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Teaching Ethics to Engineers: Ethical Decision Making Parallels the Engineering Design Process

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Abstract In order to fulfill ABET requirements, Northern Arizona University's Civil and Environmental engineering programs incorporate professional ethics in several of its engineering courses. This paper discusses an ethics module in a 3rd year engineering design course that focuses on the design process and technical writing. Engineering students early in their student careers generally possess good black/white critical thinking skills on technical issues. Engineering design is the first time students are exposed to "grey" or multiple possible solution technical problems. To identify and solve these problems, the engineering design process is used. Ethical problems are also "grey" problems and present similar challenges to students. Students need a practical tool for solving these ethical problems. The step-wise engineering design process was used as a model to demonstrate a similar process for ethical situations. The ethical decision making process of Martin and Schinzinger was adapted for parallelism to the design process and presented to students as a step-wise technique for identification of the pertinent ethical issues, relevant moral theories, possible outcomes and a final decision. Students had greatest difficulty identifying the broader, global issues presented in an ethical situation, but by the end of the module, were better able to not only identify the broader issues, but also to more comprehensively assess specific issues, generate solutions and a desired response to the issue.

Keywords Engineering ethics · Professional ethics · Engineering design · Teaching ethics to engineers

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Introduction

This paper discusses a novel approach in teaching ethics to engineering students by illustrating the similarities between a common tool used in the ethical decision making process and the step-wise design process commonly taught in engineering programs. This problem-solving method is taught in an engineering course that included teaching ethics to engineering students. Motivations for teaching ethics within the content of existing courses in the curriculum comes from: (1) the ABET program Criterion 3f that states that students must have "an understanding of professional and ethical responsibility" upon graduation (ABET 2009); (2) the need to satisfy other ABET Criterion (3a–k and 5) and 24 credits of NAU liberal studies requirements in the program of study; and (3) maximum 120-credit hour program caps desired by the state university system. Each of these factors have combined to make the allotment of an entire 3-credit course for some topics a luxury of the past.

Northern Arizona University (NAU) engineering programs have a common four-course sequence called Design4Practice that teaches engineering design, with increasing levels of complexity from technical, managerial and communications standpoints over the freshman, sophomore, junior and senior years. The first 2 years are interdisciplinary. The third course in the sequence for Civil and Environmental Engineering (CENE) students, CENE386W, is considered a technical writing course and heavily emphasizes individual writing skills for technical proposals and design reports. Course content also includes engineering economics, professional ethics, and moving the students beyond a generalized use of the design process to a more highly refined, technical use that will be needed in the 4th year capstone course. It is the professional ethics content of CENE386W that is the subject of this paper.

Methods: Background

The study of ethics in the CENE curricula is via a multi-pronged approach. In addition to a formal course from the Philosophy department (Introduction to Ethics or Environmental Ethics) that also fulfills a liberal studies requirement, applied/professional ethics are topically introduced in several of the engineering courses in both programs of study. CENE386W is one of those courses, and student may or may not have had the required philosophy course prior to this course.

This course was a new prep for the instructor, as well as her first time teaching significant ethical content. A brief survey of the literature in the teaching of ethics to science and engineering students (Davis 2006; Graber and Pionke 2006; Zandvoort 2008) indicated that in addition to a basic foundation in ethical theory, understanding the global, or broader, institutional frameworks that impact the ethical considerations of practicing engineers was also important. This broader view provides for the demonstration of further ethical complexities that are encountered in practice. These topics, coupled with a suite of practical examples, were determined to be the most meaningful ethical content for this class. After a review of several engineering ethics texts, Martin and Schinzinger (1996) was selected as

the source for primary content. The ethical decision making process as proposed in this text (p. 16) was used for this course.

Unlike the other courses in the Design4Practice sequence, this course did not involve team design projects. There were 46 students in this class and there were 46 individual design projects assigned; some overlap was written into the projects so that group in-class work sessions could be utilized to help foster creativity when needed, and to provide review and critique of others' work. The course started with a literature review and writing assignment based on each student's topic in order to jump-start the technical writing and background technical knowledge aspects of the course.

The ethics portion of the course was taught early and in three modules, or, content blocks: ethics in writing, general ethics and applied/professional ethics. The first module, ethics in writing, was delivered on day 2 and dealt with the author's responsibility to appropriately cite the work of others and not plagiarize. Content of this module included NAUs Student Code of Conduct regarding plagiarism, examples of what plagiarism is, ethics in one's own writing, when a citation is needed, where citations occur in writing, use of quotations, and proper citing formats for a variety of sources such as books, journals, documents, and internet resources. Students were given a quiz where they indicated what content in a given section had to be cited and a homework assignment to find references from a variety of sources for their technical project and cite them properly.

The second module, general ethics, was delivered on day 3 and the third module, applied/professional ethics, was delivered on day 5. Detail on the contents of these two modules is in the "Methods: The Ethical Decision Making Framework" section below. It was in the day 3 lecture that the ethical decision-making tool was presented, along with an example. An in-class quiz similar to the example was given after the lecture so students had a chance to use the tool themselves; it was then discussed in class. On day 6 a case study was presented via a role play. Homework included preparatory reading for the role play and an individual homework assignment that included an analysis of the case study and use of the ethical decision-making tool.

This material was reinforced with one review session prior to the midterm exam which had both general and applied/professional ethics questions as well as use of the ethical decision-making tool. This reinforcement was repeated at the end of the course before the final exam which had similar ethical content.

Methods: The Ethical Decision Making Framework

Content of modules two and three included background on general ethics and applied/professional ethics topics as shown in Tables 1 and 2.

Table 3 shows both the generalized engineering design process (Dominick et al. 2001) and the ethical decision making process (as defined in Martin and Schinzinger). In the ethical process, steps four and five are combined to maintain the parallelism between the two processes; step six, implementation, an obvious step, has also been added.

Table 1 Content of module 2—general ethics

Topic	Description
Ethical development	Moving from pre- to post-conventional thinking
Moral theories	Virtue ethics: self-directed, public-spirited, teamwork, and proficiency
	Utilitarianism
	Duty ethics
	Rights ethics
Ethical factors: inquiries	Normative questions
	Conceptual questions
	Factual questions
Moral dilemmas	Vagueness in applicability of moral theory
	2 Applicable moral theories but conflicting outcomes
	Disagreement in interpretation of moral theory
Ethical decision making process	Table 3

Table 2 Content of module 3—applied/professional ethics

Topic	Description
Professionalism	Definition, criteria
ASCE code of ethics	Fundamental principles, canons
Responsibility for safety and reducing risk	Serving the public
	Margin of safety
	Fault tree analyses
Responsibility to employers	Collegiality
	Loyalty: agency, identification, misguided
	Respect for authority
	Confidentiality/dilemmas
	Conflict of interest
Rights of engineers	Rights: human, employee, professional
	Whistle-blowing
Relativism/relationism	Appropriate/inappropriate ethical analysis
Ethical decision-making process	Table 3

It is easy to see the parallels between these two processes. Because the students were required to perform engineering design projects in this course, the engineering design process was revisited. What is often seen with students early in their academic careers, when presented with simple, well-defined and constrained problems, is the skipping of steps three and four and going immediately to step five. This often results in a poor design, failure during step six, and significant, frustrating, last-minute redesigns. When presented with more complex open-ended problems, students who ignore this process also perform steps one and two poorly, resulting in failed designs. In this class, students were given many examples of the multitude of problems resulting from such neglect.

Table 3 Comparison of engineering design and ethical decision making

Step	Engineering design process	Ethical decision making process
1	Identify the problem	Identify relevant moral factors (normative, conceptual and factual)
2	Identify the constraints	Identify conflicting moral responsibilities and dilemmas
3	Brainstorm options to solve the problem	Consider moral theories and rank
4	Develop design alternatives (preliminary design of several alternatives)	Consider alternate courses of action (full implication of each)
		Obtain alternative perspectives
5	Selection of final design and completion of design	Make decision
6	Implement the design	(Implement the decision.)

Similarly, in the author's previous experiences with professional ethics in the 1st-year Design4Practice course, students tended to jump to a conclusion, without formal recognition of a detailed analysis such as steps one through four, based upon their feelings of right/wrong and limited knowledge of the professional codes. While this is not inherently wrong, nor do poorer decisions necessarily result from such a method, the ethical situation is not fully understood, important consequences may not have been considered, the final decision is not as well thought-out or justifiable, and may result in a variety of problems later on, such as exacerbating the problem, disciplinary actions being needed or the occurrence of a scandal (Martin and Schinzinger 1996). It is the formulation of the normative question that provides the foundation for a more comprehensive analysis of the situation. Time spent considering the aspects of the ethical problem via steps one, two and three increase the likelihood that the broader, global, or institutional responsibility aspects of the ethical problem will be identified. Therefore, it was decided that this rational decision making process be emphasized and taught to the students so that, as in engineering design, a comprehensive approach could be followed every time.

After modules two and three, detailed instructions/questions were provided with the decision-making tool. Examples were also provided demonstrating use of the method. In the examples, actual decisions were not made by the instructor; rather, the class took over the discussion of the various decisions. A vote was often taken to show that, like the engineering design process, multiple acceptable solutions can be obtained. The template for use of the tool is shown in Table 4.

A role-play activity completed the modules. Two different role plays were performed, based on a case study; the ethical contents were safety and corporate responsibility. The first was an enactment of a private corporate meeting to discuss product failures and a pending lawsuit; participants included company executives, legal counsel, an external technical consultant, the plant manager, and plant engineers. The second was an enactment of the court case where liability was assigned; participants included defendants, plaintiffs, legal counsel on both sides, engineers, technical expert witnesses and jury members representing various cross sections of society and interest groups. Students selected a role that interested them; several students had the same role and one spokesperson was elected to act in the

Table 4 Ethical decision making template

Ethical Decision Making Worksheet	
Description of case here; specific ethical question asked.	
Step 1. Relevant moral factors:	
(1) List pertinent normative questions.	
(2) List pertinent conceptual questions.	
(3) List pertinent factual questions.	*Note: factual information was provided by the instructor, either with the initial description of the case, or in a separate section after Step 1*
Step 2. Dilemmas. List pertinent moral dilemmas, if any	
Step 3. Consider applicable moral theories: specify as appropriate for EACH person involved	
(1) List any applicable virtue ethics:	(a) Self-directed:
	(b) Public-spirited:
	(c) Teamwork:
	(d) Proficiency:
(2) List any applicable utilitarian ethics	
(3) List any applicable duty ethics	
(4) List any applicable rights ethics	
Step 4. Develop at least 3 alternative courses of action and list consequences of the action, considering which of the above moral theories are satisfied or not satisfied by the decision. *Note: as these assignments were to be done individually, the "obtain alternative perspectives" part of this step (which is the discussing of the case with other parties) was not required*	
Step 5. Select course of action. Justify	

role play. Students were given class time prior to the enactments to prepare, and were allowed to consult with their group during the role play. The instructor provided prompting during the role play as needed. The students enjoyed the role play and it was interesting to note that decision of the jury (i.e., proportion fault and the final monetary award) was close to that of the actual jury; the students were not given information prior to the role play on the outcome of the case.

Outcomes—Ethics in Writing Module

At the beginning of the course, many students were well-versed in the use of the MLA citing style that was used in the course and almost none had difficulty with the required formats. Achievement on the homework assignment averaged 98 $\pm$ 1.5%. The majority of the students easily grasped what content required citing, how to paraphrase and properly cite. Two (of 46) students were unable, after doing their literature review, to write any meaningful synthesized/internalized content on their own—their work was nearly all quoted material or citation and after citation.

However, once these students were shown examples/received corrections to their draft documents, they quickly understood the concepts and had no further problems. By the end of the module, all students had corrected all citing errors, but by the end of the course, when the final reports were due, approximately three students improperly cited internet sources. This is significant because internet sources are becoming more widely used. Additionally, a sporadic check for plagiarism indicated that no plagiarism was occurring.

Outcomes—Ethical Decision Making Framework

The problems/cases presented to the students were clearly defined and all students appeared to understand the question being asked. Most students found step one to be the most difficult. Within step one, the formulation of normative questions was difficult for many students; several students confused the normative question with the conceptual question. Formulation of at least one factual question was easy for all students. It was expected that the normative and, to a lesser extent, the conceptual questions would be the most difficult because most students do not have experience in taking a specific moral question and looking at the broader foundational questions behind it. Additionally, the development of a normative question is a relatively high-level cognitive task (as defined by Bloom et al. 1956), requiring analysis, synthesis and evaluation skills. After additional examples, discussion in class and practice, a majority of the students were able to write an appropriate normative question. Almost all students were able to identify important moral dilemmas in each case. The primary problem seen in step three was that most students only filled in the table for the person who had to make the ethical decision rather than all the persons involved. Additionally, several students had difficulty defining the utilitarian ethic for the problem. The majority of the students could satisfactorily identify the most obvious of the pertinent moral theories, although many analyses were incomplete, suggesting that they had not thought through the problem sufficiently. Additional discussion in class improved the ability of the students to identify the utilitarian ethic. By the end of the course, many students still did not consider the ethical concerns of other participants in the problem; this may have been because the instructor did not realize until after the midterm that this was the reason students were not completing the table. This was corrected before the final and some improvement was seen. Step four, the most creative step, requires a high level of knowledge because students must be able to step outside their own prejudices and recognize and develop alternatives and subsequent consequences that may not be obvious. Generally and somewhat surprisingly, almost all students did very well with this step. It is possible that is because when a person is faced with an ethical problem, this step is often the first step in their decision making process when the other steps are ignored, and thus, most people have experience with this step and are generally competent on some level in thinking things through.

Achievement on the homework assignment immediately after the modules averaged 83 $\pm$ 19%, while achievement on the ethics portion of the final exam averaged 86 $\pm$ 5%. It is believed that the significant, intensive review of the areas

that students had difficulty with on the homework assignment improved the variance seen on the final exam. An ethics-only score on the midterm was not computed. Comments from the students at the end of course regarding the helpfulness of the ethical decision-making tool ranged from 2 to 5 (0 = no effect; 5 = significantly helpful) with the majority of responses at 3 (somewhat helpful). Additional comments and specific quotes on the module included:

- Helpful to recognize different situations from both sides.
- Breaking the ethical situation into steps is not just an approach engineers prefer but also makes it easier to come to reasonable conclusions.
- Made the analysis of a situation is easier, but formulating an effective response is based on too many personal morals and ideas for a decision making process to be very effective.
- "… the change in this skill category was positive. This occurred because of the thorough review on ethics and its logical thinking procedures. In addition, the frequent case studies and homework helped with my comprehension and retention on ethics."
- "I am able to correctly assess ethical situations and am more familiar with the ethical standards for engineers."
- "By the presentations in class and discussing the ethics involved in real world situations I have become more aware and confident in conducting myself in an ethically professional manner."

As previous offerings of this course were taught by different instructors with slightly different ethical contents, a direct comparison of the effectiveness of this technique to that of other professional ethical problem-solving pedagogies cannot be made at this time.

Conclusion

This paper describes a methodology for teaching ethics to engineering students in a condensed format within the framework of an engineering design class. It is clear that engineering students must move from making ethical decisions based on a "doing a good job" perspective to a more global recognition of their roles as citizens who are also the users of their designs and are able to question the use and appropriateness of their works, as well as to understand the political, social, organizational and legal frameworks that set the stage for the decision-making process. Engineering students need ethical decision making tools in order to gain confidence that they can indeed make good ethical decisions. A methodology reduces knee-jerk emotional reactions to a situation. Reminding students of the similarities of ethical decisions to design decisions gives them a familiar frame of reference for action. Additionally, many ethical questions are likely to occur during the design process itself, thus strengthening the link between the two processes. A benefit of this methodology is that the asking of normative, conceptual and factual questions provides a place for broader, global background questions, including those of organizational responsibility, to be considered.

Recommendations for improvement of this work include consideration of the following:

- develop additional specific content/questions relating to organizational roles and corporate culture;
- enhance the role play with better preparation and follow-up discussion, especially on corporate culture, to solidify the ethical concepts in the students' minds;
- add content that requires ethical consideration of the students' individual design problems;
- add an ethics instructor (team-teaching) to enhance instruction and case studies; and
- develop comparative outcome data with other ethical decision-making pedagogies.

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