Implementation of Ethics Education Throughout an Engineering College

Robert H. Wolverton, Janet Bear Wolverton
United States Air Force Academy/Oregon Institute of Technology

I . Introduction

The engineering community is rediscovering its roots of professionalism. During the past decade engineering education moved beyond single minded devotion to science and technology by embracing multidisciplinary studies. To complete the transition from engineering scientists back to engineering professionals, education for the next decade is focusing on incorporating ethics and social responsibility into the curriculum. Davis illuminates the nature of professional engineering; "knowing engineering ethics is as much a part of knowing how to engineer as knowing how to calculate stress or design a circuit is. Indeed, insofar as engineering is a profession, knowing how to calculate stress or design a circuit is in part knowing what the profession allows, forbids, or requires."[1]

In this paper we look at ethics across the curriculum and implementing engineering ethics education via the case methodology. A brief presentation on the history of engineering education is followed by a discussion of ethics in engineering education. Case methodology is examined including a look at sources for cases and case research. Finally, the two-stage engineering ethics education model used by the United States Air Force Academy is discussed, and a plan for improving ethics across the curriculum is outlined.

II. Engineering Education

Prior to 1950 the emphasis in engineering education was on design according to codes and other standardized methods outlined in handbooks. It was seen as a very practical subject, with little application of mathematics beyond elementary calculus. During the 1950s and 1960s engineering education experienced a true paradigm shift from this applied, practice-oriented focus to a mathematical, academic, 'engineering science' focus.[2] Although this model has undergone various revisions during the past 40 years, it is still the predominant pedagogy used in engineering education.

Since the late 1980s there have been a number of studies that suggested changes are needed in engineering education. Many of these studies were conducted in response to the expressed needs of employers who want graduates with stronger skills in communication, teamwork, and critical thinking, in addition to sound technical competence. These studies range from the 1989 National Science Foundation (NSF) group of engineering experts recommendations regarding undergraduate engineering education to the NSF 1996 report on shaping the future in engineering education.[2,3]

In the late 1990s reform in the engineering education curriculum again emerged as a high priority item.[4] A powerful force driving this change has been the Accreditation Board for Engineering and Technology (ABET) Engineering Criteria 2000. ABET Criterion 3 concentrated on program outcomes and assessment and included "an understanding of professional and ethical responsibility" among the general criteria for basic level programs in the undergraduate engineering curriculum.[5] ABET Criterion 4 also presents requirements for the professional component of engineering including ethical and social considerations. Smerdon offers the observation that Criteria 2000 may have more impact on engineering education in the United States than all the reports preceding it.[6]

III. Engineering Ethics Education

The focus of the new ABET Engineering Criteria 2000 on professional and social responsibility in conjunction with the media attention given to catastrophes such as the Challenger disaster, the Kansas City Hyatt-Regency Hotel walkways collapse, and the Exxon oil spill have resulted in an increased public awareness of engineering ethics. These two forces have contributed significantly to the current emphasis on ethics in engineering education. Injecting ethics education into an engineering curriculum can be accomplished in a variety of ways. The three prevalent methods are a freestanding course in engineering ethics, ethics taught across the engineering curriculum, and a multi-course ethics program offered through the liberal education departments.

The freestanding course is often a single semester course taught by the Philosophy Department of the institution. Several problems are associated with the freestanding course. Unless the required course is supplemented by further ethics instruction in mainstream engineering courses, students may be left with the impression that ethics is a sidebar rather than an integral part of their engineering studies.[7,8] In a single course there is rarely enough time for students to practice applying the ethical principles throughout a variety of situations.

The second method integrates ethics instruction into the engineering courses. When ethics are integrated across the engineering curriculum, each instructor is expected to include some ethics materials in their course. This is usually done by incorporating ethical components or modules into the course materials. Problems with this method may arise due to lack of coordination over the integration of the ethics across the curriculum (EATC).[7] But the majority of problems with EATC stem from three faculty objections.

The first of these objections concerns comfort level. Faculty are unprepared to teach material in which they've had no formal training. They are uncomfortable going from the traditional lecture style format in the classroom to a more open discussion format that ethical problem analysis requires. Second, faculty using this model have no ownership of the ethics content of their course; they do not see the relevance of ethics to their subject matter. Many assume that everyone is ethical and will know the appropriate thing to do in a given situation.[9] The final objection has to do with time constraints. It has been found that due to insufficient time and large class sizes, ethics was addressed in a superficial manner when directly integrated into classes, often inhibiting open discussion.[10]

The third method delegates ethics education to the liberal education departments. Engineering students attend multiple courses focused on theoretical and practical ethics. This model is based on the assumption that liberal education faculty are better equipped to facilitate ethics education. An excellent description of this method was given by Manion and Moshe.[11] While some of the liberal education departments contain ethicists and moral reasoning experts, the disadvantages here are similar to those associated with a free standing course. Namely, students may perceive ethics as unrelated to the engineering profession.

In response to the problems encountered with the freestanding course and the EATC methods, a two-stage model has been proposed for teaching ethics in engineering.[7,8,9,12] The two-stage model overcomes the shortfalls of the two methods most commonly used while incorporating the positive aspects of each.

The two-stage model consists of a general ethics foundation course followed by practical application through ethics across the curriculum. The foundation course is taught by the Philosophy (or equivalent) Department and focuses on application as well as theory. The outcome of the course is to provide a foundation in ethical theory along with the decision making tools to apply the theory to specific situations. This is accomplished by identifying moral problems and the stakeholders involved, analyzing the problems, and resolving problems in the context of the theories learned. This course "equip[s] students with the tools to recognize arguments based on different types of moral theories. The students also learn the strengths and weaknesses of the theories. As a result, when a student needs to convince a colleague that a particular course of action is right, she or he is in a better position to make a rational case."[13]

The second stage incorporates ethics across the engineering curriculum. It sets the tone at the top and takes advantage of the fact that many students look up to faculty as role models and mentors. When faculty throughout the engineering college integrate ethics into their courses, students see ethical issues as an important and integral part of engineering – it places ethics in the mainstream of engineering education.[14] This stage looks at environments where engineers make specific decisions applying engineering codes of ethics to issues such as safety, risk assessment, professionalism, conflicts of interest, threats to public health and safety or to the environment, trade secrets and proprietary information, gift giving and receipt, and honesty in research and testing.[15] The outcomes of this stage are to apply the theory and processes learned in the foundation course to a number of specific examples so students have an understanding of the place and importance of ethics in the engineering profession, an increased ethical sensitivity, increased knowledge of relevant standards of conduct, and improved ethical judgment.

Incorporating ethical decisions into the technical materials covered in the course enables students to see how abstract concepts can be applied to real world problems. Students need practice solving ethical problems first hand. While many engineering students discuss ethical case studies like the Space Shuttle Challenger incident or the Ford Pinto gas tank problem, most ethical issues faced in the real world are nothing of this magnitude. Most are more subtle, and engineering students need more practice in typical day-to-day experiences.[9]

IV. Case Methodology

Cases have been used in engineering education since the 1960s. Interest in cases as an instructional tool in engineering has fluctuated over the past few decades. In engineering courses the case method seemed to reappear during times of perceived crisis - that is, when course content didn't appear to correspond to industry needs. Cases are incorporated into engineering education for a variety of purposes. Many engineering cases present an ethical dilemma, technical oversight, or business issue, while others provide a design challenge. Although cases may be used throughout the engineering curriculum, there are several engineering arenas where cases are used more consistently than others. These include failure analysis, design, ethics, and technology management.[4]

Regardless of the discipline, case methodology as it is commonly defined began at the Harvard Business School in 1921.[16] Gragg's classic definition of a case, and the definitions and descriptions of case research are as applicable to the engineering sciences as they are to the various business disciplines.[17] The advantages of integrating cases are the same for engineering courses as they are for business courses.[18,19]

By common definition, a case is a written descriptive history of a real situation. Specifically, it is a written account of an event as it actually occurred with the key players in place. The case "commonly involves a decision or a problem. It is normally written from the viewpoint of the decision maker involved and allows the student to step figuratively into the shoes of the decision maker. The basis of each case is the fundamental fact that an actual person truly faced the situation described."[20]

The purpose of the case methodology is to bring reality into the classroom by providing students with real world problems that promote in-depth analysis and discussion. The ultimate goal of the case method is to train students to make effective decisions by recreating, as closely as possible in a classroom setting, the reality of situations.[21] In doing this, students gain both professional knowledge and experience in problem-solving skills.

The use of cases at the freshman and sophomore levels to introduce engineering concepts and to encourage students to continue in engineering has been increasing.[22,23] It has been found that the most popular tool in teaching engineering ethics is the case method.[24] This method focuses on ethics by presenting cases that deal with a wide range of ethical issues. The characteristics of the case method encourages students to identify ethical issues, formulate and justify decisions, and to express ethical opinions. The case methodology encouraged students to develop a sense of the practical context of ethics as well as enabling them to practice their problem solving skills.[25]

V. USAFA Engineering Ethics Education Model

Since its inception in 1955, the United States Air Force Academy (USAFA) has prioritized character development by giving it equal standing along with academic, athletic, and military excellence. A center devoted to character development was established to oversee all character

related issues including honor education as related to the USAFA Honor Code, Academy Character Enrichment Seminars, the National Character and Leadership Symposium, a Professional Mentorship Program, and Ethics Across the Curriculum. With the exception of EATC, most of the character development programs relate to general ethics training and the profession of arms.

A compulsory course on general ethics has always been part of the curriculum. This philosophy course presents the history and foundation of theoretical ethics. Students read, discuss, and analyze classic as well as contemporary ethics theory. The practical application of ethical principles is completed via in-class discussions and required papers. While this course is not focused on the application of ethics to engineering, students are well grounded in ethical theory and the general application of ethics in decision making.

In 1998 USAFA adopted the second piece of the two-stage model discussed in section III. The Ethics Across the Curriculum initiative stated that all academic courses need to incorporate ethics education into their curriculum. While no formal requirement exists, faculty are expected to "raise ethical issues with cadets and to address them forthrightly."[26] Ethics Across the Curriculum was integrated to alleviate the compartmentalization of ethics to philosophy and the profession of arms. The EATC initiative aims to expose the omnipresent nature of ethics since all academic disciplines require ethical sensitivity and moral reasoning. While the initiative met with some success, emphasis in many engineering curricula fell short of the program's expectations.

The principle challenge facing effective implementation of EATC is faculty development. Herkert states that the key to success of ethics across the curriculum instruction is "overcoming the resistance of engineering faculty to the importance of ethics instruction and demonstrating to them, through faculty development initiatives, how ethics material can be incorporated into their classes."[7] USAFA is implementing a three phase program to motivate, educate, and facilitate faculty incorporation of ethics into engineering courses. Motivating faculty to recognize and accept their roles as professionals is fundamental to EATC. Helping faculty adapt EATC into their courses eliminates most faculty concerns.

In order for any program to be successful, faculty must internalize professionalism and agree that ethics is an intrinsic component of engineering education. This ownership of EATC by faculty members is critical. During new instructor orientation at USAFA, ethics across the curriculum is presented to entering faculty. The briefing includes an overview, contextual motivation, and participatory expectations. The following excerpt from the orientation briefing provides the motivation for including EATC, "We hope to develop an appreciation for the fact that professionals are accountable for their judgment and to foster that judgment as a part of the Academy experience."[26] To further emphasize the relevance of ethics, faculty attend a one day "character enhancement" seminar. The seminar focuses on demonstrating the role of ethical sensitivity and moral reasoning in a variety of settings. In addition, ideas for initiating discussions on ethical issues with students are presented.

Next, faculty must be given a way to feel comfortable teaching ethics. An increased comfort level may be achieved through active learning workshops and by providing a blueprint for incorporating ethics into specific courses**.** Active learning workshops focus on alternatives to the standard lecture style paradigm which is inadequate for ethics education. Since many engineering faculty are uncomfortable with seminar style presentations, combining moral reasoning with classical engineering concepts leads to a systematic process for ethical decision making. Davis argues that "what an instructor needs is … one easy to use method for guiding discussion, focusing on reasons, and forcing judgment."[1] There are several step-by-step models readily available.[1,6,27] Whitbeck argues that the problem solving approach used in engineering design is a useful method for solving ethical problems.[27] At USAFA each academic department offers active learning workshops for new and returning faculty. To move faculty toward teaching ethics, interdepartmental seminars are planned in order to present the step-by-step models associated with solving ethical problems.

VI. USAFA Plan to Improve EATC

The final stage in the ethics across the curriculum process at USAFA will enable faculty to feel more comfortable while teaching ethics. In order to reduce the workload of incorporating ethics education into an engineering course, pre-established case packages will be made available to faculty. Case packages will consist of thee parts. The first part will be the case itself, the second part will be the associated teaching note, and the third part will contain ideas for effectively integrating the case into a class. The first will be the case itself. The second will be the associated teaching note, including objectives, possible uses of the case, and relevant questions relating directly to the case. The teaching note will also contain a brief discussion of possible solutions to the questions. Good engineering cases with integrated teaching notes are currently difficult to locate in the literature. Appendix A lists a variety of web sites that contain information on engineering cases and case research.

The third part of the case package will contain ideas for effectively integrating the case into a class. To meet the primary goals for ethics education, additional questions will be included with each case to help spark thoughtful discussions among students and between students and faculty. An integrated copy of engineering codes of ethics will give a baseline for discussions and decision making. Another piece of the package will be a framework for written assignments. These can vary in scope and magnitude to fit the needs of individual instructors. To help new engineering faculty become comfortable managing open discussions during class, their colleagues from the Philosophy department have generously volunteered to facilitate student discussions.

The collection of complete case packages will continually evolve. There is no prescribed method for locating excellent cases, so the process will rely heavily on faculty feedback. The personnel responsible for compiling and maintaining case packages will incorporate individual faculty feedback to continually improve the packages. Since few existing engineering ethics cases include a complete teaching note, much of the maintenance will be aimed at improving the question and answer portions of the case packages.

The use of ethics cases meets the outcomes suggested by Koehn: 1) an increased awareness of ethical theories, public concerns, and potential conflicts; 2) a greater familiarity with codes of conduct; 3) an appreciation for the frequency with which ethical dilemmas are encountered by engineers in their work experience; 4) a heightened ability to recognize ethical dilemmas; 5) a better understanding of one's own values; and 6) an enhanced ability to resolve ethical dilemmas by applying traditional engineering inquiry methods of getting facts, listing options, testing the options, making a decision, and acting.[28] By targeting these outcomes, the ethics and social responsibility emphasis in ABET Criteria 3 and 4 can be successfully addressed.

VII. Conclusion

Many engineering colleges and universities across the nation have placed increased emphasis on ethics in their curriculums. While some have created a new course in engineering ethics, others have revised their curriculum to introduce ethical issues in a number of required undergraduate engineering courses. Still others have created a comprehensive ethics curriculum provided by the liberal education departments. Independent of method the goal is to provide students with "the understanding that being professional engineers requires not only technical expertise, but also insight into their social and professional roles."[29]

A two-stage model has been proposed since students need to develop a foundation based on ethical theory and moral reasoning. They need to learn how to recognize ethical problems. They need to be given the decision-making tools and use the tools to practice ethical decision making through examples. "Ethics needs to be engrained into the minds of the students so that their thinking process comes as naturally as breathing. The way this can happen is through constant exposure and practice and the best way to do this is through integrating ethics throughout the curriculum."[9]

Bridging the gap between a plan for engineering ethics education and implementing the plan effectively is all that remains for many colleges and universities. For those who adopted EATC, cases provide an excellent tool. Incorporated into self-contained packages, cases offer a structured framework for effectively implementing ethics across the curriculum. Motivated faculty can be encouraged to merge ethics into the curriculum via case packages with only a slight increase in workload.

Appendix A: Information Sources for Cases and Case Research

The primary source for engineering cases is the Engineering Case Library. The Engineering Case Program, begun at Stanford University in 1964, continues under ASEE sponsorship and the Rose-Hulman Institute of Technology in Indiana. These organizations jointly administer the ASEE Case Program. The Engineering Case Library is located at Rose-Hulman, and a catalog of cases, as well as hard copies of the cases, may be obtained from them.

For convenience of access a hypertext version of the catalog was developed by the Department of Civil and Environmental Engineering at Carleton University. A classification of cases by disciplines, areas and suggested assignments allows professors to search for relevant case abstracts. The Engineering Case Library web site (www.civeng.carleton.ca/ECL) contains references to over 250 engineering cases as well as to selected papers on engineering cases and two engineering case books.

There are several other excellent web sites for engineering cases. Two Texas universities have taken a leadership role in engineering ethics. The National Institute for Engineering Ethics (NIEE) is an independent organization housed at the Murdough Center for Engineering Professionalism at the College of Engineering, Texas Tech University. Texas A & M University has been a leader in using the case methodology in the engineering ethics classroom. Both university web sites on engineering ethics, www.niee.org/cases/main.htm and http://ethics.tamu.edu/otherethicslinks.htm, contain links to a number of sources for engineering codes of ethics and cases.

The Online Ethics Center for Engineering and Science at Case Western Reserve University web site contains links to many engineering cases (wysiwyg://107http://onlineethics.org/eng/cases). The Web Clearinghouse for Engineering and Computing Ethics site contains links to a number of engineering case collections (http://www4.ncsu.edu/~jherkert/ethicind.html).

There has also been an increase in the number of papers presented at engineering conferences dealing with cases in all areas of engineering and the use of these cases in the engineering classroom. The largest of the engineering education conferences is the ASEE annual meeting. The ASEE web site (www.asee.org) allows access to papers presented at the annual conferences from 1996 through 2002. A search on the term “cases” produced references to hundreds of conference papers dealing with this topic.

Papers on case research have also been presented at conferences of the American Institute of Aeronautics and Astronautics (www.aiaa.org/Research/index.hfm) and the American Society of Mechanical Engineers (www.asme.org). The Frontiers in Education (FIE) Clearing House web site (http://fie.engmg.pitt.edu) contains links to engineering education sites and professional organizations. A search of these links produced many references to both cases and the use of cases in engineering education.

References

1 Davis, Michael (1999). "Teaching Ethics Across the Engineering Curriculum." Paper available at http://onlineethics.org/essays/education/davis.html 11/18/2002.

2 Prados, John (1998). "Engineering Education in the U.S.-Past, Present, and Future," *ICEE 1998*, Rio de Janeiro, Brazil, August 17-20.

3 Ernst, Edward (1998). "Review of Reports, Studies and Conferences on Engineering Education 1981-1997," *Proceedings of the Engineering Found. Conference*, June 3-6.

4 Richards, L.G., Gorman, M., Scherer, W.T., and Landel, R.D. (1995). "Promoting Active Learning with Cases and Instructional Modules," *Journal of Engineering Education*, October.

5 ABET. "Engineering Criteria 2000," 3rd Edition., Engineering Accreditation Commission of ABET, Inc., Baltimore, MD, 1998, available at http://www.abet.org/eac/EAC_99-00_Criteria.htm#EC2000

6 Smerdon, Ernest (2000). "An Action Agenda for Engineering Curriculum Innovation." Presented at the 11th IEEE-USA Biennial Careers Conference, November 2-3, San Jose, CA

7 Herkert, Joseph R (2002). "Engineering Ethics Education Finally Reaches 'Critical Mass'." At http://www.spectrum.ieee.org/INST/dec97/ehtics.html.

8 Frey, William J., Sanchez, Halley D., and Cruz, Jose A. (2002). "Ethics Across the Curriculum: An Effective Response to ABET 2000," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition: Session 0461.*

9 Jakubowski, Gerld S. (2002). "Integrating Ethics into the Engineering Curriculum." Keynote address at the Ethics and Social Responsibility in Engineering and Technology Conference sponsored by Gonzaga University, May 23-24, Coeur d'Alene, ID.

10 Lam, Margaretha, J. (2001). "Ethics Workshop Through LEAP," *Proceedings of the 31st ASEE/IEEE Frontiers in Education Conference.*

11 Manion, Mark and Moshe, Kam (2000). "Engineering Ethics at Drexel University," *Proceedings of the 2000 American Society for Engineering Education Annual Conference & Exposition: Session 2561.*

12 Haws, D.R. (2001). "Ethics Instruction in Engineering Education: A (Mini) Meta-Analysis," *ASEE Journal of Engineering Education*, 90:2, 223-229.

13 Bernhardt, K. L. S., Roth, M. J. S., Brandes, D., and Kney, A. D. (2002). "Engineering Ethics: Teaching Moral Theories to Engineers," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition.*

14 Herkert, Joseph R. (2002). "Continuing and Emerging Issues in Engineering Ethics Education," *The Bridge*, vol. 32, no. 3, Fall 2002.

15 "ASEE Statement on Engineering Ethics Education." Available at http://www.asee.org/welcome/statements/ethics.cfm.

16 Christensen, R. (1997). *Teaching and the Case Method*. Harvard University, Cambridge, MA.

17 Gragg, Charles I. (1940). "Because Wisdom Can't be Told," *Harvard Alumni Bulletin*, October 19.

18 Barrott, J.L. (2001). "Why Should Cases be Integrated into the Engineering Technology Curriculum?" *Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition:* Session 35650.

19 Henderson, J.M., Bellman, L.E., and Furman, B.J. (1983). "A Case for Teaching Engineering with Cases," *Engineering Education*, January.

20 Erskine, J.A. and Leenders, M.R. (1989). *Case Research: The Case Writing Process*. London, Canada: Research and Publications Division, School of Business Administration, University of Western Ontario.

21 Little, Cinny (1993). "The Boardroom Comes to the Classroom," *Women's Review of Books*, 10(5), 27.

22 Morgan, J., Rinehart, J., and Froyd, J. (2001). "Industry Case Studies at Texas A & M University," *Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition: Session 3553.*

23 Birge, J., Henderson, S., and Olsen, L. (1997). "Improving Quality in Introductory Industrial Engineering through Case Studies and Communication," *Proceedings of the 1997 American Society for Engineering Education Annual Conference: Session 3657.*

24 Harris, C., Jr., Prichard., M. and Rabins, M. (2000). *Engineering Ethics: Concepts and Cases, 2nd Edition*. Belmont, CA: Wadsworth.

25 Davis, Michael (1999). *Ethics and the University*. London: Routledge.

26 Casebeer, William (2002). Faculty Orientation: Ethics Across the Curriculum, USAFA, July.

27 Whitbeck, C. (1998). *Ethics in Engineering Practice and Research*. Cambridge, U.K.: Cambridge University Press.

28 Koehn, E. (2002). "Ethical Issues Confronting Students and Practitioners," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition: Session 2406.*

29 Soudek, Ingrid (1999). "Turning Belief Into Action: Aims of Teaching Engineering Ethics," *Proceedings of the 1999 American Society for Engineering Education Annual Conference & Exposition: Session 1661.*