

Problem Solving in Engineering and Ethics: Points of Intersection

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Introduction

Ethics can be intimidating: as one of the ancient fields of study, it has a substantial body of literature, employs a complex vocabulary, and seems to be rather ethereal and subjective. Whether students take stand-alone courses, in or out of the engineering/technology department, or instructors use an ethics across the curriculum approach, the general feeling among students, according to Jonassen et al's recent *Journal of Engineering Education* article, is that "the study of ethics is irrelevant and therefore a waste of time, and that their time would be better used learning more engineering."¹ Instructors thus may feel trapped in a catch-22, required to meet an ABET criterion that might result in student disinterest and ennui.

Rather than spending valuable class time trying to convince students of the importance of ethics, the creative instructor may take a different tack, to present ethics as a part of engineering by focusing on the similarities in problem solving. For ethics, like engineering, is a field that requires creativity and critical analysis to solve open-ended problems, and appropriate engineering decisions may hinge on ethical considerations.

This paper focuses on the convergence of problem solving in ethics and engineering. Specifically, it examines challenges, problem-solving strategies, and applications.

Meeting Challenges

As a 10-year veteran of teaching a course in professional ethics, I have identified three areas that may frustrate students as they embark on their initial foray into ethics. Effectively addressing these concerns will help students better understand the ethical dimension of engineering as well as appreciate the problem-solving process involved.

Language

As in any academic discipline, philosophy has a rich technical language. Because the field dates back some 2,500 years, its vocabulary is quite sophisticated and precise, which may be a source of frustration or even irritation to students, especially considering the rather frightening fact that the average reading level of college students in the United States is grade 9.6.²

The language of philosophy is multisyllabic. Words are long and foreign to a technical novice audience: “deontology,” “utilitarianism,” “consequentialism,” for example. But these words encapsulate philosophical theories, which may be used in analyzing and solving a particular ethics problem. As such, students need to become familiar with definitions and usage and resist the impulse to skip over big words.

I have found it helpful to point out that the field of engineering also has a dense technical language with long, precise words, such as “thermodynamics” and “concatenation,” which may intimidate a novice. As in ethics, knowing the vocabulary is essential for understanding the underlying concepts, which, in turn, determine design decisions.

In fact, even in everyday communications, such as IMing or texting, students use a whole host of acronyms and shortcuts, which comprise a technical vocabulary: “LOL” [“laugh out loud” or “lots of love,” depending on context], “l8t” [“late”], “gnblfy” [“got nothing but love for you”].³ Like a reader new to Kant, a beginning texter may find this terminology confusing and obscure.

Abstraction

Because of the language and the highly theoretical nature of many philosophical treatises, students may have difficulty with the level of abstraction. A reader of philosophy needs to work at it, not simply skim over material while simultaneously checking Facebook, IMing several friends, and watching television. Ethics articles require concentration and re-reading to grasp the concepts.

A common refrain from students reading original works, such as contemporary philosopher Peter French’s “Corporate Moral Agency,”⁴ is “Why doesn’t he just say what he means? Why does he keep repeating himself?” Such comments indicate a need for learning how philosophers write. The basic mode is argumentation, as it is in numerous engineering documents,⁵ and to develop a position, writers take a concept, toss it in the air, examine it from multiple perspectives (a technique called the “moral imagination”⁶), and finally settle on a possible solution, which is supported by the broader theories and principles.

While this approach differs dramatically from the explanations in a typical engineering textbook, theoretical writings in the technologies and sciences pose a similar level of abstraction: reading and comprehending Einstein is no picnic, and neither is tackling something titled *Designed Polymers by Carbocationic Macromolecular Engineering: Theory and Practice*.⁷

The point here is that all fields present a level of abstraction that is confusing and somewhat frustrating to a newcomer. But students who exhibit intellectual curiosity and commitment, as well as perseverance, can develop familiarity with a new field.

Subjectivity

Typically, within the first week or so of ethics studies, students begin to complain about the “subjectivity” of ethical decision-making, a result of their own misperceptions: at this early stage, they see ethics more as personal preferences, based on their own upbringing, and feel uncomfortable with the qualitative nature of the field, as opposed to the perceived objectivity of engineering.

Bourgeois and Olds, biomedical engineering educators at Northwestern University, conducted a classroom experiment that included queries regarding subjectivity in ethics. They administered a short survey prior to an ethics case analysis in a technical class, and about two-thirds of the respondents indicated that ethics is subjective. In a post-case survey, less than one-half noted subjectivity as a factor.⁸ While this is a preliminary study, it does verify what I have observed in the classroom over the years.

Introducing professional and corporate codes of ethics, as more “objective” measures, is helpful. Professional codes explain behavioral expectations for the practitioner, and corporate codes are very specific regarding performance within a particular firm. Clear expectations allow students to see a less subjective side to ethics and, subsequently, make decisions relatively uncluttered by personal values.

Using a case-based methodology can also help students perceive the more “objective” side of ethics and the problem-solving process. Using real problems, rather than hypothetical textbook cases, is essential for illustrating complexity, even with “easy” cases.

A major benefit of cases is that they require students to exercise the higher-level thinking skills of Bloom’s taxonomy: analysis, synthesis, and evaluation.⁹ To offer a better reflection of cognitive processes, the most recent revision of the taxonomy rearranges the topmost skills to include creation: analyze, evaluate, and create.¹⁰ In a problem-solving context, these skills involve rigorous examination of the problem as well as the ability to develop multiple potential solutions. The ability to think is crucial for the process in any field. As James Stice wryly comments, developing aptitude in clear thinking is much more important than acquiring technical skills: while technical skills come and go, students “will have to think . . . for the rest of their lives.”¹¹

Problem-Solving Strategies

Perhaps the most obvious common denominator between engineering and ethics lies in the process of problem solving. Both fields use similar strategies to identify problems, generate and test solutions, and make decisions. As engineering ethicist Carolyn Whitbeck explains, open-ended engineering design problems are highly analogous to those problems requiring ethical analysis in that both exhibit similar characteristics of

multiple variables, potential solutions, and constraints, as well as a discernable level of ambiguity. Moreover, positioning ethics in the realm of design circumvents the temptation to view ethics as a multiple choice venture, rather than one that involves creativity and the moral imagination.¹²

Donald Woods, emeritus professor at McMaster University, has written widely on problem-solving methods. In analyzing more than 150 plans in fields as far flung as architecture, nursing, and music, he notes that many are simply based on instructor preference, not evidence, even though they exhibit similar characteristics, such as problem identification. A well-reasoned strategy, he maintains, is essential for the development of problem-solving skills, as well as providing a natural structure for the process, supplying a common language for communication purposes, and increasing student confidence.¹³

A good problem-solving strategy, according to Woods, entails a consideration of multiple criteria, including flexibility, usefulness, ease of explanation and implementation, and clearly identifiable stages. It emphasizes the application of cognitive and attitudinal skills, such as focus, organization, description, interpretation.¹³

Early in their education, all engineering and technology students are exposed to a problem-solving method, which they then refine as their education progresses. By the time they near the end of the college experience, the process is firmly entrenched: students have developed significant interpretive and evaluative skills through repeating the problem-solving process. In addition, the iterative nature of the process necessitates serious and close examination of several potential solutions.

Because of significant similarities in engineering and ethics problem-solving processes, as students approach ethics-related problems, they can effectively employ familiar skills to explore solutions to less concrete, qualitatively-based situations. Table 1 shows the similarities between problem solving in the two fields, using two representative frameworks that meet Woods' criteria for effective strategies.

Table 1. Typical problem solving strategies

Engineering¹¹	Ethics¹⁴
Define	State problem
Think about it	Check facts
Plan	Identify relevant factors Develop list of options
Carry out plan	Test options Make a choice
Look back	Review

Attention to specific steps may differ in the two fields. Engineers may apply more quantitative techniques whereas an ethicist engages in extensive questioning:

1. After stating the problem, it is important to investigate it. A closer examination of the problem may alter it dramatically or it may disappear altogether. Is the problem really a problem or merely a disagreement? Is it a conflict?¹⁵ Is it a policy or ethics code violation?
2. Identifying who or what the problem affects is essential: What people, agencies, or organizations are involved? Are professional codes relevant? What laws are pertinent? Who or what is responsible and accountable?
3. Developing a list of options is similar in both fields, with an emphasis on creativity.
4. The greatest difference in the two fields occurs in the testing stage. Whereas an engineering approach probably requires quantitative procedures, using statistical analysis or other numerical methods, testing in ethics touches upon several areas and is mainly concerned with pinpointing impact on identified others. The strategy from Illinois Institute of Technology's Center for the Study of Ethics in the Profession presents the most comprehensive testing phase of the numerous plans available for ethical decision-making:

Harm: Does this option do less harm than any alternative?

Publicity: Would I want my choice of this option published in the newspaper?

Defensibility: Could I defend my choice of this option before a Congressional committee or committee of my peers?

Reversibility: Would I still think the choice of this option good if I were one of those adversely affected by it?

Colleague: What do my colleagues say when I describe my problem and suggest this option as my solution?

Professional: What might my profession's governing body or ethics committee say about this option?

Organization: What does the company's ethics officer or legal counsel say about this?¹⁴

A matrix approach is useful for engineering students, as verbal abstractions may not be regarded as "practical." William Frey, University of Puerto Rico at Mayaguez, has developed several matrices for evaluating alternative solutions that include typical engineering concerns, such as constraints on resources (time, cost, money) and technology (applicability, manufacturability).¹⁵

Making and implementing a choice is not the end of the process; the "Review" step is essential. In ethics, it involves what could be done differently next time to avoid a similar situation, such as precautions an individual can take or effecting a policy change in the organization.¹⁴

Applications

Deciding how to apply the problem-solving strategy depends on how an instructor integrates ethics instruction. In a course that focuses on technical material, small cases—those stemming from typical engineering practice—are probably more appropriate than larger cases, such as the Challenger or Bhopal disasters, simply because of the time factor involved. Another consideration is what students will actually *do* after graduation; the chance that they will be involved in a Challenger-scale event is probably negligible, and therefore students may find that more mundane situations, such as colleagues stealing company supplies or breaching confidentiality, to be more relevant to their careers.

Instructors must make several decisions regarding the nature of the ethics problems presented:

- Is the focus macro (related to engineering in general) or micro (involving an individual engineer)?¹⁶
- Is the problem simple (fairly straightforward, with one right solution) or complex (problems within problems)?⁵

- Is the pedagogical method passive (contained within a lecture) or active (engaging students via general discussion or small groups)?
- Is the problem issue-oriented (*e.g.*, privacy) or action-oriented (*e.g.*, whistleblowing)?
- Is the problem real or hypothetical?

For the purposes of example, this short, real software engineering case, adapted from Martin and Schinzinger's engineering ethics text, can be used to illustrate the concept of confidentiality:

An engineer working as a computer programmer plays a minor role in developing a computer system for a state department of health. The system stores medical information on individuals identified by name. Through no fault of the programmer, few controls are placed on the system to limit easy access to it by unauthorized people. Upon learning of this, the engineer first informs his supervisor and then higher management. All refuse to do anything about the situation because of the expense required to correct it.

In violation of the rules for using the system, the engineer easily obtains a copy of his own medical records. He sends them to his state legislator as evidence for his claims that the right of citizens to confidentiality regarding such information is threatened by the system.¹⁷

Small group discussion is an effective technique for engaging students in moral deliberation and emphasizes the verbal aspect of problem solving that James Stice sees as so essential to the process.¹¹ Instructors can jumpstart the process by posing salient questions, such as

- X Does the engineer's action, that is, downloading his own records and sending them to his state legislator, constitute a breach of confidentiality?
- X Is the engineer's action proper? What else could he have done?
- X What would be appropriate action for management to take, if any?

After discussing the case in small groups, students record group responses on the board. They typically suggest that the engineer has done nothing wrong, since he accessed only his own records, and indicate that management should publically commend him for his actions because he "did the right thing." (Using this scenario in a faculty ethics training session, by the way, yields similar reactions.)

Such answers indicate that further work is needed, both in regards to the laws governing privacy of medical records and to the software engineering professional code, as these responses violate both.

Applying the process for ethical problem-solving, we can define the problem as follows: to pursue his concern about lax security measures in a public health database, an engineer goes into the database, prints out his own records, and sends them to his state legislator.

This action violates company policy, as noted in the case, as well as the engineer's professional code. While an individual does, by law, have access to his/her own medical records, this engineer does not, ethically or legally, have the right to enter the database for that information. Had the engineer used the testing protocol explained above, he probably would have made a different decision regarding the best course of action. A further consideration is recalcitrant management, whose financial concerns override the moral responsibility to protect sensitive information. While it seems more logical to protect the client's information, in a capitalistic economy, putting profit before people not an uncommon occurrence.

Student groups are an amazingly fertile source of creative options for this engineer; most are more efficacious than the action he pursued:

- Do nothing (although this does not solve the problem)
- Pursue the complaint with management
- Write a letter to the legislator outlining the problem
- Download legislator's or management's records and send them off (the shock approach)
- Release information about the problem to the media (whistleblowing)

After subjecting each possibility to the tests in the IIT framework, most groups agree that either pursuing the problem with management or writing a letter to the legislator are more appropriate actions, with a higher potential for success, than breaching database security and violating company policy.

So what happened to this engineer? In reality, he was fired for his effort, for infringements of company confidentiality policy. Students, however, suggest other, more compassionate, possibilities:

- Give the engineer a warning
- Write a letter for the engineer's personnel file, reprimanding him
- Commend him for his moral responsibility in alerting a state legislator of the problem

Conclusions

Acknowledging the similarities in problem-solving strategies between engineering and ethics can help ward off student indifference and even spark interest in a field that is critical to their chosen

profession. Given the current ABET criteria, engineering and technology educators must address the broader contexts and impacts of engineering. This causes a concern that adding an ethics component may somehow detract from technical content and squander valuable class time. However, much anecdotal evidence exists for the opposite conclusion: that a consideration of ethics actually complements technical material and compels students and faculty to engage in another, related mode of thinking. Geoffrey Williamson, an ECE instructor and graduate of IIT's ethics across the curriculum seminar, offers a representative comment:

I initially feared that devoting much time to ethics would take away from the technical material. After all, it had been difficult enough to discuss all the topics already in the course syllabus. This fear proved unfounded. The course material concerning ethics enhanced the technical material; and the work I put into the "ethics part" of the course has broadened my perspective on my role as an educator of engineers.¹⁸

Engineering is, from one perspective, a delicate balancing act. According to Pantazidou and Nair, the engineer walks a fine line between the technical and the artistic, the content expert and the compassionate practitioner: "the engineer has to have the technical competence, objectivity and confidence of the expert, and the empathy and consideration

of a caregiver."¹⁹ While technical coursework produces the competence and objectivity, it is the inclusion of ethics in technical curricula that produces the empathy. Ethics, in fact, reveals the human face of engineering.

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