AC 2008-2240: LOWERING THE BARRIERS TO ACHIEVE ETHICS ACROSS THE ENGINEERING CURRICULUM

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Lowering the Barriers to Achieve
Ethics across the Engineering Curriculum

Abstract

Despite the importance of ethics training to accreditation agencies, future employers, instructors, and students themselves, many students graduate from engineering with only a cursory understanding of ethical issues and little experience in making ethical decisions related to their discipline/profession. Furthermore, many instructional obstacles exist to incorporating ethics into the engineering curriculum, including instructor hesitancy to teach about issues in which they may have little training, difficulty identifying which ethics teaching practices are effective, and already-packed syllabi that allow little room for introduction of new topics. Thus, in this paper, we describe a module in ethical problem-solving and an accompanying assessment mechanism developed by the authors. This ethical problem-solving module addresses the aforementioned obstacles and may be readily adapted to other courses and engineering disciplines to achieve ethics education across the engineering curriculum. Implementation of this ethics module in biomedical engineering courses led to measurable and significant improvements in students' ethical problem-solving skills. In addition to providing an effective and measurable way to improve student understanding of ethical problem-solving, this module can be implemented by instructors who do not have formal training in ethics and smoothly integrated into a course's tight schedule. Lastly, we discuss our communication of this ethics module to engineering instructors and their responses with respect to likelihood of adopting this module into their own courses.

A. Background

A Glance at the Numbers

Before we begin to talk about the details of our research, it is important to understand the context in which we are working. The University of Wisconsin-Madison is a Research I institution, with an overall student population of 40,000, and a sizable College of Engineering consisting of approximately 4,500 students. A recent national study listed the UW-Madison as having the 2nd highest research expenditures of any US college or university, at roughly $830 million over the past year.[1] That amounts to an average of over $400,000 per faculty member in an era when funding rates tend to be decreasing. The pressures to continue that achievement – and to produce the high quality research on which such funding depends – are enormous. Thus, while education is certainly an important component of the university (particularly given its status as a land-grant, public university), it is hardly the only one, and there are many faculty for whom research takes priority over education. This is particularly the case for certain educational topics, such as ethics, that are considered to fall outside of their immediate subject area or expertise.

The Engineering Curriculum

In a positive step toward achieving an emphasis on ethics in the engineering curriculum, the Accreditation Board for Engineering and Technology (ABET) now requires that all engineering bachelor's degree graduates possess "an understanding of professional and ethical responsibility."[2] Furthermore, several other ABET criteria emphasize the need for students to understand the technical aspects of engineering in a broader context that includes safety, sustainability, and other issues closely related to engineering ethics.

Although ABET identifies the necessary outcomes for engineering graduates, rather than the necessary coursework, the reality is that engineering programs are still structured around the courses and credits that make up the curriculum. Most American undergraduate engineering programs are roughly 120-148 credits, or at least 4.5 years long, and many of those credits are specified; ironically, these specifications often arise from the same ABET criteria that encourage breadth. In short, US engineering programs allow little room for adding courses.

One other characteristic of US engineering schools is important to note: engineering faculty, perhaps more than faculty in some other fields, are trained to be convinced by data, particularly quantitative data. As a result, many are uncomfortable with the notion of teaching and assessing ethics, which to many seems to be an impossibly qualitative and uncertain discipline.

ABET's requirement that our graduates possess an understanding of professional and ethical responsibility is helpful as a starting point, but overly vague when it comes to guiding pedagogy and assessment. Thus, we have developed for our students three main desired and measurable outcomes. For the purposes of this paper, we will focus on the last of these three, although the instructional module we describe supports the first two as well.

Desired Student Outcomes

- An awareness of types of dilemmas faced by engineers
- A familiarity with resources available to help resolve dilemmas
- An ability to identify a range of possible and appropriate solutions (moral imagination[f] and judgment)

The Liberal Education Division of the American Society for Engineering Education issued a white paper in 2002 proposing a set of goals for ethics instruction. Their goals related to "ethical reasoning" are compatible with those listed above:

- An ability to identify stakeholders in an engineering solution
- An ability to identify moral problems and dilemmas
- An ability to analyze moral problems from different ethical perspectives.[3]

One important commonality in these two sets of outcomes is that they do not stress whether students are ethical, but rather emphasize students' ability to identify and respond to ethical dilemmas. Put another way, the desired outcome is that students possess analytical skills rather than that they engage in particular [ethical] behaviors. This approach is in keeping with that identified by Pfatteicher as "teaching vs. preaching" about ethics.[4]

B. Goal of this Study: Lower the Barriers to Integrating Ethics across the Engineering Curriculum

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[f] "Moral imagination" is defined by Mark Johnson in his book *Moral Imagination* (Chicago: University of Chicago Press, 1993) as "an ability to imaginatively discern various possibilities for acting within a given situation and to envision the potential help and harm that are likely to result from a given action." Patricia Werhane has elaborated on the concept to include the notion of moving beyond one's assumptions and "striving for fresh points of view." Patricia Werhane. "A note on moral imagination" (Darden Case Bibliography UVA-E-0114): Colgate Darden Graduate School of Business Administration, University of Virginia (1996).

Although courses devoted to the study of professional ethics exist on campus, the prevailing approach to introducing ethics in the University of Wisconsin-Madison College of Engineering relies heavily upon individual instructors to develop modules to suit their syllabi. And, while many engineering instructors have a strong desire to incorporate ethical discussions and problem-solving activities into their courses, there are many challenges to doing so, including:

1) the difficulty of finding out the 'best' ways to teach these topics and subsequent development of new course materials
2) the need expressed by engineering faculty for instructional modules to have quantifiable, measurable outcomes
3) instructor hesitancy to teach about issues in which they may have little or no training
4) already-packed syllabi that allow little room for introduction of new (and non-technical) topics
5) the challenge of identifying relevant and appropriately scaled case studies.

To be successful in incorporating ethics across the entire engineering curriculum, it is necessary to address these obstacles facing engineering instructors at our institution. Moreover, there is a need to allow autonomy for individual instructors while assessing the student learning outcomes in a way that can be consistently and concisely reported to the accreditation agency and to administrators. Thus, this paper describes a module and an accompanying assessment mechanism developed by the authors for courses in biomedical engineering that can be readily adapted to other courses and disciplines. *The overall goal of this work is to develop an introductory-level instructional module in ethical problem-solving that lowers the barriers to integrating ethics instruction into engineering courses*. Our study is divided into three sub-studies in order to address this goal and the first four aforementioned challenges (we will address challenge #5 later in the paper):

Sub-study 1: Identify an efficacious approach to presenting ethical problem-solving to engineering students and develop corresponding assessment mechanism (addresses obstacles 1 and 2)

Sub-study 2: Optimize the ethical problem-solving instruction module to meet the time constraints of engineering courses and overcome the lack of instructor expertise in ethics education (addresses obstacles 3 and 4)

Sub-study 3: Investigate whether this ethics instruction module meets the needs of engineering instructors who currently feel challenged by the aforementioned obstacles

C. Sub-study 1: Identifying efficacious instructional approach and corresponding assessment mechanism

C.1. Methods for Sub-study 1

The study participants consisted of two groups of junior- and senior-level undergraduate students enrolled in the Biomedical Engineering degree program at the University of Wisconsin-Madison. Both groups of students received similar 30-minute lectures on ethics and ethical problem-solving, and were then asked to complete a 20-minute quiz which required them to formulate solutions to an ethical problem relevant to biomedical engineering. An example of an ethical problem used in these quizzes is given below:

An example problem

You are working in a lab on a project that involves the use of human embryonic stem cells (hESCs) – your research project is to study cellular differentiation in order to better understand and control its mechanisms. You are NIH-funded, meaning that you are constrained to using only the federally-approved hESC lines. Unfortunately, these cell lines are pretty much unusable, and being constrained to these unusable cells greatly inhibits your research progress, which also significantly hinders your ability to make research advances that will help sick people. You know that others in the lab next door are working with private funds on newer, more usable hESC lines. You doubt that their private donor would be interested in funding your specific project, since it will take a long time for your work to be made into a commercially marketable product. You also know that absolutely no one would notice if you started using some of the new (non-federally-approved) hESC lines in your experiments instead of your current cells.

What action should you take? You want to meet your research goals, serve the public good, and obey the law, but these goals seem to be opposing one another.

One group of students (n=46, designated Control Group) was given this question as written above, without any specific instructions to guide them through the ethical decision-making process. Meanwhile, the second group of students (n=16, Experimental or DISORDER Group) was asked to address this ethical problem by following an ethical problem-solving framework known as DISORDER.

A Framework for Ethical Problem-Solving

In 2006, we developed a module to assist students in developing elementary ethical problem-solving skills, and drew heavily on a mnemonic device crafted in 1998 by Professor Lisa Newton.[5] The word DISORDER signifies an 8-step process for reasoning through an ethical problem, as follows.

- Dilemma[f] – *define it.*
- Information – *acquire it.*
- Stakeholders – *identify them.*
- Options – *explore them.*
- Rights/Rules/Results – *consider them.*
- Decision – *make one.*
- Effects – *evaluate them.*
- Review & Reconsider – *to improve the current situation and to learn from it.*

One clear advantage of this process is that it gives students a clear and structured path to follow. A less obvious advantage is that the steps mirror the engineering design process, with which many of our students are already familiar.[6]

[f] It should be noted that, throughout this paper, the word 'dilemma' is intended to mean 'a difficult situation or problem,' and is not limited to its strict and dichotomous definition.

C.2. Results of Sub-study 1: Engineers like DISORDER

Student responses to the ethical dilemma were categorized according to the complexity of the answer. For instance, the ethical problem presented above has two 'extreme' solutions – 1) continue using the current, uncooperative cells, or 2) start using hESCs from the lab next door – that were immediately recognized by all students taking the quiz. Solutions other than the aforementioned options were deemed to be 'alternative' answers, and included options such as:

- "apply for private funding, after finding out how you can make your research more attractive to private donors"
- "try to obtain better hESCs that are also approved for use with federal funds"
- "use your current funding to research how to make your current hES cell line better"
- "lobby legislators for support in changing laws, and hire lawyers to find out if law is being interpreted correctly"

Using these classifications for student answers, the following results were obtained:

Table 1: *Comparison of free-form to DISORDER-based answers*

	Control Group	**DISORDER Group**
% of students with 'alternative' answers	34.8%	92.9%
Average # of alternative solutions/student	0.37	1.7
% of solutions that were alternative	18.1%	49%
% of final solutions that were alternative	13.3%	83.3%
% of final solutions that were illegal	13.3%	0%

As evidenced by the data in Table 1, use of the DISORDER ethical problem-solving framework enabled students to generate more complex answers and exhibit greater moral imagination. These results demonstrate that providing students with a structured approach to analyzing ethical problems – particularly one that mirrors the engineering design process with which they are already familiar – enabled students to develop a broader range of potential solutions and to resolve problems in a more complex fashion than those students who received more open-ended instruction. The data were also analyzed with respect to gender, and no significant differences in answer complexity existed between male and female students.

Because these studies were performed in a post-hoc manner, the number of participants in each group was not equal. However, the data are sufficient to still make statistically significant conclusions, as the number of alternative solutions/student in the DISORDER group was significantly higher than that in the control group ($p<0.001$ using unpaired, two-tailed t-test).

The method of assessment used to analyze these quizzes provided measurable outcomes. This type of quantitative data is desired for accreditation purposes, but may also prove useful in persuading other faculty to recognize the value and efficacy of this approach to ethics instruction. Because the data in Table 1 clearly demonstrate that use of the DISORDER framework is an effective way to engage engineering students in meaningful ethical problem-solving exercises, our next step was to address the remaining two obstacles facing engineering instructors with respect to ethics instruction, namely the time constraint of introducing new material into their courses and lack of instructor expertise in ethics instruction.

D. Sub-study 2: Optimizing the ethical problem-solving module to meet the time constraints of engineering courses and overcome the lack of instructor expertise in ethics education

D.1. Methods for Sub-study 2
For this study, we expanded our pool of participants to include a group of Biomedical Engineering students who had not participated in Sub-study 1. These students (n=9) were given a brief, 5-minute overview of the DISORDER framework, followed by the same 20-minute quiz described for the DISORDER group in Sub-study 1. Student responses were categorized and analyzed as described earlier.

D.2. Results of Sub-study 2: Paring down DISORDER with little consequence
As shown in Table 2, reducing the ethics background instruction to a simple 5-minute overview of the DISORDER framework did not negatively impact student performance on the ethics quizzes. The short overview of the DISORDER process provided enough information to maintain the complex problem-solving skills elicited by the full-length ethics and DISORDER lecture.

Table 2: *Student outcomes after shortening the DISORDER-based module*

	Full DISORDER	**Short DISORDER**
% of students with 'alternative' answers	92.9%	85.7%
Average # of alternative solutions/student	1.7	1.86
% of solutions that were alternative	49%	50%
% of final solutions that were alternative	83.3%	85.7%
% of final solutions that were illegal	0%	0%

The reason for paring down the length of the DISORDER presentation was to make this instructional module more attractive to engineering instructors who may be concerned about the class time and expertise needed to include ethics in their courses. Because the shortened version of DISORDER remains as efficacious as the full-length version with respect to our evaluated outcomes, we hope that we have addressed the obstacles of expertise and time constraints. However, to truly gauge our success in overcoming these barriers to incorporating ethical problem-solving instruction in engineering courses, it is necessary to investigate the response of other engineering faculty to this instructional module.

E. Sub-study 3: Investigating whether this ethics instruction module meets the needs of engineering instructors who currently feel challenged by the aforementioned obstacles

E.1. Methods for Sub-study 3
An informal, 30-minute presentation was prepared for an audience of instructors (n=9) who teach in STEM (science, technology, engineering, and math) disciplines at the University of Wisconsin-Madison. The presentation contained a description of the DISORDER-based ethics instruction module, in addition to the results presented herein for Sub-studies 1 and 2. Following the presentation, instructors were surveyed on:

- their self-reported understanding of DISORDER
- whether they felt this module would be helpful to students

- the degree to which they felt the DISORDER module addressed four of the aforementioned barriers to ethics instruction
- the likelihood that they will adopt the DISORDER-based module into their courses

All survey questions were on a scale of 1-5, with '5' representing the 'strongly agree' or otherwise strongly positive response.

E.2. Results of Sub-study 3: Positive instructor attitudes toward DISORDER

As evidenced by the data in Table 3, instructor attitudes toward the DISORDER-based ethics module were very positive. Instructors generally agreed that the module successfully addressed several barriers that typically inhibit incorporation of ethics into engineering courses, and indicated that they would be interested in adopting this module into their own courses.

Table 3: *Instructor responses to DISORDER module*

Question	Score
How well understood?	4.5 /5
Helpful to students?	4.3 /5
Barrier: Limited time	4.2 /5
Barrier: Instructor expertise	3.6 /5
Barrier: Measurable outcomes	3.8 /5
Barrier: Improved outcomes	4.6 /5
Likelihood of adoption	3.9 /5

The strongest positive response from instructors was in the area of whether the DISORDER-based module successfully enhanced student performance in ethical problem-solving. However, we also note that instructors perceived this module to be less effective with regards to addressing the barrier of 'lack of instructor expertise'. In discussion and written comments, several instructors expressed a desire to be provided with appropriate case studies for their specific courses before they would feel comfortable introducing any ethics instruction.

F. Discussion

We can assess our project in two ways. One is to determine the extent to which we have overcome the challenges faced by engineering faculty as they consider whether and how to incorporate ethics into their classes, while the other is to determine the extent to which we have helped students to develop in these areas.

With respect to instructional challenges, the results of our sub-studies demonstrate that we have made advancements toward overcoming some of the obstacles faced by instructors in introducing ethics across the engineering curriculum. Specifically, the abbreviated version of the DISORDER-based ethical problem solving module was effective in generating improved, quantifiable student outcomes compared to open-ended ethics questions, and implementing this module required little class time or instructor expertise. Upon presenting this module to a faculty audience, a fifth obstacle arose: identifying relevant and appropriately scaled case studies for use in ethics discussions. Thus, future directions for our work include pairing this instructional module with case studies from a variety of disciplines, or combining this work with the case studies available at sites such as the National Academy of Engineering's Online Ethics Center (www.onlineethics.org). In this manner, we will not only address the remaining challenges of instructor expertise and identification of appropriate case studies, but also broaden the applicability and availability of this work to disciplines beyond Biomedical Engineering.

With respect to student outcomes, we noted above that our desired outcomes were:

- Awareness of types of dilemmas faced by engineers.
- Familiarity with resources available to help resolve dilemmas.
- Ability to identify a range of possible and appropriate solutions (moral imagination).

With respect to increasing students' awareness of the types of dilemmas faced by engineers, this module is limited by the length of the presentation given to the students. In an hour-long version, some attention can be paid to the variety of situations in which engineers might find themselves. In the short version, students will be exposed only to the case study being used. However, it must also be remembered that the ultimate goal of this work is to define a module that can be easily integrated across *many* engineering courses. Thus, while a single dose of the DISORDER module exposes students to only a small range of ethical problems, administering this module only once in the curriculum is not the intended goal. The implementation of this module across several courses will greatly expand the exposure of students to a wide range of ethical problems, thereby addressing the first learning outcome.

As for improving students' familiarity with the resources available to them, the module is again limited. In the short version, DISORDER is the only explicit resource provided to the students. Any of the versions can be supplemented by distributing a handout with lists of ethics codes, relevant websites, and people to contact for additional information and guidance.

On the third outcome, however, of helping students to identify a range of possible and appropriate solutions (in other words, helping them to develop their moral imagination) is where the module has the biggest effect. Ironically, the structure of the DISORDER device supports students' efforts to think creatively about approaches to ethical problem solving, and the effects do not seem to be affected significantly by the length of the presentation.

Finally, in revisiting the goal of our study, it is important to note that this module is not intended to compete with or take the place of a thorough education in engineering ethics and ethical problem-solving. Instead, we are presenting this method as a means to achieve ethics across the engineering curriculum, particularly in our research-based institutional context. Integrating ethics discussions throughout the engineering curriculum reinforces to students that ethics and engineering are closely intertwined, and helps to prepare them for the decisions they will make in their future careers. The success of the DISORDER module encourages us to continue offering it in our own courses, and the feedback from faculty suggests that expanded use throughout the engineering curricula on the University of Wisconsin-Madison campus is a promising way to address the challenges posed by our accreditors and our institutional context.

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