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TEACHING ENGINEERING ETHICS IN A MULTI-DISCIPLINARY ENVIRONMENT

Abstract

Most engineering faculty will agree that student engineers need a strong foundation in engineering ethics. Incorporating professional ethics into an already crowded engineering curriculum can be difficult. The engineering faculty at the United States Coast Guard Academy (USCGA) have implemented a multi-disciplinary approach to teaching ethics outside of the classroom environment. Our "Engineering Ethics Lunches" bring students and faculty from all four engineering disciplines: Electrical, Civil, Mechanical and Naval Architecture/Marine Engineering together in small groups to discuss ethics as they uniquely apply to the engineering discipline.

Historically, ethics instruction at USCGA has been based upon a core "Morals and Ethics" course taken by all students, regardless of major. While this course provides the students with a good foundation in classical ethics theory, it did not include "engineering ethics". Specific instruction on engineering ethics was left to the instructors of each major's senior design capstone course. However, depending upon the knowledge, interest or even class time available to the individual faculty members, this instruction was inconsistent and varied each year.

Starting in the 2006-2007 academic year, in an effort to improve upon and formalize ethics instruction for all engineering students, the four instructors of each major's senior design capstone project began holding multi-disciplinary "Engineering Ethics Lunches". Students and faculty form small groups during scheduled lunches to discuss specific ethical topics related to the engineering profession. The discussions are based upon assigned readings and suggested talking points developed jointly by the faculty. Afterwards, the students are required to submit essays reviewing their discussions and answering an ethical question based upon the topic.

Now in its fourth semester, the multi-disciplinary ethics lunches have received overwhelmingly positive feedback from both the instructors and students. This paper will discuss the format of the multi-disciplinary ethics discussions, the type of topics covered and the authors' efforts to develop a handbook to reduce the preparation required for future lunches. The paper will also review the advantages of these lunches, including reduced workload for instructors and the integration of ethics into the curriculum without displacing discipline-specific engineering topics.

Introduction

Most engineering faculty will agree that student engineers need a strong foundation in engineering ethics. Even if there is disagreement, criterion 3f of ABET's accreditation requirement, which states that engineering programs must demonstrate that their students possess "an understanding of professional and ethical responsibility"[1], ensures that engineering programs will devote time to teaching engineering ethics. However, incorporating professional ethics into an already crowded engineering curriculum can be

difficult. Adding an additional course on "Engineering Ethics" may be an option at larger universities, but at smaller colleges there may not be the available faculty resources or availability within the student's schedule.

Ethics instruction at the United States Coast Guard Academy (USCGA) has been based upon a general education "Morals and Ethics" course taken by all students, regardless of major. This course provides the students with a good foundation in classical ethics theory; but, since it is taken by all students, it does not include "engineering ethics" topics. To meet the ABET criterion, the students in the Academy's four engineering disciplines: Electrical, Civil, Mechanical and Naval Architecture/Marine Engineering had to receive additional instruction on "engineering ethics" somewhere else in the curriculum. The solution for the past several years was to include engineering ethics as a topic within each major's senior design capstone course. However, depending upon the knowledge, interest or even class time available to the individual faculty members, this instruction was inconsistent and varied each year.

Starting in the 2006-2007 academic year, in an effort to improve upon and formalize ethics instruction for all engineering students, the four instructors of the senior design capstone courses began holding multi-disciplinary "Engineering Ethics Lunches". The premise was to have students and faculty form small groups during scheduled lunches to discuss specific ethical topics related to the engineering profession. Since the students have completed a full semester course on ethical theory, these ethical discussions ask the students to apply the theory by focusing on case studies that require them to think about the choices they would make in a given situation. Each lunch featured a different topic related to "engineering ethics" such as "Sustainable Development", "Codes of Ethics" and "Ethics of Global Development". Each topic had associated readings and suggested talking points to help facilitate the discussions. Afterwards, the students are required to submit essays reviewing their discussions and answering an ethical question based upon the topic.

Now entering their fourth semester, these lunches have proven very popular both with the students and the faculty. The topics are ones that students are interested in and promote lively discussions. Faculty involvement has also been very high, including significant participation from faculty not even directly involved with the classes. These luncheons provide the opportunity for faculty and student interaction outside of a formal classroom environment. They also allow for interaction amongst students of different engineering majors and provide varied view points.

After a brief overview of the USCGA, this paper will discuss how the multi-disciplinary ethics discussions began and their format. The paper will also review the advantages of these lunches, including reduced workload for instructors and the integration of ethics into the curriculum without displacing discipline-specific engineering topics. Finally, possible applications of USCGA's experience to other programs are discussed.

Background

The USCGA is one of four federal service academies and as such is focused on the academic, military and physical development of young men and women as leaders in service to our nation. USCGA provides the U. S. Coast Guard (USCG) with approximately 190 new Coast Guard officers each year. Upon graduation from USCGA, each graduate receives a commission as an Ensign in the Coast Guard and a Bachelors of Science in one of eight fields, four engineering majors: Civil; Electrical; Mechanical; Naval Architecture and Marine Engineering; and four non-engineering majors: Operations Research and Computer Analysis; Marine and Environmental Science; Management and Government.

The three-credit "Morals and Ethics" class has been a general education course at USCGA since 1992 and is required of all majors. Depending upon the major, it is taken by students during either the Junior or Senior year. The "Morals and Ethics" course covers basic classical ethical theories as the purpose is to examine the "…range of philosophical views on what makes our actions right or wrong and our characters good or bad."[2] Discussion of engineering ethics is not only beyond the scope of the course, but it would not be appropriate as a majority of the course's students are not engineers.

To meet ABET criterion 3f, each engineering major has found it necessary to supplement this classical ethics theory with additional instruction on professional ethics. In the past, this instruction was usually accomplished during several lectures within each major's senior capstone design course. Typically the lesson plans were discussions focused on the Code of Ethics associated with each major's professional society and the National Society of Professional Engineers. However, depending upon the knowledge, interest or even class time available to the individual faculty members, the quality of the ethics module(s) varied greatly. Hence, it was evident that improvements could be made to the engineering ethics teaching strategy.

Genesis of the Multi-Disciplinary Ethics Lunches

During the Fall 2006 Semester, the Electrical Engineering (EE) Senior Design class had a very animated discussion about the list of "Ethical Priorities" found in Michael Lindeburg's *FE Review Manual*[3]. After the class, the course's two instructors discussed how popular the ethics topic seemed to be with the students and looked for ways to build upon that enthusiasm in the future. It was proposed to have small, voluntary, "round-table" discussions between students and faculty to continue the dialogue related to engineering ethics.. Based upon positive student and faculty reaction, the idea was moved forward.

The first question was when to hold the discussions. Due to the military environment at USCGA and the curricular burden of an engineering education, engineering students' schedules are very regimented and have only a handful of randomly scheduled free hours each week. Conveniently all students are required to eat a scheduled lunch, usually in the Academy's dining hall. It is easy for faculty to submit excusals to have the students

eat their lunches in academic buildings for the purpose of faculty or student meetings. As such, it was decided to hold the ethics discussions during the lunch "period".

The next step was to develop potential discussion topics. The book "*Ethics in Engineering*" by Mike Martin and Roland Schinzinger[4] became the primary source for developing the initial topics for the lunches. The EE instructors also approached the "Morals and Ethics" faculty and asked for their assistance in developing the sessions. Both "Morals and Ethics" instructors were very supportive in helping to develop the topics and providing a level of review to make sure the ethical considerations embedded in engineering scenarios were accurate. In addition both "Morals & Ethics" instructors participated in the group discussions, providing a source of classical ethics expertise.

Approximately five potential topics were developed and the senior EE cadets were asked to choose which ones they were most interested in. The students decided that the first lunch would focus on "Engineers and Weapons Development", specifically whether an ethical engineer could develop weapons designed to kill another human. The students were asked, but not required, to read four short articles[5,6,7,8] on the topic. The readings were posted on the USCGA Intranet server so they were available to all participants.

It was at this time that the EE faculty approached the other engineering majors and asked if they wanted their students to participate. This first voluntary lunch was held on November 28, 2006 with approximately 30 students (out of a total of 72 total senior engineers) and seven instructors from all four engineering majors. One of the Morals and Ethics faculty also attended.

In an effort to foster open discussions, the lunch was held outside of the classroom environment -- the Academy's Alumni Center conference room -- with five to six round tables set up with approximately 10 seats each. As the students arrived, they were asked to sit with only about 2 or 3 members of their major, thereby assuring "multi-disciplinary" discussions. Faculty volunteers then joined the students, ate lunch, and facilitated the groups' discussions on the readings and the ethical issues associated with weapons development.

It is important to again note that at this stage, the lunches were optional and not actually part of any classes. The students were not required to attend, complete any preparation or complete any assignments. The lunch was successful in providing a forum for voluntary discussion, by both faculty and students, on an engineering ethics topic. The lunch received positive feedback from both the students and faculty facilitators. Included in that semester's senior design end of course surveys, which are completed at the end of every semester, students indicated that they preferred to discuss ethics in the round table environment and specifically asked for additional ethics lunches in the future.

Evolution of the Ethics Lunches

During the winter break, the four senior design instructors met to discuss the ethics lunch concept. The decision was made that these lunches should be expanded in number such that they could ultimately serve as a supplement or replacement for engineering ethics

content previously embedded in senior capstone design courses. As such, there was faculty desire to more closely associate student learning during the lunches with the grading and performance assessment in the capstone design courses of all four engineering majors.

In consideration of the earlier positive student feedback to the first lunch, changes made to the format were kept to a minimum. Students were still allowed to guide selection of the discussion topics and readings were kept short and intranet-available. The lunch format with small multi-disciplinary group discussions, led by a faculty member, was also maintained.

Improvements to the lunches included the development of faculty facilitator "talking point" papers, which were 1-2 pages for each ethics topic that covered some applicable information from the reading and suggested facilitator questions or comments to help focus the groups' discussions. Appendix A provides an example of one of these talking point papers including readings, notes and facilitator discussion points. A collection of these talking point papers is the basis for the development of a USCGA Engineering Ethics Handbook (draft completed) that will be used by students and faculty to conduct engineering ethics lunches in future years.

The biggest change decided upon was to make the lunches a mandatory part of each capstone design course. The faculty decided to hold four monthly lunches during the spring semester of 2007. The topics and dates of the multi-disciplinary lunches for the spring semester are listed in Table 1.

Table 1: Topics and Schedule of Multi-Disciplinary Ethics Lunches, Spring 2007

Topic	Date
Engineering and the Environment: Is Sustainable Development Important?	30 Jan 2007
Engineering Ethics and the Junior Coast Guard Officer: Ethical Dilemmas Faced by Academy Graduates	06 Mar 2007
Engineering Ethics and the Law: When the Law and Code Conflict	27 Mar 2007
Engineering Ethics and Global Issues: Clash of Cultures	17 Apr 2007

The students were to attend 2 of these lunches as a requirement for their capstone design course. Since the topics selected by the students and were therefore of significant interest to the students, many of them attended more than the two required lunches. The feedback from the students remains positive despite the move from voluntary to a required assignment.

As the lunches were now part of the capstone courses, faculty evaluation of the students was necessary. This turned into a requirement that each student write a short (500 – 700 word) essay after each required lunch; students attending more than two lunches only had to submit two essays. The essays took one of two forms, either the students could provide their thoughts on the discussion or they could answer an engineering question with an ethical dilemma based upon the discussion. To minimize the impact on the

instructor, a ten-point grading rubric was developed that equally weighted the student's writing and ethical reasoning. Appendix B provides an example of an assignment along with the developed grading rubric. In addition to providing grades for the course, these assignments were also effective ways to demonstrate the students were meeting ABET's criterion 3f.

As can be seen by the example talking points paper and assignment (Appendices A and B), the focus of these ethical discussions is to have the students think about the choices they would make in a given situation. This changes the ethical lessons form a purely theoretical discussion to one requiring the students to develop, apply and defend their moral values and choices. The faculty feel this is a better way to teach engineering ethics. Student written comments such as "It made me realize how sometimes I will be alone in one of those arguments and will have to put my ethical values to the test" validated faculty assumptions. Students learned that it is not always the choice made, but the reasoning behind the choice that is most difficult to develop.

Advantages and Disadvantages of Multi-Disciplinary Engineering Ethics Lunches

A multi-disciplinary environment for the discussion of engineering ethics is advantageous for a number of reasons. For the faculty, the workload of individual teachers has been reduced. With multiple instructors developing and providing input on the topics, there is less preparation required for each, relative to that associated with the development of ethics content within individual courses. An additional academic benefit is that the engineering ethics instruction is now consistent across all four majors, without requiring an entirely new course.

More importantly are the benefits to the students. By taking the students out of the classroom environment, they are more relaxed and comfortable with sharing their honest thoughts, opinions and even questions regarding sensitive ethical topics. Also, a typical senior design course at USCGA has 15-24 students. By dividing the students in smaller groups of 8 to 10, all students are given an opportunity to voice their opinions, where they many not have a chance in the larger group. This openness is reinforced even further when students sit and discuss topics with instructors other than their own, removing any concerns that a question or comment might negatively impact their course grade. Finally, with multiple disciplines represented, students with varying viewpoints can express themselves on the topics, thereby enriching the learning by all.

Ideally the students would be able to take a full course that combines both ethical theory and practical engineering ethics, and the authors are aware this is the practice at other universities. However due to USCGA's smaller size and already large required student course load (most engineering students only have 1 free elective) this is not practical. Due to time constraints; the lunches focus on case studies with very little review of ethical theory. The students use and apply the theory from the core "Morals and Ethics" course. Even this is not the case, the students still must make a decision based upon their individual moral compass, whether or not they can name the particular ethical theory they

are applying. Individual facilitators may bring in some theory to the discussion, and this may be an area that can be improved upon in future.

Another advantage to an entire course is that more of the topics can be included. As it is now, students are only required to attend four lunches (two during each semester). In senior capstone design courses, the students also are required to discuss any ethical implications associated with their design project. The faculty believe that the lunches, in combination with the "Morals and Ethics" course and the application to their project, are enough to meet ABET requirements. This is bolstered by the fact that before the lunches the students were getting much less formal ethical instruction.

The creation of the draft Engineering Ethics Handbook (see Appendix C for the Table of Contents) has positioned USCGA to provide more consistent and comprehensive instruction on engineering ethics. It will be a resource that students and faculty can use to determine which topics they want to discuss. As new faculty and students use the Handbook, it is planned that the topic list can be expanded and that past topics can be refined and expanded based upon lessons learned.

The authors believe that the USCGA engineering ethics lunch concept might be applied at other small colleges where the lack of faculty resources or availability within the student's schedule might preclude adding an additional course on "Engineering Ethics". We realize that in a military college environment that students are more likely to "accept" a transition from voluntary lunches to required lunches. But, based upon the USCGA experience, the joint student-faculty ownership of the ethics lunches fosters such student interest that many students choose to attend lunches beyond those that are required for course credit. As such, it is expected that such a model should also be effective for other institutions.

Conclusion

In an effort to improve the teaching of "professional ethics" to our engineering students, the engineering faculty at the United States Coast Guard Academy (USCGA) have implemented a multi-disciplinary approach to teaching ethics outside of the classroom environment. Our "Engineering Ethics Lunches" bring students and faculty from all four engineering disciplines: Electrical, Civil, Mechanical and Naval Architecture/Marine Engineering together in small groups to discuss ethics as they uniquely apply to the engineering discipline, in an environment specifically designed for open, honest discussion.

Students and faculty form small groups during scheduled lunches to discuss specific ethical topics related to the engineering profession. The discussions are based upon assigned readings and suggested talking points developed jointly by the faculty. Afterwards, the students are required to submit essays reviewing their discussions and answering an ethical question based upon the topic.

Now entering their fourth semester, these lunches have proven very popular both with the students and the faculty. The topics are ones that students are interested in and promote

lively discussions. Faculty involvement has also been very high, including significant participation from faculty not even directly involved with the classes.

The model that has been developed at USCGA could easily be used by other institutions. Especially at smaller colleges where the lack of faculty resources or availability within the student's schedule might preclude adding an additional course on "Engineering Ethics".

References

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2 *United States Coast Guard Academy Catalog of Courses: 2007-2008*. USCGA, New London, CT.

3 Michael R. Lindeburg, *FE Review Manual,* 2nd Edition, pg 54-2, © 2006, Professional Publications, Inc. Belmont, CA.

4 Mike W. Martin and Roland Schinzinger, Ethics in Engineering, 4th Edition, © 2005, McGraw-Hill Companies, Inc. New York, NY.

5 *American Association of Engineering Societies Code of Ethics***.** Available from: http://www.aaes.org/public_policy/9_9_00.asp **(**Accessed on 23 November 2006.)

6 Dale Bateman, LCDR, USCG, Excerpt from "*A Just War Case Against War in Iraq*" (2002) with additional comments about *jus in bello*.

7 David M. Kennedy**,** *"Crossing the Moral Threshold"***,** TIME article (25 July 2005). Available from: http://www.time.com/time/magazine/article/0,9171,1086166,00.html (Accessed on 23 November 2006.)

8 TryEngineering.org Website, "Ask an Engineer: Archived Questions". The answer to the question "*As a design engineer, could I work for a firearms manufacturing company, designing weapons?"* Available from: http://www.tryengineering.org/ask_archive.php?show=71&cat=eng&page=7 (Accessed on 23 November 2006.)

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Appendices

Appendix A: EXAMPLE OF AN ETHICS LUNCH TALKING POINTS PAPER

Appendix B: EXAMPLE OF AN ETHICS LUNCH ASSIGNMENT

Appendix C: DRAFT TABLE OF CONTENTS FROM USCGA ENGINEERING ETHICS HANDBOOK

APPENDIX A: EXAMPLE OF AN ETHICS LUNCH TALKING POINTS PAPER

Engineering Ethics and the Law: When the Law and the Code conflict.

Objectives:

1. Understand the difference between an ethical and legal requirement.
2. Discuss an engineer's ethical duty when the law and a code of ethics conflict.
3. Participate in a facilitated discussion on how you would convince a boss that the law is not enough.
4. Compose an essay that incorporates the group discussion that effectively answers a related ethical question.

Readings:

1. **"Titanic: An Engineering Success and a Human Failure"** by Dillon Lunn. Dillon Lunn Individual Web Page, hosted by University of Pittsburgh. Available from: http://www.pitt.edu/~dsl6/titanic.html (Accessed on 20 March 2007.)

Notes:

Lifeboat Requirements (from the reading):

- British Board of Trade required 16 lifeboats
- TITANIC had required 16 lifeboats plus an additional 4 collapsible
- Original design called for 32 boats

Engineering innovations developed for the TITANIC (from the reading):

- Hull was divided into watertight compartments
  - Watertight doors were controlled from the bridge
- Designed to withstand flooding in two compartments

Other Notes:

- Contract was "Cost-Plus" basis – cost of extra life-boats would not have impacted the engineering/shipbuilding company's profits. However, the article says nothing about if TITANIC's owners could afford the extra costs?
- One of the TITANIC's designers actually wanted to make the hull thicker but was overridden by the ship owners/engineering firm because it would have made the ship too heavy & therefore too expensive to run.[1]

Talking Points:

1. Given that the R.M.S. TITANIC actually had more than the legally required number of life-boats, did the TITANIC's engineers have an ethical duty to ensure there were enough life-boats on board for the number of passengers and crew? Did the TITANIC's owners? Why or why not?
2. Would your answer change if you found out (hypothetically) that the TITANIC's owners pressured the British Board of Trade's decision not to increase the number of lifeboats?
3. How do you think that the belief that the TITANIC was unsinkable (i.e., the engineers had designed the ship as safe as the technology allowed) impact this ethical responsibility?
4. How would you convince your boss of the need to exceed the legal requirements for a design – especially if there were substantial costs associated with the redesign?
5. This is a case where the code of ethics forces the engineer to "overdesign" or "improve upon" what is legal – so the "ideal" solution is both legal and ethical. Can you think of cases where:
   - what is ethical would be illegal?
   - what is legal would be unethical?

[1] *TITANTIC'S ACHILLES HEEL*, Television Program, aired 8:00 PM Sunday 14 October 2007 on HISTORY CHANNEL.

APPENDIX B: EXAMPLE OF AN ETHICS LUNCH ASSIGNMENT

Engineering Ethics and the Law: When the Law and the Code conflict.

Assignment:

In an essay, from 500 – 700 words, answer the following questions:

> You are an engineer assigned to design a waste-water treatment plant. The current legal limits for substance "X" is 5 parts per million. Based upon a series of recent articles in a refereed journal, you have learned that some scientists think that this level is enough to cause cancer in humans and a safer level is 2 parts per million. **However, there is still much scientific debate about the safe level of this substance and the exact risk to humans that this substance poses.**
>
> Designing a system to reduce substance "X" to 2 parts per million would increase the overall design of the project by approximately 25% over the 30 year-life cycle of the plant. You estimate it would take **at least** 5 years for new regulations to be enacted and another 5 years before the plant would need to be retro-fitted at a cost of roughly 18% over budgeted costs over the 30 year-life cycle.
>
> Do you have an ethical responsibility to include the upgrade in the design? Why or why not? If you do, how do you convince your supervisor of the need? If not, what additional information would you want/need to have to be convinced that you need to improve your design?

Grading: Your essays will be graded on a 10 point scale by your course instructor using the following rubric:

Ethical Discussion How effectively the ethical principles were identified and applied to the engineering process. How well the author argued the case that there was an ethical requirement to upgrade the design.	5 – Uses ethical analysis and theories convincingly. Effective arguments on if there is an ethical requirement to upgrade the design. Convincing arguments to "supervisor" on need for redesign or convincing arguments or why current evidence doesn't support the need. 3 – Uses ethical analysis and theories. Either doesn't provide effective ethical argument for/against need for redesign or doesn't provide convincing argument to supervisor/discussion on what additional evidence is needed. 1 – Doesn't make use of ethical analysis or theories. Arguments unconvincing about ethical requirement and doesn't provide convincing argument to supervisor/discussion on what additional evidence is needed	
Writing Style Spelling, grammar, punctuation and clarity of writing. Paper's audience and purpose are obvious and consistent. Required length.	5 – Paper easy to read, and relatively free of grammar and punctuation problems. The paper's grammar and punctuation respects the audience's need for clarity. 3 – Grammar, punctuation or spelling is good – but better proofreading is necessary. Meets required length. 1 – Spelling errors, grammar problems & punctuation problems common with definite patterns of misuse. Basic writing interferes dramatically with the section's meaning. Doesn't meet required length.	

APPENDIX C: DRAFT TABLE OF CONTENTS FROM USCGA ENGINEERING ETHICS HANDBOOK

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