through an understanding of the

Mechanical Engineering 333T
August 30, 2004

TO: ME 333T Students

FROM: Ms. Moore

SUBJECT: Memo Proposing a Research Project

In the wake of Enron, there is growing concern about professional responsibility and ethics. In 2002 Congress passed the Sarbanes-Oxley Act " a sweeping bill overhauling corporate fraud, securities and accounting laws" [Bumiller, 7/31/2002]. [9] Directed specifically at corporate accounting and disclosure practices, the Sarbanes-Oxley Act impacts all aspects of corporate culture by demanding more stringent prosecution of white collar crime and increasing the penalties for such crimes significantly. As a result, corporate conduct and values are being scrutinized more closely than ever. Your research project in this class will involve an analysis of a corporation or firm that employs engineers and that has faced a crisis. Your research will explain the nature of the crisis and will evaluate the corporation's policies, practices, and values. Every company must weigh different variables, such as financial reward, safety, environmental impact, and efficiency, in order to decide business strategies. Every company prioritizes those variables in a way that will hopefully allow the company to prosper and benefit its employs and clients. Obviously, different companies give different weights to different variables. Your job in your research project is to identify the most significant variables in your company's matrix and determine what trade-offs the company made regarding the crisis you investigate. One of the variables you must look at is the role ethics play in the company's policies. Your first major assignment in this class is a memo to your TA and me proposing a company to research this summer.

Figure 1. Excerpt from Memo Assignment.

Engineering Method, to analyze and evaluate professional behavior. Students are not expected to end up either condemning or exonerating the companies they research. Instead, the Engineering Method is used as a tool to help them understand that every action has a context that involves trade offs. Ethical behavior involves using the best sota to make the best trade offs in

[9] Bumiller, Elisabeth, "Corporate Conduct: Bush Signs Bill Aimed at Fraud in Corporations," *New York Times*, July 31, 2002.

the context of a particular situation. Researching corporate behavior in crisis situations seems a promising way for students to learn the best practices in the engineering.

Student Performance on the Project

When the assignment was first introduced in the summer of 2004 students identified interesting, original topics without difficulty. The resulting research papers investigated corporate crises such as the lawsuits Ford faced as a result of the Pinto, the environmental damage caused by the Exxon Valdez, an evaluation of the bankruptcy of Pan American Airways, the impact of Nike's policy of employing children in developing countries. Other topics included a comparison of Coca Cola's environmental and health policies in India as compared to the EU or the US; a historical review of the 1972 failure of Pittston Coal Company's impoundment dam on Buffalo Creek; and an evaluation of Johns Mansfield Company's failure to disclose information about asbestosis to its employees. Figures 2 and 3 display the cover pages and gives the urls of two papers from that course. Figure 2 is from a student paper on Boeing's contract negotiation with the government for the leasing of the KC-767 tanker. The topic was original and the research the students did for the project led them to an interesting analysis.

Figure 2. Examination of Boeing's Corporate Culture: Events Surrounding the Boeing KC-767 Tanker Leasing Contract by Eric Houston, Patrick Paullus, and Adolpho Zubia http://home.engr.utexas.edu/houstoej/formalreport.htm[10]

Figure 3 is from a student paper on the Firestone tire recall. The timeliness of the topic and its relevance to Mechanical Engineering made the presentation on this research particularly interesting to students in the class.

[10]"Boeing KC-767 Programs Multimedia," Boeing, Inc. 2005. http://www.boeing.com/defense-space/military/tanker/767tanker_media.html

Figure 3. The Firestone Tire Recall of 2000[11] by Chris Delzell, Alberto Martinez, and Ryan McCurry http://home.engr.utexas.edu/delzelcr/formalreport.htm.

An Evaluation of the Pedagogical Effectiveness of the Project

In general, the topics were fascinating and lead students to unexpected findings and conclusions. The most significant benefit of the assignment was that all of the projects, even the weakest, addressed issues of ethics, professional responsibility, and the social and global impact of corporate policies and engineering decisions. As one student put it in a course evaluation: the course helps students to "examine the possible effects of [their] actions and attitudes."[12] Moreover, the projects integrated these issues seamlessly into the research and the final product. The course was not compromised by a "unit on ethics" which might seem beside the point or even gratuitous to students. On the contrary, the discussion of ethics was initiated by students as they made presentations on their projects. For instance in one class, the question and answer sessions after a series of presentations involved students in a discussion about the effectiveness of economic sanctions that was prompted by a presentation on Halliburton. In response to the next presentation on a Coca-Cola bottling operation in India, students continued on the theme of economic sanctions and asked questions about the responsibility of consumers to impose standards on companies by choosing the products they purchase more carefully. Finally, the period ended with a presentation on Tyco that led students to reflect on and discuss the responsibility of companies to disclose information (about financial records in the case of Tyco and about pesticides in the soft drinks in the case of Coca-Cola) to the public. None of these topics were prompted by the instructor or the teaching assistant; all of the discussion arose from students in the audience questioning the presenters, who were also students in the class.

The assignment had the further benefit of enhancing the goals of the course which has always required a research project that allows students to learn the standards for sound academic research. With the new assignment, students are still involved in learning the correct way to credit and use other sources, ways to evaluate sources and determine which ones are credible,

[11] Legal Information Center, "Overview of the Firestone Tire Recall," http://www.firestone-tire-recal.com/page3s/overview.html (Firestone Tire Recall Legal Information Center, 2000)
[12] A comment from an informal course evaluation by students.

and effective ways to structure, compose, and revise reports. In fact, the assignment enhances the goals of the course because it pushes students to a higher standard of rhetorical skill by requiring their in-depth analysis of a company's portrayal of itself and the media's critiques of those public relations profiles.

Of course, there were challenges, too. One of the difficulties in teaching ethics to engineers is that failures are always more prominent fodder for discussion than successes. Although our goal was not to emphasize failures, the assignment lent itself to a discussion of engineering problems rather than successes because problems and failures get so much more coverage in print. And a successful research project depends on literature. In the summer of 2004, several students wanted to write papers about companies that had been successful, responsible, and admirable, but each one gave up the task in favor of a company that had fallen for the simple reason that there were more sources on companies that failed. One student, for example, was interested in S.C. Johnson Company, a corporation that makes cleaning supplies such as Shout, Windex, and Pledge, and advertises itself as a "family company" that is unparalleled in "environmental and community leadership."[13] Because no one seems to be disputing S.C. Johnson's claims there was little written about the company except what the company has published about itself. A credible research project, of course, requires critical sources.

The other significant problem is that the concepts involved in evaluating corporate behavior are complicated. The concepts of sota, heuristics, and the Engineering Method are difficult and require some effective emphasis and repetition in order to become natural parts of a students' analytical vocabulary. That problem is one that we hope will become less of a burden as we discover our own sota for integrating those concepts into the lessons and exercises that make up the class.

Plans for the Future

We will continue to refine assignments and develop curriculum to support this project in the spring and summer of 2005. Working with the PRiME (**P**rofessional **R**esponsi**i**bility **M**odules in **E**ngineering) Project we are developing web-based modules (see Figure 4) that will introduce students to the fundamentals of Professional Ethics and the Engineering Method. The first of these modules, Introduction to Professional Ethics (see Figure 5), was developed as a result of a student paper on the Buffalo Creek flood of 1972. The module uses the flood and Pittston Coal Company's behavior before and after the flood as a case study to introduce students to the concepts of responsibility, professional ethics, and the function of codes of ethics. The next module in the sequence will use the Union Carbide chemical leak in Bhopal, India as a case study that will introduce students to the Engineering Method. We plan to develop a series of

[13] S.C. Johnson: A Family Company," S.C. Johnson, Inc. 2005. http://www.scjohnson.com/family/default.asp.

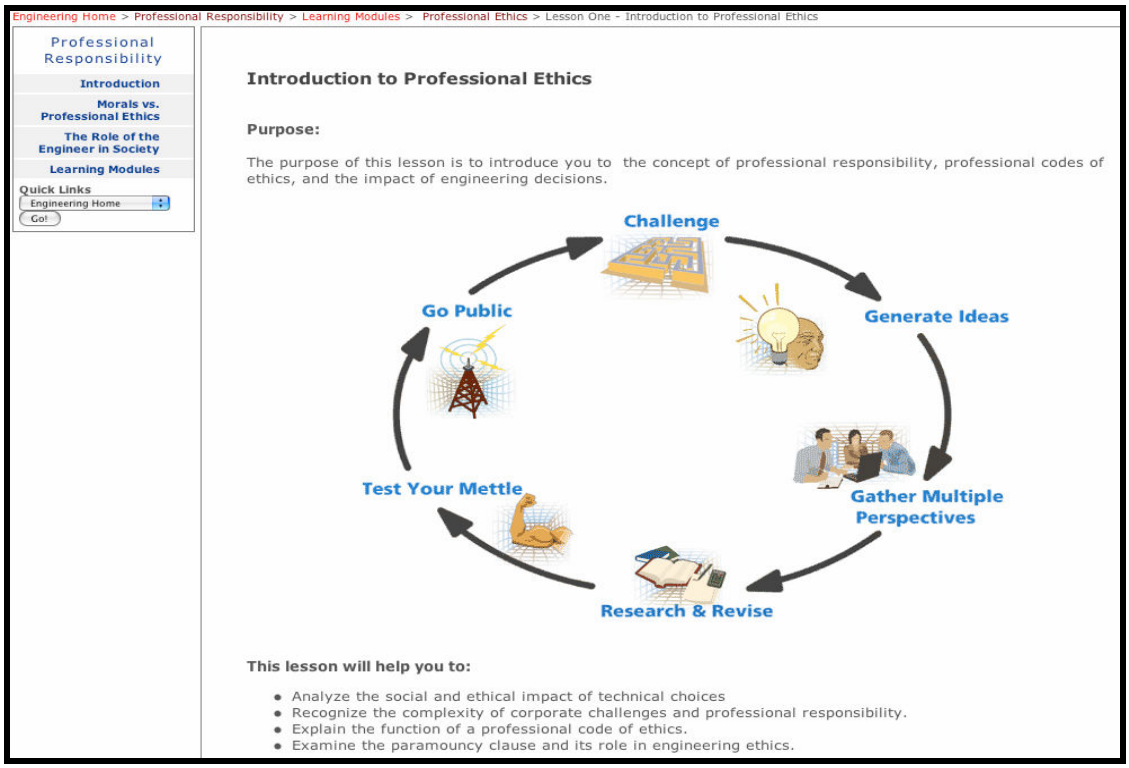

Figure 4. The Challenge Cycle is a web-based format that leads students through educational material in a six-step sequence that will help them to develop their analytical skills.

modules that use corporate conduct and the ways that professionals respond to crisis as a foundation for evaluating professional ethics. Subsequent modules on the topic of Professional Ethics will expand the discussion of the Engineering Method and the heuristics that engineers use to make decisions.

Challenge

Introduction to the Buffalo Creek Flood

Earl Benton/Charleston Daily Mail, (published February 11, 1999)

"Aftermath: Many rescue crews described Buffalo Creek in February 1972 as being more like a battlefield than a flood." (from *Buffalo Creek Changed It All*)

On February 26, 1972 after heavy rains, a coal impoundment dam in West Virginia failed. The resulting flood, which was one of the worst in U.S. history, devastated the valley and destroyed the communities on Buffalo Creek. Visit one of the resources below for an introduction to the Buffalo Creek Flood. Think about what circumstances may have led to this disaster?

Visit a pictorial introduction to the Buffalo Creek Flood

Read an excerpt from an article on the Buffalo Creek Flood

Figure 5. Introduction to Professional Ethics: The Challenge.
Instructors can use one of two possible paths on this page. One takes students to an excerpt of an article by Tom Price about the flood; the other takes them to a web site operated by the West Virginia Archive Society that describes the flood using both photographs and text.[14]

The approach to incorporating ethics into an Engineering Communication course which is described in this paper is currently being assessed. That assessment involves a review of the final papers in the class by several engineering faculty in the Department of Mechanical Engineering. Each faculty member will review 50 papers from the fall semester and evaluate the success of the project in engaging students in a meaningful exploration of topics with ethical dimensions. We believe this analysis from faculty who are not involved in or invested in the course will provide us with valuable feedback. In addition, portions of the course are being evaluated in the assessment of PRiME Project which includes a student survey, focus groups, and feedback from faculty and observers in the classroom.

Conclusions

The preliminary feedback on the pilot study shows that students have an appreciation of and capacity for ethical discussion and debate that we have failed to elicit with other approaches. Initial feedback from students in the course and an evaluation of the quality of the projects indicates that the practical application of the Engineering Method in our Communication course

has proved to a valuable experiences for students. We contend that the Engineering Method is a sound, philosophical foundation for ethical problem-solving in general and may well be the best available pedagogical tool for engaging students in a discussion of ethical dilemmas.

Bibliography

"Boeing KC-767 Programs Multimedia," Boeing, Inc. 2005. http://www.boeing.com/defense-space/military/tanker/767tanker_media.html

Bumiller, Elisabeth, "Corporate Conduct: Bush Signs Bill Aimed at Fraud in Corporations," *New York Times*, July 31, 2002.

Comment from an informal course evaluation by students.

Davis, Michael, "Teaching Ethics Across the Engineering Curriculum," *The Online Ethics Center for Engineering and Science* Case Western Reserve University: 2004.

Koen, Billy Vaughn, *Discussion of The Method: conducting the engineer's approach to problem solving,* NY: Oxford University Press, 2003.

Koen, Billy Vaughn, "Engineering Method," entry in *Encyclopedia of Science, Technology, and Ethics*, NY: Macmillan Reference U.S.A. June 1, 2005.

Koen, Billy Vaughn, "On Defining Engineering Ethics: A Challenge to the Engineering Community," Proceedings of the 2003 American Society for Engineering Education Annual conference & Exposition, 2003.

Koen, Billy Vaughn, "On Teaching Engineering Ethics: A Challenge to the Engineering Professoriate," Proceedings of the 2003 American Society for Engineering Education Annual conference & Exposition, 2003.

Legal Information Center, "Overview of the Firestone Tire Recall," http://www.firestone-tire-recal.com/page3s/overview.html (Firestone Tire Recall Legal Information Center, 2000).

S.C. Johnson: A Family Company," S.C. Johnson, Inc. 2005. http://www.scjohnson.com/family/default.asp.

Whitbeck, Caroline, "Undergraduate Education in Practical Ethics," *The Online Ethics Center for Engineering and Science* Case Western Reserve University: 2003.

Biographical Data

O. Christene Moore, M.A.
Senior Lecturer
Department of Mechanical Engineering
The University of Texas at Austin

Christene Moore is a Senior Lecturer in the Department of Mechanical Engineering at the University of Texas at Austin. Ms. Moore's current research is focused on ways of expanding the undergraduate engineering curriculum to better incorporate topics of professional responsibility and ethics. She has developed curriculum for a Mechanical Engineering course in engineering ethics and a freshman seminar which focuses on the impact of technology on society and the influence of consumers and citizens on technology. Ms. Moore is currently working on the PRiME (Professional Responsibility Modules in Engineering) Project the goal of which is to create flexible teaching materials to help engineering faculty incorporate units on professional responsibility, leadership, and engineering ethics into their courses.

Billy Vaughn Koen, PhD.
Professor, Mechanical Engineering
University of Texas at Austin

Dr. Koen's expertise spans the theory of engineering design and the application of artificial intelligence to nuclear engineering. Dr. Koen is a faculty member of the Manufacturing & Design program and the Dynamic Systems & Control program of the Mechanical Engineering Department. He has served on the College of Engineering faculty since 1968 and has three years of industrial experience. In addition, he has published more than 110 technical articles and reports and authored or edited three books and three book chapters. Dr. Koen conducted Sabbatical Research in the CRADLE department of The Tokyo Institute of Technology in 1998-99.