"Ethics in the Details": Communicating Engineering Ethics via Micro-Insertion

Tutorial

—Feature by
KATHRYN RILEY, SENIOR MEMBER, IEEE, MICHAEL DAVIS, SENIOR MEMBER, IEEE, APRYL COX JACKSON, AND JAMES MACIUKENAS

***Abstract*—*Work is described on a National Science Foundation grant that supports the development, assessment, and dissemination of "micro-insertion" problems 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 write micro-insertions for graduate engineering courses, with particular attention to how the grant develops engineering students' (and faculty members') ability to communicate across disciplinary boundaries. We also describe previous and planned methods for assessing the effectiveness of micro-insertions. Finally, we 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 disseminate micro-insertions developed during the grant.*

***Index Terms*—*Assessment, content management, engineering pedagogy, ethics, micro-insertion.*

Educators have developed three major approaches to ethics education in engineering and science: (1) freestanding courses, such as Ethics in Engineering; (2) modules, large-scale insertions of ethics instruction into technical courses (e.g., an hour-long discussion of conflict of interest or screening of a pedagogical movie such as *Incident at Morales*); and (3) micro-insertions, small-scale insertions of ethics instruction into technical courses, resulting in a dozen or so "ethics mini-lessons" during a semester, each lasting only a few minutes.

In September 2006, Illinois Institute of Technology (IIT) received a three-year National Science Foundation (NSF) grant to develop the third approach, micro-insertion, as a way of integrating ethics into the graduate engineering curriculum. The following discussion explains three components of the grant project, with particular emphasis on how it develops the abilities of students and faculty to communicate across disciplinary boundaries. First, we describe 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, including a description of how both groups are taught to write ethics components for engineering problems. Third, we describe previous results from assessments of micro-insertions and describe plans for expanding the assessment of this method. Finally, we outline the main features of the Ethics In-Basket, one of the main deliverables of the project, and discuss the role of technical communication in this component. We conclude by situating micro-insertions in the context of writing-in-the-discipline approaches that make use of "messy problems": that is, problems that move beyond well-structured data sets to which there is a right answer that can be arrived at algorithmically and that challenge students to engage in more complex critical thinking.

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K. Riley is with the Humanities Department, Illinois Institute of Technology, Chicago, IL 60616 USA (email: riley@iit.edu).
M. Davis is with the Humanities Department and the Center for the Study of Ethics in the Professions, Illinois Institute of Technology, Chicago, IL 60616 USA (email: davism@iit.edu).
A. C. Jackson resides in Chicago, IL 60647 USA (email: ammcox@yahoo.com).
J. Maciukenas is with the Humanities Department, Technical Communication, Illinois Institute of Technology, Chicago, IL 60616 USA (email: jmaciuke@iit.edu).
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STRUCTURE, PARTICIPANTS, AND OBJECTIVES

"Ethics in the Details" is being administered by PI Michael Davis and co-PIs Kathryn Riley and Vivian Weil. Together, these faculty members 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 participants include nine engineering faculty and over 30 engineering graduate students

> 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.

Fig. 1. Original thermodynamics problem [4, problem 10.21].

from IIT, Howard University, and the University of Illinois at Chicago. The cross-disciplinary nature of the grant, as well as its communications component, is further enhanced by the involvement of graduate students and faculty from IIT's technical communication program, as described in more detail below.

The objectives of the grant project are as follows:
(1) to develop workshops and follow-up activities for teaching engineering faculty and selected engineering graduate students how to write micro-insertion problems that can be used in engineering courses and 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.

BACKGROUND: THE MICRO-INSERTION APPROACH TO TEACHING ETHICS

The micro-insertion approach is one that has been the unique emphasis of CSEP since the early 1990s. Under previously funded NSF grants during this period, Davis has taught faculty how to revise ordinary technical problems in science and engineering to bring out the ethical issues underlying such problems [1]–[3]. Consider the problem in Fig. 1, which shows an early micro-insertion problem developed 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. Fig. 2 shows how one professor of mechanical engineering at IIT rewrote it.

The analyses that students must perform in the two versions of the problem are identical, except for an additional one-line cost calculation in the revised 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, decontextualized problem has been given a realistic context and become a "mini-design problem": The student ("you") now has to make a professional decision within a larger context that considers the long-term consequences for those affected by the decision. The transformation of this problem provides a good example of how relatively minor adjustments to a 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 extraneous material 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 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

> 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.

Fig. 2. Revised thermodynamics problem, illustrating micro-insertion of ethics component (as modified by John Way, a faculty member in IIT's Department of Mechanical, Materials and Aerospace Engineering).

in making a recommendation. For example, the faculty member might include a comment such as the following:

> As the code of ethics says, the public's 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 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 a series of micro-insertion 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 developed larger-scale ethics components—for example, 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 discuss ethics. Micro-insertion fits the technical curriculum in a way that larger-scale approaches to ethics do not.

Micro-insertion has two other advantages. First, by introducing ethical issues frequently throughout the curriculum, it treats ethics as a routine part of ordinary engineering, not as something that occurs rarely and comes labeled as "ethics." In contrast to approaches that set ethics aside as somehow separate from engineering content (e.g., the "Ethics Day" approach), micro-insertion gets students 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 "ethics modules" began with smaller decisions that (if they had been handled differently) could have prevented later, larger problems (e.g., [3]). The assumption is that micro-insertion helps students learn how to prevent those larger ethics problems by recognizing and attending to the smaller, day-to-day ethical decisions that often lie at their origin.

In short, the micro-insertion 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.

TEACHING FACULTY AND STUDENTS TO WRITE MICRO-INSERTIONS

A well-known proverb says, "Give a man a fish, and you have fed him for today. Teach a man to fish, and you have fed him for a lifetime." In a similar way, one of the central purposes of the current NSF grant is to teach engineering faculty and graduate students to write their own micro-insertions, either by modifying existing engineering problems or by constructing original problems. The long-term goal of this grant activity is to generate three waves of micro-insertion development. The first wave consists of instruction conducted in grant-funded workshops, during which engineering faculty and graduate students learn to write micro-insertions and evaluate students' responses to them. The second wave consists of workshop attendees—both faculty and graduate students—continuing to develop micro-insertions once they leave the workshops. The third wave consists of these faculty and graduate students helping other students develop micro-insertion problems during graduate engineering courses or work in laboratories.

We already have evidence that graduate students can develop interesting ethics problems appropriate for the modular approach to ethics instruction. From 1996 through 2001, the Association for Practical and Professional Ethics (APPE) ran an NSF-supported workshop each summer at Indiana University for graduate students in science and engineering from around the country. In many ways, the workshop was a conventional five-day introduction to issues in research ethics. But, in one significant respect, it was quite different. Each graduate student had to write a case study and commentary. Generally, the students drew on their own experience as graduate students, resulting in cases quite unlike anything then in the literature. The workshop faculty also wrote commentaries on the cases. The cases and commentaries, published in six volumes, provide a resource for teaching research ethics by means of a modular approach. They are available at [4]. However, only a few of these cases are about engineering.

Our project differs from the APPE project both because it focuses on engineering (rather than on science) and because it investigates graduate students' ability to formulate micro-insertions (rather than case studies). The engineering faculty participating in the grant, along with graduate students they selected, attend a one-day (eight-hour) workshop led by Davis and using materials that he created as a guide. A typical workshop contains four 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, chemical, civil, and electrical engineering.

This section outlines in more detail the workshop process and activities used to teach faculty and students to write micro-insertions.

Defining Ethics The first hour of the workshop focuses on the general "what," "why," and "how" of teaching engineering ethics. For the purpose of the workshop, the "what" is defined as professional ethics: 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 that would mean having to do the same. As such, professional ethics differs from ordinary morality (i.e., standards of conduct that every rational person wants everyone to follow—e.g., "don't lie," "don't kill," "keep your promises") in that professional ethical standards apply only to members of the relevant group (e.g., engineers). Davis explicates the relation between ordinary morality and professional ethics as follows:

> To say that [professional] ethics ... applies only to members of the relevant group (engineers) is not to say that the standards in question may not resemble those of another group (or even be identical word for word). It is, rather, to identify the origin of the standard, the domain over which it has jurisdiction, and those who have authority to revise, interpret, or repeal it.
>
> Something similar is true of the relation of ethics to (ordinary) morality. For example, most codes of professional ethics include standards of ordinary morality like honesty (don't lie, cheat, or steal). Professional ethics differs from ordinary morality, when it does differ, only in demanding more ("a higher standard"). So, for example, honesty for engineering ethics includes a duty of candor that goes beyond ordinary morality and, indeed, beyond what is generally required of people in business—and, indeed, of philosophers. To say that professional ethics applies only to members of a profession is not to deny any similarity between the profession's ethics and (ordinary) morality but to deny that ordinary people are bound by whatever **additional** obligations the profession has taken on. [5, p. 719]

The "why" of teaching ethics encompasses four (increasingly difficult) goals, which Davis outlines during the workshop, along with ideas about various teaching strategies—the "how" element—for achieving each via micro-insertions as well as by other means:

(1) raising ethical sensitivity;
(2) adding to ethical knowledge;
(3) improving ethical judgment; and
(4) increasing ethical willpower (commitment).

Increasing students' ethical sensitivity means simply making them aware that ethical issues permeate engineering activities. For example, instructors may raise ethical sensitivity by regularly bringing up questions, vignettes, or "war stories" about ethical problems encountered in the engineering field. Adding to students' ethical knowledge involves, among other things, introducing them more formally to the code of ethics in their field, both the content of the code and the rationale for various elements of it. (Davis routinely finds that 75% of students at the junior/senior level have never seen the code of ethics for their profession; an index of codes for various professions is available at [8].) Instructors may raise relatively easy issues in class and have students locate the answer in the code. Adding to students' ethical knowledge may also be accomplished by assigning problems with difficult ethical issues and requiring students to consult practitioners for advice.

Improving students' ethical judgment implies having students respond to situations, real or hypothetical, where they must make a decision. The first part of improving judgment is to require students to provide both a solution (written or oral) to an ethics problem and a rationale for their solution. The second part is addressing the advantages and disadvantages of each student's solution. Davis also suggests engaging students in real scenarios such as those encountered in internships or co-op programs and having students write about or discuss ethical issues encountered, their resolution, and the consequences.

Unlike the first three goals of teaching ethics, the fourth—increasing students' ethical willpower—can be difficult to assess because its effects may become apparent only after the student becomes a professional. However, faculty may "plant the seed" of ethical willpower by emphasizing that most people in their profession want everyone to act ethically, thereby making it apparent to students that there is strength in numbers. Instructors can also introduce students to organizations or departments that will provide support for individuals when they face ethical dilemmas, such as a professional society, government agency, employer's legal department, or advocacy group. Giving students practice in articulating and defending their recommendations in a classroom setting may also make it easier for them to do so later in a professional setting.

Rewriting Engineering Problems to Include an Ethical Component Following the introductory section, the remainder of the workshop is dedicated to the process of writing ethics micro-insertions for existing engineering problems.

The first step in writing a micro-insertion is identifying an ethical problem or issue. Therefore, writers of such problems need to be aware of sources for ideas—in traditional rhetorical terms, strategies for invention. Some sources that faculty members commonly find useful include the following:

- reviewing the relevant code of ethics;
- reflecting on the writer's practical experience;
- asking practitioners about what comes up in their work;
- reviewing newspaper stories, fiction, or other written works that deal with the profession;
- asking students to write up problems based on their own work experience or on the experience of someone they have interviewed;
- reviewing the CSEP website [9].

The workshop participants then spend about 1.5 hours reviewing sample problems (such as that in Fig. 2), each of which has been written or revised to include an ethics micro-insertion. These illustrate a range of emphases within each problem on technical versus ethical components. For example, a mechanical engineering problem might ask the student for a series of technical answers involved in designing an autopilot for a sailboat, then add the following question:

> While testing your electronic controller with real hardware, you notice that, on rare occasions, the boat makes sudden large heading changes. After further analysis, you discover that the compass was sending out erroneous heading information. Since you have already signed off on your design to your boss, the order for the compass sensors has already been processed. What should you do? Please provide three alternative courses of action and a reasoned discussion of how you arrived at your choice.

In contrast, other problems have an implicit ethical component that may be brought out in class discussion after students have presented their solutions to technical components. For example, Fig. 3 contains an agricultural engineering problem developed by Bernard Tao of Purdue University.

Although the problem itself asks primarily for technical calculations, the nature of the product involved and the recommendation component lead naturally into a discussion of ethical issues. In

You have been hired as the environmental engineer in a local pharmaceutical manufacturing plant. Your first assignment is to measure the concentration of Zeepox in waste water discharged to the Wabash River, just upstream of Purdue University. Zeepox is an extremely profitable and potent neurodepressant used to sedate violent criminals and hyperactive children. Dosages are based on body weight, typically 0.0001–0.001%.

The plant is trying two new processing methods. During the 8-hour shift running Process 1, your measurement of Zeepox concentration in the effluent is given in Table 1. Process 2 data is given in Table 2.

Table 1: Process 1		Table 2: Process 2	
time (hr)	conc (ppm)	time (hr)	conc (ppm)
0	0	0	0
0.5	1.3	0.5	0.5
1	7.9	1	1.6
1.5	12.4	1.5	9.7
2	10.3	2	14.9
2.5	9.3	2.5	27.5
3	11.5	3	35.6
3.5	13.5	3.5	48.1
4	14.1	4	57.8
4.5	14.2	4.5	62.1
5	13.9	5	51.3
5.5	14.0	5.5	40.1
6	14.1	6	29.8
6.5	14.0	6.5	20.1
7	14.2	7	10.7
7.5	9.7	7.5	6.0
8	0	8	0

A. Develop models for the Zeepox effluent concentration vs. time using natural cubic splines. Develop an 8^{th}-order polynomial model for Process 1 and a 6^{th}-order polynomial model for Process 2.

B. Using the spline models, calculate the total amounts of Zeepox dumped into the river for each process per 8-hour shift. Assume effluent flow rate is constant at 1000 lb/hr. Which process dumps more Zeepox into the river?

C. If the river water flowrate is approximately 9000 lb/hr, is there any reason to be concerned with the Zeepox effluent stream? What would you recommend to the plant manager regarding Zeepox emissions in the two processes?

Fig. 3. Agricultural engineering problem developed by Bernard Tao, Purdue University.

particular, a suggested answer to question C is as follows:

> The effluent gets diluted by a factor of 10, assuming complete mixing. This results in a maximum instantaneous possible concentration of Zeepox in the river of 1.42 ppm for Process 1 and 6.2 ppm for Process 2. Converting these values to mass %, Process 1 = 0.000142%, and Process 2 = 0.00062%. According to the text, the normal dosage level is on the order of 0.0001%. To achieve this concentration, a person would have to drink approximately 1/6 their weight in water, or about 25 lb. for a 150-lb. person. This is highly unlikely. However, this concentration may be a problem for aquatic life in the river, as fish and amphibians may process several

times their body weight in water via respiration or skin permeation.

In turn, the calculations can lead to discussion of questions like the following:
- What is the ethical problem(s) here?
- What facts are known, and what facts need further determination?
- Who are the affected parties if this waste disposal process continues?
- What alternatives/consequences are available/feasible?
- What could you do to implement these actions?

Participants read and discuss about a half dozen examples of similar problems (i.e., micro-insertions that were created by previous workshop participants) and brainstorm ways to incorporate ethics. The following basic steps, developed by Davis, are offered to participants as guidelines for creating an ethics micro-insertion:

- Decide what aspect of teaching ethics should be addressed. For example, is the aim to raise ethical sensitivity, improve ethical knowledge, 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 CSEP website at IIT also offers examples of how previous workshop participants have incorporated ethics into engineering and other fields [9].
- 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 dilemma covered in the problem or 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. 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 and making the student the "you" in the problem will make the problem seem more real to the student being addressed: Use, for example, "Which option should you choose?" instead of "Which option should the company choose?"

Fig. 4 illustrates a "before and after" problem that was developed by technical communication graduate student Apryl Cox Jackson on the basis of this advice to include an ethics micro-insertion. Fig. 4 also points out relevant features of the revision that correspond to these suggestions.

Participants are then given the opportunity to revise engineering problems that they have brought with them, either from textbooks or other course materials. Participants begin by working in small groups, each comprised of an engineering faculty member and the graduate students who accompanied the faculty member to the workshop. Each group works for about 30 to 45 minutes (sometimes borrowing a few minutes from the lunch break) to identify and then revise a textbook problem. All participants then reconvene, and each group presents its micro-insertion to the entire workshop for discussion and critique.

Following these presentations and a discussion of grading ethics assignments (summarized in the following session), each individual participant is given time to write an additional problem. Individual problems are then presented to the entire workshop group for discussion and critique.

Grading Ethics Problems Because many engineering faculty and graduate students have little experience in grading ethics problems, part of the workshop is dedicated to this skill. Some general guidelines offered include the following:

- Clearly identify the objective of the micro-insertion: Is it designed to raise ethical sensitivity? Increase ethical knowledge? Improve ethical judgment?

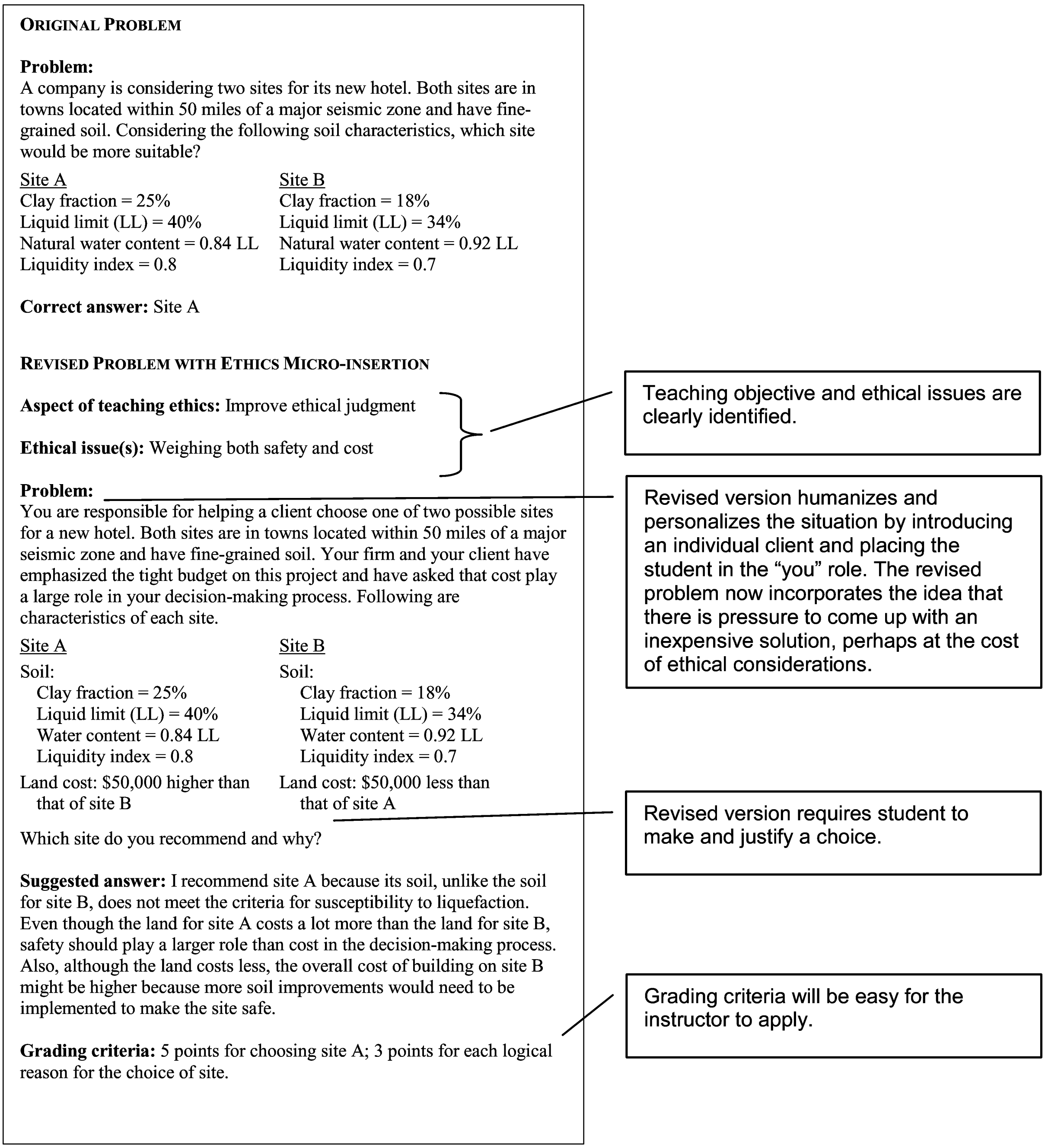

Fig. 4. Original problem on soil liquefaction and revised problem with ethics micro-insertion.

- Design the problem or exercise to measure the objective. For example, if the objective is to measure ethical sensitivity, the grade should depend on the student's correct identification of a particular number of ethical issues.
- Make sure that items being graded are those that have been covered with students.
- Choose a grading format consistent with other material in the class. For example, if calculations are required for other problems, try to put the ethics component into a calculation.

Participants are advised to keep grading simple—an especially important consideration for faculty who may feel that including an ethical component increases the teaching and grading load in an already-full curriculum. 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 (e.g., grading answers on a 0-1-2 point basis). Davis also suggests using the Pittsburgh-Mines (P-M) Engineering Ethics Assessment Rubric [10]. The P-M rubric has five attributes, each with five levels of achievement: 1 (lowest) through 5 (highest):

- Recognition of ethical dilemma or problem. This attribute evaluates the student on a continuum from not comprehending that a problem exists to clearly identifying and framing the key ethical dilemma(s). Successful recognition provides evidence of the student's sensitivity to ethical issues.
- Information. This attribute evaluates the student on a continuum from ignoring pertinent facts to making and justifying assumptions. Successful performance on this component provides evidence of the student's knowledge about ethical resources such as codes of ethics.
- Analysis. This attribute evaluates students on a continuum from providing no analysis to citing analogous cases with considerations of the risks associated with different each alternatives. Successful performance on this component provides evidence of both sensitivity and knowledge.
- Perspective. This attribute evaluates students on a continuum from providing no perspective to considering the global view of the situation, as well as the perspectives of the employee, the profession, and society. Successful performance in this component provides evidence of the student's knowledge and judgment.
- Resolution. This attribute evaluates students on a continuum from citing rules as resolution to the highest level of proposing a creative middle ground ("win-win") resolution. Successful performance in this component provides evidence of the student's judgment.

The workshops conducted so far under the grant have already shown that graduate students can develop interesting micro-insertion problems during a one-day workshop. We are waiting to see whether they can continue to do so under the guidance of trained faculty and whether the students and faculty can transfer that skill to graduate students who have not gone through the workshop.

ASSESSMENT OF THE MICRO-INSERTION METHOD

There is some evidence that both freestanding courses and modules can improve students' moral judgment and the grasp of "intermediate ethical concepts" such as data integrity, duty to the public, and so on [11]. However, much of this evidence derives from the study of dental students. Much of the remaining evidence, more closely related to the graduate education of engineers, is concerned mostly with students and faculty in the biomedical sciences. Despite ABET's emphasis on integrating ethics into engineering education, surprisingly little has been published on the effectiveness of various methods for teaching ethics to undergraduates in engineering, and even less on the effectiveness of methods at the graduate level.

Can a "low-dose" approach affect students' ability to recognize, understand, and respond to ethical issues? Assessment data collected so far on the micro-insertion method indicate that the answer is yes. Student evaluations have been conducted in courses taught by 45 faculty members who participated in one of the micro-insertion workshops taught by Davis since the early 1990s and who subsequently incorporated the method into their courses. The generally positive responses of over 3,700 students in these courses indicate that micro-insertion provides an effective method for educating students about ethical issues. Student responses to an eight-item questionnaire yielded the following results from five closed-ended questions (percentages are approximate):

- 68% of the students reported that they had not had any professional or business ethics in a course prior to the current one.
- 88% agreed that the course improved their awareness of ethical issues likely to arise in their profession or job.
- 72% agreed that the course changed their understanding of the importance of professional or business ethics.
- 75% agreed that the course improved their ability to deal with the ethical issues it raised.
- 69% felt that they spent "just the right amount" of time on professional and business ethics. Just 16% responded "too little," and only 9% responded "too much." (The remaining responses could not be clearly classified.)

The current NSF grant funds further research into assessing the effectiveness of the micro-insertion technique. Three forms of assessment are planned. First, we will continue to use, in a slightly modified form, the questionnaire described above to evaluate student responses at the end of the semester. The primary change we are making is offering response options that use a more discriminating Likert scale rather than the yes/no questions we have used until now. (We will still be able to convert the Likert responses into binary data, allowing comparison with earlier responses.)

While the questionnaire provides a subjective assessment of effectiveness (i.e., an assessment of how students **perceive** the effectiveness of the method), it does not assess actual changes in students' ethical sensitivity, knowledge, or judgment during a particular course. Thus, one goal of the current grant is to develop additional methods for assessing these characteristics.

One challenge that we face is developing pretest and posttest materials that engineering faculty can incorporate quickly and easily into their class schedules. Once we began recruiting engineering faculty for the workshops, we quickly learned that no one would join the project if either the pretest or posttest occupied more than 15 minutes of class time. Thus, a second assessment goal is to develop a 15-minute (maximum) test of intermediate concepts. An "intermediate concept" is a category for guiding conduct (or organizing deliberation) that falls between the most general moral categories (such as "morally good") and specific applications ("I should do this"). The idea for testing knowledge of intermediate concepts as a way of assessing the effectiveness of teaching professional ethics comes from Muriel Bebeau's work at the University of Minnesota dental school over several decades [12]. Our current working list of intermediate concepts is as follows:

- accessibility (designing with disabilities in mind);
- animal subjects research;
- authorship and credit (coauthorship, faculty and students);
- collaborative research;
- computational research (problems specific to use of computers);
- confidentiality (personal information and technical data);
- conflicts of interest;
- cultural differences (between disciplines as well as between countries);
- data management (access to data, data storage, and security);
- human subjects research in engineering fields;
- national security, engineering research, and secrecy;
- obtaining research, employment, or contracts (credentials, promises, state of work, etc.);
- peer review;
- publication (presentation: when, what, and how?);
- research misconduct (fabrication, falsification, and incomplete disclosure of data);
- responsibilities of mentors and trainees;
- responsibility for products (testing, field data, etc.);
- treating colleagues fairly (avoiding or responding to discrimination);
- whistle-blowing (and less drastic responses to wrongdoing).

We will need to fit our collection of intermediate concepts to the courses with which we are working. This is more difficult than we anticipated since graduate courses tend to be focused on very specific technical problems. These differ a good deal from discipline to discipline even within the four engineering disciplines represented by the IIT faculty and students whom we have recruited (biomedical, chemical, civil, and electrical). The recruits from Howard University and University of Illinois at Chicago add to that mix. So far, we have used the IIT workshops to help us identify appropriate concepts. We have also used lists drawn up for other purposes, especially a list that Jason Bornstein of Georgia Tech developed while planning an online course in research ethics for engineers. And, of course, we have circulated our list among relevant faculty and graduate students after the workshop.

Our general approach for assessing the effectiveness of ethics teaching in increasing students' sensitivity, knowledge, and judgment was to be built on methods that Bebeau and Thoma developed for dentistry [12], that others have successfully applied to social work, journalism, and other fields outside of science and engineering [11], and that has been applied to engineering undergraduates by Loui [13]. For example, to see whether students have become more sensitive to the ethical issues raised by data integrity, we give them situations in which data integrity is an issue (say, a problem involving a data set that is "too good to be true"). If more students recognize the problem (the need at least to flag a suspicious data set) after the course's micro-insertions than before, they are that much more sensitive to that issue.

Our challenge was developing a test that provides useful data across a wide range of engineering courses, in contrast to the more tightly controlled curricula in which work by Bebeau and Thoma and by Loui has been carried out. We eventually abandoned this approach for another.

That assessment strategy involves having individual faculty construct their own pre- and posttests of sensitivity and knowledge. Under this strategy, faculty will (a) give a pretest early in the semester, before introducing micro-insertions of ethics; (b) embed engineering ethics via micro-insertion problems, as taught in the workshop; (c) test for the ethics learned (as part of the usual exams) using the same question(s) as in the pretest; and (d) report the before-and-after test scores for each student in class. The ratio between pre- and posttest scores will provide a measure of improvement. We chose this method because the numbers generated can be compared across courses, just as grades can be, while accommodating the widely disparate material taught in various engineering courses. Whether the comparison will produce any meaningful data is still an open question; as far as we can determine, the ratio approach has not been tried elsewhere.

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 Ethics In-Basket as an evolving resource for compiling and disseminating micro-insertions, rather than as a static archive. As new micro-insertions are developed, they will be added to the Ethics In-Basket, not only during the three-year grant period but afterward. The site is being designed to allow anyone with a micro-insertion to submit it for review and eventual posting by the site's coordinators. 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 builds upon an existing CSEP resource that archives materials developed in previous faculty workshops on ethics across the curriculum [9]. While the Ethics In-Basket focuses 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 is being designed with 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. Fig. 5 shows an early prototype of the Ethics In-Basket homepage, indicating search terms for ethical issues. As illustrated, cloud tags are being used to reflect the relative number of micro-insertion problems within various ethical areas, engineering fields, and levels of difficulty.

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 Jackson) with previous editing experience edited the initial set of micro-insertion problems as they were developed by engineering faculty and graduate students. Areas of special attention during the editing process included 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 writer to develop a set of key terms for indexing the problem once it is posted to the site. Additional expertise on search terms and indexing is being provided by the CSEP librarian, Kelly Laas.

Content Management Expertise Users of the Ethics In-Basket will rely especially on its navigation and search functions. Therefore, a technical communication graduate student

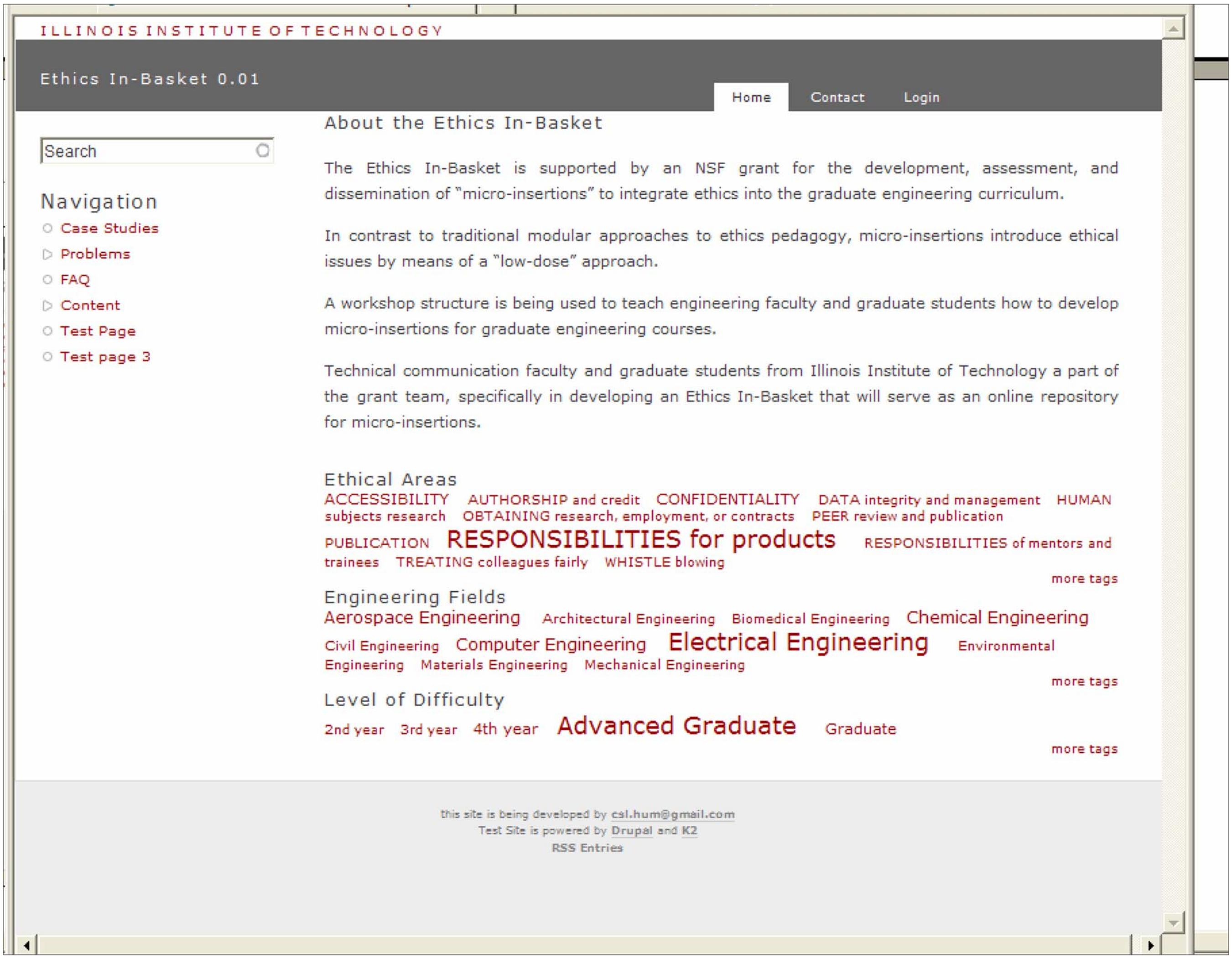

Fig. 5. Early prototype of Ethics In-Basket homepage.

(James Maciukenas) with experience developing other databases is addressing 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 at IIT for another project) is approximately US $25,000 for an initial setup fee, in addition to an annual subscription fee of approximately US $9,500.

After considering available options to implement a content management system for the Ethics In-Basket, the open-source solution Drupal 5 was selected. (The prototype in Fig. 5 is powered by Drupal.) Drupal was deemed an ideal web application development environment due to its modular framework and active web-based support community. As noted above, this community not only responds quickly to technical support requests but also actively contributes to the development of modules that make Drupal so flexible. Drupal relies on PHP to display webpages which interact with a MySQL database storing user-submitted content to the site. Both PHP and MySQL are open-source projects and contribute to the open nature of the Ethics In-Basket.

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 and giving engineering students practice in communicating about ethical issues and decisions. Micro-insertion offers a way to communicate ethics using a "low-dose" approach. In addition, modifying conventional engineering problems to include an ethics micro-insertion can be accomplished by engineering faculty and graduate students with relatively little investment of time and instruction. For faculty seeking a repository of micro-insertions that have already been prepared, the Ethics In-Basket will offer a permanent, continuously evolving resource for communicating ethics in engineering (and eventually in other technical and scientific fields) using the micro-insertion method.

The micro-insertion method described in this paper is not intended to replace freestanding courses in ethics. Ideally, curricula for engineering and for other professional fields such as architecture, business, and computer science would include at least an elective course focusing in depth on the ethics of that profession. As argued by Davis [7], a freestanding course allows for deeper analysis of ethical issues, and also is more likely to be taught by a specialist in ethics (e.g., a faculty member from philosophy). In our experience, however, engineering curricula are increasingly filled with required courses from within the engineering discipline, often leaving students with little room to take elective courses such as engineering ethics. (Recall that over two-thirds of the students surveyed about micro-insertions reported that they had not encountered any professional or business ethics in a course prior to the one in which they encountered micro-insertion problems.) Micro-insertion offers a feasible way to integrate discussion and writing about ethical issues into a curriculum that otherwise might not include these topics at all. More subtly, as argued earlier, the micro-insertion approach also avoids treating ethics as an "elective" component of engineering. Instead, ethical dimensions of engineering problems are integrated pervasively throughout the curriculum.

As a way of providing students with opportunities to recognize, discuss, and write about ethical components within engineering, micro-insertions also challenge students to engage in the kind of "messy problems" that are essential to assessing and developing critical thinking. As Carrithers and Bean found in the context of business students, challenging students with more open-ended problems requires

> a higher level of sustained and systematic disciplinary thinking than does a typical homework set addressing well-structured problems with right answers. Only through presenting students with an ill-structured ... problem, in which the students must identify the issues, determine which tools to apply in addressing them, correctly and effectively use them, and meaningfully communicate the results, can those skills be discerned and deficiencies diagnosed and improved. [14, p. 23]

We would argue that, in a similar way, micro-insertions bring many conventional engineering problems into the realm of "messy problems" that promote writing and learning within the discipline.

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Kathryn Riley is Professor and Chair, Lewis Department of Humanities, Illinois Institute of Technology, Chicago, IL. She has published extensively on linguistics, grammar, and applications of linguistic theory to professional communication. She serves as editor-in-chief of *Business Communication Quarterly* and, with Jo Mackiewicz, is coauthoring a textbook for Prentice-Hall on *Visual Composing*.

Michael Davis is Senior Fellow, Center for the Study of Ethics in the Professions, and Professor of Philosophy, Illinois Institute of Technology, Chicago, IL. His recent publications include *Conflict of Interest in the Professions* (Oxford, 2001), *Profession, Code, and Ethics* (Ashgate, 2002), *Engineering Ethics* (Ashgate, 2005), and *Ethics and the Legal Profession*, 2nd ed. (Prometheus, 2008).

Apryl Cox Jackson received the M.S. degree in Technical Communication and Information Design from Illinois Institute of Technology, Chicago, IL, in 2008. Previously, she worked as a technical writer and project manager for Physicians Postgraduate Press, Inc., and as a technical editor for the University of Tennessee Health Science Center.

James Maciukenas is a Ph.D. candidate in Technical Communication at Illinois Institute of Technology, Chicago, IL. He received the M.S. degree in Technical Communication and Information Design from IIT and completed graduate work in Digital Technologies and Design Art Practice at Concordia University, Montréal, Canada. His interests include research-based interface design and the relationship between print and electronic media.