AC 2009-976: THE CASE-STUDY APPROACH TO ENGINEERING ETHICS

William Loendorf, Eastern Washington University

William R. Loendorf is currently an Associate Professor of Engineering & Design at Eastern Washington University. He obtained his B.Sc. in Engineering Science at the University of Wisconsin - Parkside, M.S. in Electrical Engineering at Colorado State University, M.B.A. at the Lake Forest Graduate School of Management, and Ph.D. in Engineering Management at Walden University. He holds a Professional Engineer license and has 30 years of industrial experience as an Engineer or Engineering Manager at General Motors, Cadnetix, and Motorola. His interests include engineering management, real-time embedded systems, and digital signal processing.

Case Study Approach to Engineering Ethics

Abstract

Engineers are routinely called upon to make decisions that affect the users of the products they design, develop, and manufacture. The desired outcome is to produce a product that is without defects and safe for the public to use. However, the potential impact could be very harmful if the wrong decisions are made. The technical aspects behind these decisions are studied in detail as an integral part of the engineer's undergraduate curriculum. This training is of substantial benefit for many problems, often resulting in a straightforward solution. Nevertheless, this preparation alone may not be enough to resolve all issues. Frequently the problems encountered are in a gray area, without clear-cut answers, requiring engineers to use their best judgment for solution. These types of problems are commonly referred to as ethical challenges. Unfortunately problems of this nature are often handled with little formal training or guidance leading to improper or detrimental results. In order to better prepare our students to practice engineering with integrity and honesty a case study approach to engineering ethics has been implemented. It begins with a reflective look at the type of decisions engineers make, professional obligations, codes of ethical conduct, and contemporary issues. This is followed by class discussions of real world case studies applying this knowledge. Then two assessment methods are used to determine the students understanding of engineering ethics, an in-depth essay exploring two case studies and a written examination evaluating four case studies. During the last academic year, over 200 students from six classes have participated in this program. The results from the essays and examinations indicate that students have a fundamental foundation, from which they can build a better understanding, of how to handle real world ethical engineering challenges.

Introduction

Engineers make numerous decisions every day that affect the products they design and the people that will ultimately use them. Many of these choices are of a technical nature and the engineer's academic training has primed them for their resolution. However, others are of a moral or ethical sort without an apparent answer and academic training may not have adequately prepared new engineers for their solution. Little of the undergraduate engineering experience is devoted to the potential moral, social, political, and economic issues they may encounter. Instead, they focus on the mathematics, physics, and engineering aspects of problem solving. Thus leaving a void in their preparation that should be addressed.

The organization responsible for accrediting American undergraduate Engineering and Engineering Technology programs has recognized this need. As a result the Engineering Accreditation Commission (EAC) and Technology Accreditation Commission (TAC) of ABET, Inc.[1] has mandated that undergraduate engineering curricula include the study of ethics. This is a precautionary approach requiring students to think in ethical terms at all times and not just when things go wrong. It could be viewed as defensive ethics by training students how to respond to possible events and anticipate the consequences of their actions. Many ethical lessons are unfortunately learned during an engineer's career only after some unforeseen consequence or

unnoticed flaw. The intent is to educate and guide students through ethical issues they are likely to encounter in real world engineering situations.

The way students are exposed to engineering ethics varies from institution to institution. At Eastern Washington University (EWU), two main approaches are used. One uses the National Society of Professional Engineers' (NSPE) Ethics Exam[2] as an assessment tool (Durfee & Loendorf[3], 2008). While the other extensively utilizes case studies and is the focus of this paper. By combining these two modes of instruction, the students receive a varied and diverse exposure to engineering ethics.

Background

A variety of definitions for case study research exist but generally they fall into two basic versions. First, "a case study is an exploration of a 'bounded system' or a case (or multiple cases) over time through detailed, in-depth data collection involving multiple sources of information rich in context. This … system is bounded by time and place" (Creswell[4], 1998, p. 61). Second, a case study is "a method used to study an individual or an institution in a unique setting or situation in as intense and as detailed a manner as possible" (Salkind[5], 2006, p. 205). Both definitions stress the capturing of detailed data about individuals, events, and programs in particular situations with the hope of generalizing the results. This methodology may also be utilized to gain insight into little known or perhaps poorly understood events and examining how things change over time.

Case study research excels at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Case studies have been used for decades in law, business, and engineering schools with great success. Perhaps the reason for this can be traced to the scenarios studied, since they are likely to be encountered during a professionals' career. This same approach has been applied to ethical inquiry. By using real or realistic cases, engineering ethics comes to life and students appreciate and understand the importance of their decisions. They become part of the solution. This is opposed to starting with theories and later considering how they might be applied to real situations. Rather reviewing cases leads to theoretical solutions. This approach has been incorporated into engineering ethics texts by Baura[6] (2006); Pinkus, Shuman, Hummon, and Wolfe[7] (1997); Whitbeck[8] (1998); Martin and Schinzinger[9] (2005); and others.

One approach to reviewing engineering ethics case studies in the classroom incorporates active learning exercises. Active learning encompasses techniques that engage and connect students within the subject matter they are studying (Crawford, Saul, Mathews, & Makinster[10], 2005). This can be accomplished through discussion, interaction, application, demonstration, or knowledge as stated by Allen[11] (2002) and Tileston[12] (2007). Each of these instructional methods builds on the others to reinforce and broaden the student's perspective and exposure to engineering ethics. Real world ethical problems and issues taken directly from real world engineering situations are reviewed, analyzed, and critiqued. The case studies utilized range from the well known to the obscure. However, each emphasizes the level of trust and confidence placed on the engineering profession by society.

It is interesting to note that a single standard system of ethical conduct covering all of the engineering professions does not exist. Rather ethical approaches vary by discipline, jurisdiction, and type of employment. However, the National Society of Professional Engineers (NSPE) represents engineers from all disciplines and has developed a comprehensive code of ethics[13] covering professional obligations and rules of practice. Other professional societies have codes of ethics that are more specific to their particular discipline. Among them are the American Society of Mechanical Engineers[14] (ASME), the Institute of Electrical and Electronic Engineers[15] (IEEE), the Society of Manufacturing Engineers[16] (SME), along with many others.

All of these codes of professional ethics have been incorporated into the material covered by courses in the Engineering and Engineering Technology curriculum. Programs are offered in Electrical Engineering, Computer Engineering Technology, Mechanical Engineering Technology, Manufacturing, Design, and Construction Management. Such a variety of programs requires a good overall view of engineering ethics. Of particular interest for this paper is a junior level course, required for all of those majors, that has an entire learning module dedicated to engineering ethics where codes of ethics are examined, case studies are discussed, case study essays written, and a case study examination administered. Specific aspects of ethical behavior corresponding to the course objectives and outcomes are studied, analyzed, and critiqued.

These codes of ethics function as guides providing frameworks for judgment while assisting in resolving ethical issues. These codes for maintaining proper engineering conduct should be considered as a starting point that requires additional thought and reflection in order to reach an ethical decision. All of the potential scenarios encountered by practicing engineers could never be covered in one code of ethics. They are principles and standards to follow and not a cookbook solution outlining steps to resolve every ethical situation.

Methodology

A junior level course was developed a number of years ago titled Technology in World Civilization (Loendorf[17], 2004) that was designed to broaden the students' perspective of past technologies and how they were discovered and used. The main objectives of the course were to: (a) promote awareness of technological development, and (b) provide a rudimentary understanding of their social, political, economic, and cultural impact. Three years ago, a learning module was added to this course focusing on engineering ethics. It evolved over time into a case study approach consisting of code of ethics lectures, case study discussions, case study written essays, and a case study ethics examination.

The learning module begins with a reflective look at the type of decisions engineers make, professional obligations, codes of ethical conduct, and contemporary issues. A variety of handouts were created to accompany the lectures and emphasize each of the key areas of engineering ethics. The topics covered were divided into two categories: personal ethics and professional ethics. The personal ethics[6,18,19] topics included What Are Personal Ethics, The Five cornerstones of Ethical Behavior, and The Top Ten Questions You Should Ask Yourself When Making an Ethical Decision. The professional ethics[9,20,21,22,23] topics include What are Professional Ethics, Core Concepts in Engineering Ethics, the National Society of Professional

Engineers (NSPE) Code of Ethics[13], Guidelines for Facilitating Solutions to Ethical Dilemmas in Professional Practice[24], and Nine Basic Steps to Personal Ethical Decision Making[24].

The case studies selected for analysis, review, and discussion were obtained from a variety of sources. A number of them were derived from engineering websites[24,25,26,27,28], engineering ethics textbooks[6,9,18,19], Fundamentals of Engineering Examination Review Manuals[21,22], and newspaper articles. Additional case studies were developed from the author's 30 years of engineering and engineering management experience detailing actual cases encountered during the practice of engineering. The engineering ethics case studies for the essay and examination were obtained from the library of cases compiled by the National Society of Professional Engineers Board of Ethical Review available from the National Institute for Engineering Ethics[24] (NIEE) website. These selections were made after an extensive review process, by a group of engineering and engineering technology faculty members, and judged to be suitable, representative, and appropriate.

The next phase involved class discussions of real world case studies applying the ethical knowledge and decision-making process along with a team exercise. The students in the class were divided into teams and assigned a variety of case studies to review, analyze, and critique. These cases were derived from the large database of engineering ethics case studies available from the National Institute for Engineering Ethics[24] (NIEE), the Center for Ethics in Science and Technology[25], and excellent university engineering ethics websites[26,27,28]. Each team then presented their solutions to the class and opened the floor for discussion. The case studies used were by design typical of real engineering dilemmas and did not have a clear-cut solution. Lively debates followed and occasionally a unanimous solution could not be reached, much like in many real life ethical situations. Finally, additional case studies were addressed as a class to complete this phase of the exercise.

Two assessment methods were used to determine the students understanding of engineering ethics. Both of the methods involved engineering case studies. First, each student working independently submitted an in-depth essay exploring the same two case studies. This was followed by a second method, an in class written examination evaluating four case studies.

The two case studies assigned for the essay were relatively complex with no obvious or easy solutions. The ethical situations were described and the students asked to resolve the issues. Both of these case studies were derived from the National Society of Professional Engineering (NSPE) Board of Ethical Review Cases available from the National Institute for Engineering Ethics[24] (NIEE) website. The first case was Case 92-6 Public Welfare - Hazardous Waste. It involved the discovery of drums filled with potentially hazardous waste and the informing of the client along with how the drums should be properly disposed of. The second case was Case 89-7 Duty to Report Safety Violations. This case addressed the structural integrity of an old building with electrical and mechanical deficiencies and how they were reported.

The essay could not exceed two pages, single spaced, for each case study. The students were required to not only state the solution but back up their decisions by building a strong case in its favor. This required research into solution methods, codes of ethics, and other avenues. The students were given a week to complete the assignment. After grading, the essays were returned

to the students and the two case studies discussed in detail during class time. A grading metric was developed allocating percentages of the final grade to four key areas: content (30%), clarity of thought and expression (30%), supporting materials and argument (30%), and proof reading and grammar (10%). The students were informed of this grading metric when the essays were assigned and the metric was written on the assignment handout.

The second assessment method utilized a written case study ethics examination. Four case studies were provided along with six possible solutions for each one (multiple choice). Once again, the four case studies were derived from the National Society of Professional Engineering (NSPE) Board of Ethical Review Cases available from the National Institute for Engineering Ethics[24] (NIEE) website. The first case was Case 91-7 Product Specification. It addressed the issue of a product not performing according to the client's expectation. The second case was Case 00-5 Public Welfare – Bridge Structure. This case examined a bridge that required repairs for safety reasons but remained open for public use. The third case was Case 82-5 Whistleblowing. It concerned the material provided by a subcontractor to a government defense contractor and its adequacy and acceptability. The fourth case was Case 81-4 Gifts to Engineers. This involved gifts of substantial value from contractors and suppliers that were given to engineers of a consulting company that did an extensive amount of work for them.

The students were to pick the most ethical solution and then justify why that solution was selected. Blank lines were inserted on the examinations immediately prior to the six multiple choice answers for the justification. Each of the four case study scenarios was contained on a separate page of the assessment. The examination was closed book and closed notes. The correct multiple choice solution was worth 15 points and the corresponding justification 10 points or 25 points per case study. The exams were then collected and graded. During the next class period, the exams were returned and the solutions to all four case studies discussed. This completed the assessment cycle.

Results

During the 2007 - 2008 Academic Year 212 students from six Technology in World Civilization Classes participated in this engineering ethics study. The same Professor (the author) taught all six courses with essentially the same content. Measures were taken to insure that the courses were as similar as possible for this engineering ethics study. All six classes had an enrollment of 30 or more students and contained students from every major offered in the Engineering & Design Department.

The results of the case study ethics essay assessment are presented in Table 1. Each essay was worth a maximum of 100 points and the class average displayed along with the highest and lowest scores. During each Quarter, Section 01 was offered at 9 AM and Section 02 at 10 AM. In almost every Quarter, slightly better essay grades were obtained from the 10 AM classes.

The average grades by class over the academic year for both Essay #1 and Essay #2 were in the 80s. The overall average grades for all Sections and both Essays neared the mid-80s. In almost every instance, the correct solution to the case study was described. The justifications were graded based on the discussions related to the cases as posted on the National Society of

Professional Engineering (NSPE) Board of Ethical Review Cases available from the National Institute for Engineering Ethics[24] (NIEE) website. However, the supporting argument from many of the students was less than satisfactory affecting their grade. The foundation behind their decision was insufficiently presented to adequately support their argument. The "why" discussion required to back up the resolution to the scenarios was minimal and superficial. This omission detracted rather than enhanced some of the essays.

Table 1
Results of the Case Study Ethics Essays

Academic Quarter	Number of Students	Essay #1 Average Grade	Essay #1 Highest Grade	Essay #1 Lowest Grade	Essay #2 Average Grade	Essay #2 Highest Grade	Essay #2 Lowest Grade
Fall 2007 Section 01	39	82	96	72	80	98	74
Fall 2007 Section 02	35	85	98	76	81	100	76
Winter 2008 Section 01	30	84	96	74	83	96	72
Winter 2008 Section 02	33	86	100	70	82	98	72
Spring 2008 Section 001	36	85	96	72	84	96	70
Spring 2008 Section 002	39	87	98	74	86	100	72
Total Students	212						
Average Grade		84.8			82.7		

Some individual student essay grades were lower than expected. This was, in part, due to the selection of an incorrect or inappropriate resolution. Even with the two case studies in the gray area and no clear-cut answer, proper solution could have been attained with further reflection and examination. It appeared as if some students "rushed to judgment" and selected an answer and then tried to justify it. Rather than reversing the solution process by justifying the response and then selecting the appropriate one. This was also echoed in their weak supporting arguments.

Other students excelled by quoting codes of ethics, core concepts in engineering ethics, and elaborately building supporting evidence. Once this foundation was established, the resolution to the case study was presented. In many instances, after the completion of their argument the solution was rather straightforward. They had analyzed the problem and followed the steps required to resolve it.

The findings from the case study ethics examination assessment are shown in Table 2. The number of students from each Section that identified the most ethically correct solution for one, two, three, or all four of the case studies is indicated. The results reflect only the number of suitable solutions and not the supporting justifications behind the decision. In almost every case, when the student identified the incorrect resolution to the scenario, their justification backing up the decision was also faulty.

Table 2
Results of the Case Study Ethics Examinations

Academic Quarter	Number of Students	All 4 Case Studies Correct	3 of the 4 Case Studies Correct	2 of the 4 Case Studies Correct	1 of the 4 Case Studies Correct	None of the 4 Case Studies Correct
Fall 2007 Section 01	39	17	17	4	1	0
Fall 2007 Section 02	35	10	19	4	2	0
Winter 2008 Section 01	30	17	8	5	0	0
Winter 2008 Section 02	33	10	16	7	0	0
Spring 2008 Section 001	36	14	15	7	0	0
Spring 2008 Section 002	39	18	11	8	2	0
Examination Totals	212	86	86	35	5	0
Examination Percentages		40.6	40.6	16.5	2.3	0.0

The majority of the students determined the correct solution for three or more of the case studies. None of the students from any class selected the incorrect answer for all four case studies. After examining the student responses to the case studies that were incorrectly answered, no pattern was evident. That is, no one case was any more difficult to resolve than any of the others. However in most cases, when a faulty resolution to the scenario was selected an improper justification accompanied it. This finding was also uncovered earlier with the essay assessment.

Approximately 41% of all the students participating in this study identified the most ethically correct resolution to all four of the case studies. Another almost 41% selected the proper solution in three of the four case studies. Together the vast majority or over 81% of the students resolved the scenario ethically in three or more of the case studies. The findings indicate some awareness of the right or ethical answer to difficult real world engineering situations.

Well over 16% of the students incorrectly solved two of the four case studies indicating only a 50% success rate. Another group greater than 2% only answered one of the four case studies correctly reflecting a 75% failure rate. Together almost 19% of the students selected an erroneous solution in two or more of the case studies. These results illustrate the need for further training in engineering ethics throughout the students' undergraduate education.

The results from the essays and examinations indicate that students have some knowledge and capabilities to handle real world ethical engineering challenges. However, more training and preparation is required. Many students still struggle trying to determine the most ethical way to solve an engineering problem often resulting in a less than acceptable solution.

Lessons Learned

After incorporating a learning module focusing on engineering ethics into the Technology in World Civilization course numerous lessons have been learned. As a consequence, many of them have been directly incorporated into the learning module. The result has been an enhanced approach to engineering ethics utilizing case studies resulting in an improved awareness of both the problems and their resolution for the students.

The case study approach to engineering ethics is very effective and generates interest in the students. They become actively involved in the process to determine the best overall solution to challenging problems. Mathematics and science alone cannot solve these types of problems, it requires judgment and only through experience can this be acquired. Case studies fit into this scenario perfectly.

Students require a better understanding of the principles and practices that serve as a foundation for all ethical decision making. Once these are firmly entrenched in the students' mind, they become the basis for all solutions to ethical dilemmas and predicaments. As this study discovered, many students are not well enough prepared to encounter real world engineering challenges. Additional training and exercises are being planned to improve this aspect of their engineering ethics education.

This study also revealed that many students still make poor ethical decisions. This finding alone indicates that more work needs to be done. The earlier and more frequently a student becomes exposed to engineering ethics, the better prepared they will be to meet the challenges of the real world upon graduation. A single learning module incorporated into one course cannot accomplish this. It takes repetitive exposures from a variety of engineering courses to accomplish this objective.

Conclusions, Recommendations, and the Future

The use of a case study approach to engineering ethics has increased the student’s awareness and understanding of moral solutions and their social, political, economic and cultural impact on society. Case studies offer the opportunity to review, analyze, and even critique ethical solutions to engineering problems likely to be encountered by professionals during their career. The use of

assessment methods utilizing case study essays and examinations gave an accurate evaluation and appraisal of the students' ethical preparation and judgment.

Reflecting back on the case study approach to engineering ethics leads to a few recommendations. Allow ample time to cover all of the base material including professional obligations, codes of ethical conduct, and the steps required to facilitate ethical issues. Review a variety of case studies covering a wide range of situations and scenarios. Keep the material dynamic and encourage debate and discussion. Avoid the obstacles of boredom and monotony.

The future makeup of the ethics learning module will continue to change and evolve. This is as it should be since technology is changing at a rapidly accelerating pace along with its influence on society leading to even more demanding ethical dilemmas. By using case studies, engineering students can be informed and prepared for the ethical challenges that accompany technology's influences on society.

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