Teaching and Assessing Ethics in a Specialized Professional Skills Course

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***Abstract* – Ethical considerations are featured prominently in the professional codes of ethics of various engineering professional societies. Arguably, having a code of ethics is a requirement for a field to be recognized as professional. The importance of ethics is further exemplified by accreditation requirements from, e.g., ABET. One of seven ABET Student Outcomes states: "4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts". The teaching of engineering ethics would ideally be done across the curriculum and in a proper engineering context. However, due to many practical considerations, this is done in a few, often specialized, courses. In this paper, we report on the implementation of ethics education in one such specialized course at the senior (fourth year) level. We discuss the course structure and how we use rubrics to assess students' attainment of course outcomes related to ethical reasoning. We also provide guidance on scaffolding teaching materials and constructing assignments.**

Keywords – accreditation, assessment, engineering education, engineering ethics, social reading.

I. Introduction

Engineering is not immune to scandals involving various levels of unethical behavior: from cheating on emissions testing [1] to deadly design flaws in aircraft design [2]. Many other examples can be found in books, e.g., [3], but many of those are centered on failures in the area of civil engineering. While these cases present a nice introduction to the problems involved, they do not translate easily into areas of electronics and similar fields where failures and ethical misbehavior may not have as grave a consequence. Nonetheless, the need for recognizing ethical problems and acting accordingly is common across engineering disciplines.

While the need is recognized, there seems to be a debate about whether it is possible to teach ethics to undergraduate students [4]. Several objections to teaching ethics can be put forward, such as: a) ethics is an inborn trait or it is possibly a function of early childhood training, and b) ethical decision-making is not based on reasoning but intuition. While these may be serious philosophical questions there is evidence that teaching ethics does work which justifies our attempts to teach it [4].

Ethical decision-making in engineering has long been recognized as an important part of the profession and individual responsibility. In the following sections, we will briefly describe what constitutes engineering ethics, and provide the curriculum and course context in which we teach engineering ethics. This is followed by the description of assignments and assessment techniques we use with some concluding remarks at the end.

II. Engineering Ethics

Ethics is variously defined, from a simple dictionary statement such as "a set of moral principles" or "the principles of conduct governing an individual or a group" [5], to more descriptive statements such as "Ethics or moral philosophy is a branch of philosophy that involves systematizing, defending, and recommending concepts of right and wrong behavior" [6]. Ethics is often used interchangeably with morality, but most descriptions will agree that ethics "provides a framework for understanding and interpreting right and wrong in society" [7]. Therefore, ethics deals with the interpretation and application of rules to determine right and wrong behavior or actions.

Most professional societies will have codes of conduct that attempt to describe what these rules are and how to interpret them. Examples include the National Society of Professional Engineers [8], the American Society of Civil Engineers [9], and IEEE [10].

Traditionally, ethics has been taught by philosophy faculty, but business and engineering departments have become involved more recently. For the engineering programs, this was driven in part by the ABET accreditation requirements. In the most recent version of the Student Outcomes, ABET requires that engineering programs demonstrate student attainment of this outcome:

"4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [11].

This requirement presents difficulties in curriculum design and implementation. Ideally, discussion of ethics would be present across the curriculum, but engineering curricula are already full and ever-expanding. On the positive side, however, there are many resources available to instructors, such as books, e.g., [12], institutions dedicated to the promotion of engineering ethics, e.g., [13], and a variety of websites and professional organizations that have already been mentioned.

III. CURRICULUM AND COURSE STRUCTURE

The Electrical Engineering and Computer Engineering Bachelor of Science programs at Portland State University are quarter-based, 4-year long, and ABET accredited [11]. The quarters are 11 weeks long with one week dedicated to final exams. Like all ABET accredited programs, ours have a culminating design experience in the so-called Capstone course. Questions related to the interaction between engineering design and ethics come up most naturally during the Capstone course. In our curriculum, however, the Capstone course is done in collaboration with local industry and each project has different goals and constraints [14]. This has led us to separate out the discussion of ethics and other professional issues into a required 2-credit course entitled ECE 424 Engineering Professional Practice. The course is taught twice a year in the senior year and the total enrollment varies between roughly 70 and 90 students.

Ethics is specifically targeted in two additional courses in our curriculum:

- ECE 101 Exploring Electrical Engineering which is a freshman course that introduces students to a variety of subfields and some basic engineering skills. Students also learn how to recognize some basic ethical issues through watching videos and in-class activities [15].
- Introduction to Design Processes. As part of the discussion of the design process for the product they are developing, students are asked to consider the potential ethical issues related to their product in global, economic, environmental, and societal contexts (as prescribed by ABET) [16].

Further discussion of ethics may happen in the general studies segment of the curriculum, but this is dependent on the student's selection of specific courses.

A. Engineering Professional Practice Course

The goal of the course is to provide students with skills they likely did not learn in technical courses. This includes effective communication skills, teamwork, intellectual property, career planning, and similar. Specific topics covered in this class include strategies for getting a job, the importance of communication skills (written and oral), teamwork, engineering ethics, global and societal considerations, legal issues such as intellectual property, patents and compliance, and career planning. A full list of course outcomes includes:

1. Explain and follow professional standards of written communication, including email (ABET-3)
2. Describe the purpose and limits of patents and intellectual property rights (ABET-7)
3. Perform a preliminary patent search at uspto.gov (ABET-7)
4. <u>Describe the basic expectations of engineering ethics and the IEEE code of ethics (ABET-4)</u>
5. <u>Demonstrate basic knowledge of and ability with ethical reasoning through the discussion of case studies (ABET-4)</u>
6. <u>Describe the role of ethics in design decisions (ABET-4)</u>
7. Describe current social, environmental, political and economic factors influencing the development and use of technology (ABET-4, 7)
8. Describe how considerations of sustainability affect engineering decisions (ABET-4)

Underlined items directly address engineering ethics and are covered over roughly three weeks.

One problem facing instructors of this, and similar courses, is how to frame the discussion and lead students through the process of making informed ethical decisions. To make the process transparent, we like using an algorithmic approach to explain the decision-making process [17]:

1. State the problem
2. Gather and assess relevant facts in the case
3. Identify the stakeholders
4. Develop a list of at least five options
5. Test options
6. Make a tentative choice
7. Review and make the final choice

Assessment of the course outcomes is discussed in the following section.

IV. ASSIGNMENTS AND ASSESSMENT

Assignments used in the assessment of student performance include readings, exam questions, team presentations, and surveys. We will discuss only the first three assignments.

A. Readings

In this course we rely on assigned readings to provide additional information and depth of analysis that is not possible to do during the lecture time alone. In the past, there was no reliable way to determine whether students did the reading and how engaged they were with it. As discussed in [18], new tools like Perusall [19] have made this activity visible and subject to more qualitative and quantitative assessment. We have used Perusall since 2017 in courses ranging from freshman introduction to engineering courses to graduate-level research seminars and we believe it has had a positive impact on student learning.

There are three readings:

1. Start with a practical and more conversational approach to describing the types of ethical issues that are likely to arise in the workplace. This could be accomplished through case studies, but they tend to be longer and more technical. Given the time constraints, we use a selection of short chapter(s) from books like [20]. To illustrate the difference between legal liability and social responsibility at a more detailed level, students are asked to read an essay on that topic such as [21]. To help frame the reading, students also read the IEEE Code of Ethics.
2. The second reading deals with moral frameworks and we usually take excerpts from books on the topic or websites with appropriate content. This

provides students with a more complete framework that can be used to analyze cases or practical dilemmas.

3. Finally, we use a contemporary topic to illustrate the nature of the ethical problems likely to come up during their careers. One recent example would be a discussion of ethics in the context of Artificial Intelligence [22].

It is hoped that this progression helps students develop their own understanding of ethical issues but in the context of social reading, where they can discuss readings with their peers who very likely have similar questions and doubts.

Figure 1 illustrates the instructor's interface to Perusall. The central column has a list of assignments, while the details of the assignments are given in the right column. This includes overall class results for the quality of the submitted comments. In this example, 86.8% of students "Completed with maximum score", 0% had "Completed but not maximum score", further 2.6% had "Some work submitted", and 10.5% had "No work submitted." This gives the instructor immediate and easy-to-understand feedback on how well students are engaging with and performing on this assignment.

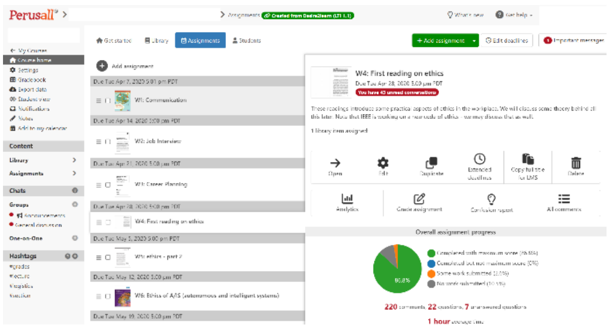

Figure 1. Example of instructor's interface to Perusall. Assignments are listed in the middle in chronological order and details of one of the assignments are on the right.

Perusall reported the following percentages for the reading assignments in one representative section of the ECE 424 course:

TABLE 1. PERCENTAGE OF STUDENTS WHO COMPLETED THE READINGS WITH THE MAXIMUM SCORE.

Reading	1	2	3
% Completed with max score	86.8	78.9	76.3

The overall performance is satisfactory, demonstrating that students are engaging with the material. The drop-off in the later assignments can be attributed to the increased complexity and length of the assignments but it is also likely that students will generally have more other coursework later in the term.

B. *Exam questions*

Several questions dealing with ethical issues are included in the final exam for the course. Given that the exam is roughly two hours long, the questions cannot be very detailed. Some questions address a basic understanding of the course material, such as basic facts of moral frameworks or the IEEE Code of Ethics. On the other end of the spectrum, we provide a brief case description that can fit into roughly one paragraph of text. Students are then asked to pick one of the multiple-choice answers and justify their selection. This gives the instructor more insight into student thinking and how they arrived at their answers. The dilemmas usually address safety or conflict of interest because these are deemed to be most easily relatable to student experiences.

The following assessment was done by analyzing four questions on the final exam. Here are some overall observations:

- Students have difficulty precisely identifying the ethics issue which then leads to mistaken identification of the applicable segment of the IEEE Code of Ethics, but
- students can identify problems related to safety relatively easily.
- Students have difficulties analyzing problems related to the responsibility to the public or dealing with unethical requests from superiors. This is expected given that these are more complex issues relative to, for example, safety concerns.

This can be summarized by stating that students have a harder time analyzing and providing justification for problems with more ambiguity. This indicates that further training is required. However, time constraints are the limiting factor, and we will have to consider expanding the course hours or eliminating some of the other content.

C. *Team Presentations*

Students are organized into teams of four and tasked with preparing and delivering a 15-minute presentation about a news item that is relevant to our discussion of ethics. Teams take up a variety of topics, from technical ones such as brain-computer interface, to privacy issues related to Amazon Ring. Presentations are judged by using rubrics that are shared with the class.

Rubrics can be designed in different formats and goals. For example, rubrics may be focused on scoring a particular assignment where the distribution of scores across different criteria is important because that determines the final score, or equivalently the grade for the assignment. Other rubrics may be designed for providing qualitative feedback to students and they are more formative than summative.

The rubric style given in Table 2 is more useful in qualitatively assessing student performance and can be used for providing feedback as well as documenting student attainment for accreditation purposes. Note that in Table 2 we have skipped level 2 for brevity. The number of Performance Levels typically varies between 3 and 5.

TABLE 2. OUTLINE OF A GENERIC RUBRIC IN A TABLE FORMAT.

Criteria	Performance level 3 (e.g. Proficient)	Performance level 1 (e.g. Beginning)
Criterion A. (e.g., Identifies ….)	Performance **indicator 1** at level 3	Performance **indicator 1** at level 1
Criterion B. (e.g. Develops …)	Performance **indicator 2** at level 3	Performance **indicator 2** at level 1

The rubric format given in Table 3 is more appropriate for scoring specific assignments. Giving the "Target characteristic" informs students about what the instructor is looking for and what they should strive to accomplish. It also gives the instructor more flexibility in assigning scores for each criterion while keeping the format simple and easy to navigate. If more than one person is grading the assignments, it may be necessary to break the criteria down into more detailed performance metrics but at the expense of generality.

TABLE 3. OUTLINE OF A GENERIC RUBRIC IN A TABLE FORMAT BUT LISTING ONLY THE TARGET PERFORMANCE INDICATOR.

Criteria	Target characteristics (Excellent or Proficient)	Score
Criterion A. (e.g., Identifies ….)	Performance **indicator 1** at the highest level	(e.g., 60)
Criterion B. (e.g. Develops …)	Performance **indicator 2** at the highest level	

In our previous paper [23], we have reported on the design of the ethics rubric in addition to several others. Table 4 is a slightly edited version of the ethics rubric published there but in the rubric style emphasizing the target characteristics.

TABLE 4. CRITERIA AND PERFORMANCE INDICATORS FOR ABET OUTCOME 4 ON ETHICS.

Criteria	Target characteristic
A. Recognition of ethical dilemma or issue	Clearly identifying the type of ethical dilemma or issue
	Focused, clear, and detailed framing of a dilemma or issue, no irrelevant digressions
	Clearly identifies stakeholders (those affected by the dilemma or issue)
B. Providing relevant information for the case at hand	Produces well-crafted arguments based on new information; justifies assumptions and brings information from their own experiences
	Identifies critical issues & components of the new knowledge
C. Analysis and fairness	Provides clear arguments
	Considers multiple points of view in their analysis; global view with perspectives from e.g. employers, professions, and society
D. Ethics in professions	Familiar with the value and importance of professional codes
	Understands personal, professional, and wider social consequences of violations of codes

Student team presentations were assessed in Fall 2019 using criteria in Table 4 with the results presented below in Figure 2. Five out of 13 teams did not approach a proficient level of performance. This is due to a couple of reasons:

- Ethical issue or dilemma was not properly identified, i.e., it is not focused enough, or it is not explicitly stated.
- Some topics dealt strictly with technical issues which were very informative and relevant but had no obvious ethical component.
- If the core ethics issue is poorly identified then criteria B. Providing relevant information for the case at hand, and C. Analysis and fairness, become difficult to decouple and assess independently.
- The logistics of the class interfere with student performance, so some teams are asked to deliver presentations before we have an in-depth, in-class discussion of ethics-related issues.

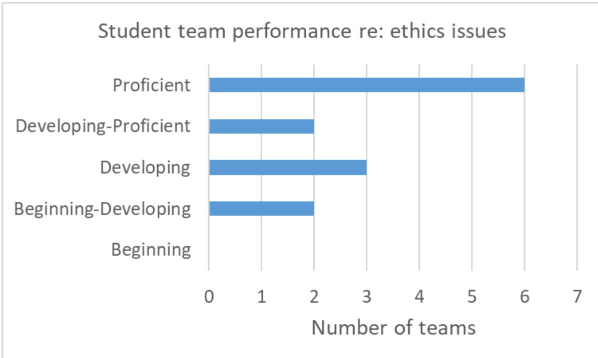

Figure 2. Assessment of team performance on the news presentation assignment. The assessment was done using the ethics rubric.

In the future, the news assignment can be improved by

- Directing teams to be even more explicit about identifying stakeholders and ethical dilemma or issue.
- Emphasizing during in-class activities that all perspectives need to be considered.
- Have teams propose their topic first and present an outline to the instructor before digging in.

V. CONCLUSIONS AND FUTURE WORK

We have presented a rationale for introducing a course dealing with engineering ethics during the senior year of undergraduate electrical and computer engineering programs. We have also provided details of how such a course can be implemented. The main constraint is the relatively low number of contact hours (lectures) which can be compensated somewhat by activities outside of the classroom. One such activity is reading additional literature on topics of interest. Students have shown good engagement with this type of social reading using the Perusall website.

As expected, students find it difficult to handle ambiguity stemming from more complex ethical dilemmas. Students perform satisfactorily on the exam questions but there is room for improvement. Performance on the team presentation assignment can also be improved but there is an additional complexity due to potential problems related to teamwork and scheduling. The latter will be addressed by adjusting the course schedule and the former by giving more direct instruction on how to approach the assignment with examples of good and bad presentations and team organization.

Ultimately, however, we have to look for ways to introduce ethical issues in other courses in the third and fourth years of study. This would not only decrease the time pressure to cover various topics but would also place the issues in their proper engineering context making it easier for students to realize their importance.

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