"Ethics in the Details": An NSF Project to Integrate Ethics into the Graduate Engineering Curriculum

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Abstract

An NSF grant is described that supports the development, assessment, and dissemination of "micro-insertions" designed to integrate ethics into the graduate engineering curriculum. In contrast to traditional modular approaches to ethics pedagogy, micro-insertions introduce ethical issues by means of a "low-dose" approach. Following a description of the micro-insertion approach, we outline the workshop structure being used to teach engineering faculty and graduate students how to develop micro-insertions for graduate engineering courses. We also explain the role that technical communication faculty and graduate students are playing as part of the grant team, specifically in developing an Ethics In-Basket that will serve as a repository for micro-insertions. Keywords: ethics, engineering curricula, content management.

Introduction

In September 2006, Illinois Institute of Technology (IIT) received a 3-year NSF grant to develop a "micro-insertion" approach to integrating ethics into the graduate engineering curriculum. The following discussion explains three components of the grant project. First, we describe the cross-disciplinary nature of the grant structure and how it incorporates contributions from engineering, ethics, and technical communication. Second, we explain the micro-insertion concept that is at the heart of the project and how it is being introduced to faculty and graduate students in engineering. Third, we outline the main features of the Ethics In-Basket, one of the main deliverables of the project.

Our hope is to make IPCC participants aware of the Ethics In-Basket as it is being developed, since it is ultimately intended as a permanent, continuously evolving resource for teaching ethics in engineering (and eventually in other technical and scientific fields).

Structure, participants, and objectives

"Ethics in the Details" is being administered by PI Michael Davis and co-PIs Kathryn Riley and Vivian Weil. Together, they represent two units at IIT: the Humanities Department (which houses philosophy and technical communication, among other disciplines) and the Center for the Study of Ethics in the Professions (CSEP, established in 1976 to promote education and scholarship in this area). In addition, the grant includes as participants 9 engineering faculty and over 30 graduate students from IIT, Howard University, and University of Illinois-Chicago.

The objectives of the grant project are as follows:

(1) to develop workshops and follow-up activities for teaching engineering faculty and graduate students how to develop micro-insertion problems that can be used in courses and in research labs;

(2) to assess the effectiveness of micro-insertion in the graduate engineering curriculum, including a comparative study of the method's effectiveness in the classroom and in a nanotechnology research laboratory; and

(3) to create the Ethics In-Basket, a content management system and Web resource for archiving and disseminating micro-insertion problems to engineering faculty worldwide and allowing faculty to contribute new problems.

Teaching ethics through micro-insertions

Educators have developed three major approaches to ethics education in engineering and science: (1) free-standing courses in ethics; (2) modules, i.e., large-scale insertions of ethics instruction into technical courses (for example, an hour-long discussion of conflict of interest or screening a pedagogical movie such as *Incident at Morales*); and (3) micro-insertions, that is, small-scale insertions of ethics instruction into technical courses, resulting in a dozen or so "ethics mini-lessons" during a

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semester, each lasting only a few minutes. "Ethics in the Details" focuses on this third approach.

CSEP's unique emphasis has been micro-insertion. Under previously funded NSF grants, Davis has, for example, taught faculty how to revise ordinary technical problems in science and engineering to bring out the ethical issues underlying such problems. Consider the section labeled "Original Version" in Figure 1, which shows a problem from a standard text in second-year thermodynamics, a course that engineering faculty describe as among the least hospitable to teaching ethics. As it stands, this problem calls for six routine calculations. There seems to be no room for ethics. Yet, with a little rewriting, this ordinary problem can become an interesting ethics problem. The section labeled "Revised Version" in Figure 1 shows how one professor of mechanical engineering at IIT rewrote it:

ORIGINAL VERSION

A vapor-compression refrigeration system for a household refrigerator has a refrigerating capacity of 1000 Btu/h. Refrigerant enters the evaporator at -10°F and exits at 0°F. The isentropic compressor efficiency is 80%. The refrigerant condenses at 95°F and exits the condenser subcooled at 90°F. There are no significant pressure drops in the flows through the evaporator and condenser. Determine the evaporator and condenser pressures, each in lbs/in^2, the mass flow rate of refrigerant, in lb/min, the compressor power input, in horsepower, and the coefficient of performance for (a) Refrigerant 12 and (b) Refrigerant 134a as the working fluid. (Moran and Shapiro, 1992)

REVISED VERSION

You work for an appliance manufacturer and are asked by your manager to produce a preliminary analysis and recommendation for a new line of electric household refrigerators. The vapor-compression refrigeration system is to provide an average cooling capacity of 1000 Btu/h and use company components wherever possible. Your company's compressors have an isentropic efficiency of about 80%, their evaporators operate between -10°F and 0°F, and their condensers operate with a saturation temperature of 95°F and (subcooled) exit temperature of 90°F. Neither the evaporators nor the condensers have significant pressure drops. Both Refrigerant 12 and Refrigerant 134a are to be considered as the working fluid. Pressure values throughout the unit are necessary to spec the plumbing and components. The required compressor input power is obviously necessary for choosing the compressor unit. The advertising department wants the annual operating cost (using $0.08/kW • h) and coefficient of performance estimates. Generate a brief report which includes your analysis, pros and cons for each working fluid, and your final recommendation.

Figure 1. Original and revised thermodynamics problem, illustrating the micro-insertion approach [1, pp. 723-724].

The analysis students must perform is identical in the two versions of the problem except for an additional one-line cost calculation in the second version. The student should find that the R-12 (Freon) unit holds a 3% advantage over the R-134a (ammonium-based coolant) unit for input power, operating cost, and coefficient of performance. This advantage must be weighed against the negative environmental impact of R-12. Using information in the text, a student could make an argument for "jumping on the environmental bandwagon" or for waiting until the ban on R-12 takes effect. Additional research beyond the text might reveal that there are differences in the cost, corrosive characteristics, and lifetime of the two refrigerants, all favoring R-12.

The chief difference between the original problem and the revised version is an enlargement of context. An abstract problem has been given a realistic context and become a "mini-design problem": The student ("you") now has to make a professional decision. The transformation of this problem provides a good example of how relatively minor adjustments to the problem can reveal its ethical dimensions. Once engineering faculty understand this example, they see that integrating ethics into technical courses need not involve bringing in anything extraneous or even a significant sacrifice of anything they are trying to do now.

How might this problem be used—without much change in the course? One way to use it (consistent with micro-insertion) is much as one would any other homework problem. In class, the faculty member just goes through the calculations for this problem as for any other, noting at the end that cost and efficiency are not the only relevant factors in making a recommendation:

> As the code of ethics says, the public health, safety, and welfare are also relevant. You need to balance risks to individuals that R-134a poses against the risk to everyone R-12 poses. Even a seemingly simple engineering decision can bring you face to face with deep questions about the environment, risk, and the definition of the public health, safety, and welfare.

The class then goes on to the next problem. This "low-dose" approach to ethics instruction takes almost no extra class time.

By integrating the resulting problems into their courses, faculty can provide students with repeated "low doses" of ethics in each course and, with proper planning, throughout an integrated curriculum. While CSEP has also done work on a larger scale—for example, developing discrete modules that might require a day or week of a technical class—it is commonplace for faculty to resist giving over that much time, in that large a chunk, to do ethics. Micro-insertion fits the technical curriculum in a way the larger-scale approaches to ethics do not.

Micro-insertion has two other advantages. First, it treats ethics as a routine part of ordinary engineering and science, not as something that occurs rarely and comes labeled as "ethics." Students get used to seeing every problem not only as a technical problem but also as a potential ethics problem. Second, there is reason to think that many of the complex, dramatic, large-scale ethical problems that have become common modules began with smaller decisions that (if they had been handled differently) could have prevented later, larger problems. The assumption is that micro-insertion helps students learn how to prevent those larger ethics problems by attending to the smaller, day-to-day ethical decisions that often lie at their origin.

In short, the micro-insertion or "small-dose" approach to ethics has three properties:

- It is integrated throughout a course (rather than being presented as a discrete module at only one point in the course).
- It is based on modifications of small-scale technical problems.
- It emphasizes ethical issues that professionals confront in the course of their daily activities and are therefore easier for students and novice professionals to imagine themselves encountering.

Workshop on developing micro-insertions

To learn how to create micro-insertions, engineering faculty and graduate students selected by them attend a 1-day (8-hour) workshop at the beginning of the semester. A typical workshop contains 4 engineering faculty and 8 to 12 graduate students. The graduate students selected are those who will be serving as teaching assistants with the faculty member during the coming semester. Participants come from a variety of engineering areas, such as biomedical, civil, electrical, and mechanical engineering. Davis leads the workshop, using materials that he created as a guide. First, he gives an overview of teaching ethics in engineering courses. Then workshop participants practice creating ethics micro-insertions for existing engineering problems and receive feedback from the group on their micro-insertions.

Teaching ethics

The first hour of the workshop focuses on the general "what" and "how" of teaching engineering ethics. For the purpose of the workshop, ethics is defined as any set of *morally permissible* standards of conduct that each member of some particular group wants every other member of the group to follow, even if everyone else's following them would mean having to follow them too. Davis outlines the four aspects of teaching ethics:

1. Raising ethical sensitivity,
2. Adding to ethical knowledge,
3. Improving ethical judgment, and
4. Increasing ethical willpower (commitment).

Instructors may raise ethical sensitivity by regularly bringing up questions or stories about ethical problems encountered in the engineering field. Instructors can add to students' ethical knowledge by introducing them to and testing their knowledge of codes of ethics as well as by assigning problems with difficult ethical issues and requiring students to consult practitioners for advice. The first part of improving students' ethical judgment is to require them to provide both a written or oral solution to an ethics problem and support for their decision. The second part is addressing the advantages and disadvantages of each student's solution.

Increasing students' ethical willpower—i.e., the likelihood that the decision-maker will act as he or she thinks is right—can be difficult but is possible. For example, instructors can emphasize that most people in their profession want everyone to act ethically. Instructors can also introduce students to organizations or departments that will provide individuals support when they face ethical dilemmas, such as a professional society, government agency, employer's legal department, or an advocacy group.

Rewriting engineering problems to include an ethical component

About 5 hours of the workshop are dedicated to the process of writing ethics micro-insertions for existing engineering problems. First, Davis explains how an example problem (such as the text labeled "Original Version" in Fig. 1) can be revised to include an ethics micro-insertion. Next, everyone looks at other examples of original problems and brainstorms ways to incorporate ethics. Then, participants are given the opportunity to revise engineering problems that they have brought with them, first in small groups and then later individually. Everyone presents their original and revised problems to the whole workshop, and participants critique one another's work. To aid participants, Davis offers some general advice on creating ethics micro-insertions.

The basic steps and guidelines involved in creating an ethics micro-insertion can be summarized as follows.

- **Decide what aspect of teaching ethics should be addressed.** For example, is the aim to raise ethical sensitivity or improve ethical judgment?
- **Identify an appropriate ethical issue.** There are many ways to find an ethics issue relevant to a course. Ethics topics can be found in codes of ethics, texts on the profession's ethics, newspaper articles, novels, and stories about the profession. Instructors can ask themselves, other professionals, and students what ethics problems have arisen at work. Faculty and graduate students can also look at existing engineering problems that require technical judgment and ask themselves how an activity or decision could harm someone or embarrass the profession. The Website of the CSEP at IIT also offers examples of how people

who attended other ethics workshops have incorporated ethics into engineering and other fields [2].

- **Design a problem or exercise to measure the chosen aspect of ethics.** For example, if the purpose is to improve ethical judgment, students must provide a solution to an ethical problem and explain their rationale.
- **When possible, include choices in the problems that have different ethical consequences.** Students should be able to consider the pros and cons of different options for the individual, the company, and the consumer/public.
- **Make sure students have been taught about the type of ethical issue in the problem or exercise.** Students may perform poorly if they have had little or no experience with the kind of ethical problem covered in the exercise.
- **Use a problem or exercise format appropriate for the class.** For example, if most problems are calculations, try to put the ethics micro-insertion into a calculation. The ethics should be continuous with the subject matter of the course, not something that dropped in from another world. Essays may be inappropriate if the faculty member does not feel comfortable grading them or does not have the time to grade them because of a large class size.
- **Add human dimensions to the problem.** For example, using the second person ("you") will make the problem seem more real to the student being addressed: "Which option would you choose?" instead of "Which option should the company choose?"

Fig. 2 illustrates a problem that was revised on the basis of this advice to include an ethics micro-insertion.

Grading ethics problems

Because many engineering faculty and graduate students have little experience in grading ethics problems, Davis dedicates part of the workshop to this skill. He advises participants to keep grading simple. For example, one can count the number of issues in answers to sensitivity problems and count the number of appropriate resources referenced in answers to knowledge problems. For essays, the number of discriminations should be kept small. Davis also suggests using the Pittsburgh-Mines Engineering Ethics Assessment Rubric [3].

Following the 8-hour workshop, faculty and their graduate students proceed to develop micro-insertions for problems in the courses that they are teaching during that semester.

The Ethics In-Basket: A technical communication component

A key goal of the "Ethics in the Details" grant is to develop an Ethics In-Basket, an online database of micro-insertion problems for engineering (and, eventually, for other fields of science and technology). We envision the

ORIGINAL PROBLEM

Problem:
A company is considering two sites for its new hotel. Both sites are in towns located within 50 miles of a major seismic zone and have fine-grained soil. Considering the following soil characteristics, which site would be more suitable?

Site A	Site B
Clay fraction = 25%	Clay fraction = 18%
Liquid limit (LL) = 40%	Liquid limit (LL) = 34%
Natural water content = 0.84 LL	Natural water content = 0.92 LL
Liquidity index = 0.8	Liquidity index = 0.7

Correct answer: Site A

REVISED PROBLEM WITH ETHICS MICRO-INSERTION

Aspect of teaching ethics: Improve ethical judgment

Ethical issue(s): Weighing both safety and cost

Problem:
You are responsible for helping a client choose one of two possible sites for a new hotel. Both sites are in towns located within 50 miles of a major seismic zone and have fine-grained soil. Your firm and your client have emphasized the tight budget on this project and have asked that cost play a large role in your decision-making process. Following are characteristics of each site.

Site A	Site B
Soil:	Soil:
Clay fraction = 25%	Clay fraction = 18%
Liquid limit (LL) = 40%	Liquid limit (LL) = 34%
Water content = 0.84 LL	Water content = 0.92 LL
Liquidity index = 0.8	Liquidity index = 0.7
Land cost: $50,000 higher than that of site B	Land cost: $50,000 less than that of site A

Which site do you recommend and why?

Suggested answer: I recommend site A because its soil, unlike the soil for site B, does not meet the criteria for susceptibility to liquefaction. Even though the land for site A costs a lot more than the land for site B, safety should play a larger role than cost in the decision-making process. Also, although the land costs less, the overall cost of building on site B might be higher because more soil improvements would need to be implemented to make the site safe.

Grading criteria: 5 points for choosing site A; 3 points for each logical reason for the choice of site.

Figure 2. Original problem on soil liquefaction and revised problem with ethics micro-insertion (developed by Apryl Cox).

Ethics In-Basket as an evolving resource rather than a static report. As new micro-insertions are developed, they will be added to the Ethics In-Basket, not only during the 3-year grant period but afterward. The site will be designed to allow anyone with a micro-insertion to submit it for review by the site's coordinators and eventual posting. Thus the Ethics In-Basket is envisioned as a permanent, continuously growing contribution to the infrastructure for teaching ethics in engineering and science.

In some respects, the Ethics In-Basket will build upon an existing CSEP resource that archives materials developed in previous faculty workshops on ethics across the curriculum [2]. While the Ethics In-Basket will focus on micro-insertion problems, we intend to keep and, indeed, to continue adding modules and other material as well. We believe the more inclusive the site, the more useful it will be—provided users can find what they are looking for, and that the material they find is written clearly and ready for use with students.

Because the Ethics In-Basket is a much larger and more sophisticated version of CSEP's current resource, we are especially concerned that it be easy to use and that the micro-insertions and other materials be well-written, allowing faculty access to materials they can use immediately in their classes. For example, the Ethics In-Basket database will have cross-referencing capabilities that allow interested faculty anywhere in the world to search quickly for problems by ethical issue (e.g., conflict of interest), engineering course (e.g., Perturbation Methods), topic (e.g., use of statistics), level of complexity, or some combination of these and perhaps other sorters.

The development of the Ethics In-Basket presents technical communication faculty and students at IIT with a unique opportunity to become involved in the work of the grant. Specifically, technical communication expertise is relevant to three grant activities.

Editing expertise

A technical communication graduate student (Apryl Cox) with previous editing experience is editing micro-insertion problems as they are developed by engineering faculty and graduate students. Areas of special attention during the editing process are making sure that the prose conforms to standard edited English (since many of the writers are nonnative speakers of English) and is clear to readers whose native language may not be English; checking accuracy of figures and calculations in consultation with the engineering faculty member; developing a consistent document design that can be easily adapted to a variety of problems; and working with the faculty member to develop a set of key terms for indexing the problem once it is posted to the site.

Content management expertise

Users of the Ethics In-Basket will rely especially on its navigation and search functions. Therefore, a technical communication graduate student (James Maciukenas) with experience developing another large database will address content management issues such as developing appropriate search terms and cross-indexing strategies.

Before content management strategies can be used to build successful repositories for content, the developer must use a multistage process to become familiar with the content as well as the audience for which the content is being developed. Activities involve assessing whether existing content is serving the audience's needs and where opportunities exist to develop new content such as the Ethics In-Basket. Taxonomies can be developed to discover relationships between areas of existing content, revealing potential areas for further investigation. Once the content developer has gained familiarity with the content and the audience, the developer can choose the proper system for delivering content.

Currently, many open-source and proprietary systems are available to content developers. Open-source solutions such as Drupal, Moodle, wikis, and even blogs can all be put into service to organize, maintain, and deliver content with varying degrees of complexity and ease of use. These open-source solutions provide a wide variety of features and active online user-groups. User-groups not only participate in the development of software but also offer extensive forums where users can post issues encountered when using the software. Through this process, software bugs are fixed and features are proposed and developed as updated releases of the software are offered to the community for download.

Along with open-source software, many proprietary solutions are available for content management developers. Proprietary solutions offer developers an extensive selection of features and options, and come with customer support. Unfortunately, these proprietary solutions often come with hefty price tags. For example, the institutional cost of ARTstor (a multimedia content management system investigated for another project) is approximately $25,000 for an initial setup fee, in addition to an annual subscription fee of approximately $9500.

After considering available options to implement a content management system for the Ethics In-Basket, the open-source solutions Drupal and Moodle are currently under consideration. Both Drupal and Moodle offer an extensive array of features and customization options. Test sites are being developed with sample content, and these sites will undergo extensive usability testing to determine which software will best deliver content for Ethics In-Basket users.

Usability testing expertise

To ensure the site's usability, funds were built into the grant budget to accommodate iterative design, including usability testing and evaluation. These activities will be conducted in IIT's Usability Testing and Evaluation Center (UTEC) and will involve IIT graduate students in technical communication working under the supervision of the UTEC director, Professor Susan Feinberg.

Conclusion

The micro-insertion approach to integrating ethics into the engineering curriculum represents a promising and innovative alternative to more traditional modular methods of teaching ethics. Although not discussed here, another component of the "Ethics in the Details" grant involves assessment efforts that will allow the grant team to gauge the success of the approach by means of post- and pre-testing. In addition, as outlined in this discussion, the Ethics In-Basket will offer a permanent, continuously evolving resource for teaching ethics in engineering (and eventually in other technical and scientific fields). We are excited both about the ultimate goal of the Ethics In-Basket and about the role that graduate students and faculty in technical communication are playing in its development. Our hope is to report further at future IPCC conferences and in other technical communication venues as our work on this project progresses.

References

[1] Davis, M. Integrating Ethics into Technical Courses: Micro-Insertion. *Science and Engineering Ethics*. 12:717-730, 2006.

[2] Center for the Study of Ethics in the Professions at the Ilinois Institute of Technology. Post Workshop Materials. Available: http://ethics.iit.edu/eac/post_workshop/index.html

[3] Sindelar, M., L. Shuman, M. Besterfield-Sacre, R. Miller, C. Mitcham, B. Olds, B. Pinkus, and H. Wolfe. Assessing Engineering Students' Abilities to Resolve Ethical Dilemmas. *Proc. 33rd Annual Frontiers in Education*. 3: S2A 25-31, 2003.

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