Engineering Ethics in Engineering Education

Report of a Conference

June 12-13, 1990

Under a grant from the Ethics and Values Studies Program of the National Science Foundation.

Vivian Weil
Center for the Study of Ethics in the Professions
Illinois Institute of Technology

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Preface

A grant from the Ethics and Values Studies Program of the National Science Foundation to the Illinois Institute of Technology made possible the Conference on Ethics in Engineering Education which generated this Report. June of 1990 seemed a good moment to bring together leaders among engineering educators and people working on ethics in engineering to determine what was needed for teaching ethics in engineering programs. The participants aimed to reach some substantive conclusions about what should be taught, how it can be conveyed, and who should teach. They believed that a summary of their conclusions could provide timely support to educators casting about for ways to begin.

This summary is the outcome. It captures the main points of agreement that emerged from vigorous, sustained discussion at the conference. That discussion generated a strong impetus to move ahead, to gather resources within engineering and support from outside agencies for a variety of new initiatives.

Conference participants reviewed earlier drafts of this Report and made helpful comments. They all agreed that ethics teaching described in the Report should be given priority by their own institutions and by the National Science Foundation. I am grateful to the participants for their comments and advice which helped to refine points presented, to avoid omissions, and to catch the spirit of an intensely interesting and lively conference. Thanks are also owed to Rachelle Hollander, Director of NSF's Ethics and Values Studies Program, and Wilbur Meier, formerly Director of NSF's Office for Engineering Infrastructure Development. Their joint backing greatly encouraged participants with differing perspectives and priorities to tackle some common problems.

I appreciate the support from NSF Award #DIR 9015610. The views found in this report are those expressed by conference participants, and should not be attributed to the National Science Foundation. I take responsibility for the Report and for any errors or deficiencies which remain in spite of all the good advice.

Vivian Weil
May 1992

Center for the Study of Ethics in the Professions
Illinois Institute of Technology

Summary Report of Conference on Engineering Ethics in Engineering Education

Chief Conclusions Reached by Conference Participants

1. Ethical concerns are integrally related to engineering problems; ethics is not peripheral.
2. Therefore, whatever anyone else does, engineering programs, as such, should incorporate ethics in their curricula. At the very least, ethics should be integrated into design courses. Ethics should be part of the content of other courses also. A strong capstone design course with ethics components is highly desirable. Free standing engineering ethics courses inside or outside engineering curricula, with instructors from engineering or a range of other disciplines, are also valuable.
3. Cases and projects pertinent to the particular subject matter are essential, for the issues must be made concrete. Cases should be used to stimulate students to focus on options for resolving problems and to practice ways to resolve them. Projects which give students real world experience (such as contacting a professional society or company) can flow from cases and are recommended for fostering appropriate problem solving skills.
4. Students should be made aware that engineers generally work in complex organizations. In responding to problems, they should be prepared to interact with others in their organizations—engineers, managers, technicians, production, and marketing people. For some tasks, they will also have to interact with "outsiders," i.e. representatives of other organizations. As professionals, they need to be able to assess organizations and procedures and to view them as capable of change rather than as fixed constraints. They can then be more assertive in acting as agents of change within these structures.
5. Ways should be found to prepare and enable engineering faculty to teach some ethics and to change the educational environment. Engineering schools and engineering school deans have roles to play in this effort. So do professional societies, the private sector, and government.
6. The National Science Foundation should make it a priority to support innovative programs to incorporate ethics in engineering education.
7. The ultimate goal is for students to understand that going through a process of investigating the facts, formulating and evaluating options, gathering support, and negotiating with others will enable them to act responsibly when facing ethics problems. This process takes thought and cannot be reduced to a mechanical procedure or algorithm.

Introduction

Both external demands and internal professional standards have engineering educators around the country casting about for ways to incorporate ethics into engineering education. To address this problem, a small conference of leaders in engineering education and in engineering ethics research and teaching was held on June 12 and 13, 1990, in Chicago, under a National Science Foundation grant. Included among the participants were engineering deans, engineering faculty (one a lawyer), social scientists, philosophers, and other humanists. (See Appendix A for a list of participants and the institutions with which they are affiliated.) The aim of the conference was to set forth some core ideas in engineering ethics that students need to encounter, to describe effective ways of conveying these ideas, and to indicate the knowledge and skills required of those who teach.

Conference participants thought that the time was ripe for focusing on the needs of engineering educators looking for a way to begin. NSF-funded research and teaching projects in engineering ethics are bearing fruit, and many engineering educators are seeking to overcome the barriers to introducing ethics. It seemed useful to try to express the collective insight of experienced ethics specialists and engineering educators about what should be included in ethics teaching and how teaching ethics can be effectively carried out, within acknowledged constraints. A report on the proceedings might then provide a timely boost to educators' efforts.

Professional ethics is multi-disciplinary. It encompasses an examination of institutions, social practices, and their history, as well as a focus on problems having technical and ethical dimensions. Faculty committed to both the study of ethics and professional education are needed. Close connections between those who study ethics of a profession and those engaged in professional education are essential. Both research and teaching are often interdisciplinary, sometimes with an interdisciplinary team approach.

Nevertheless, all who participated in the conference agreed that teachers in engineering programs can be prepared to teach some engineering ethics in ordinary technical courses. Since ethical considerations are integrally related to real-life engineering problems, it is highly desirable that ethics teaching be done by engineering faculty. Given the constraints imposed by the overburdened engineering curriculum and the limited number of ethics specialists inside or outside engineering education, it is also necessary for engineering educators to join in the task, if there is to be a serious effort to reach all engineering students.

The sections that follow report the points on which conference participants agreed. However, the Report does not capture the kinds of tensions which emerge as people from different disciplines not previously acquainted with one another begin to discuss common problems. Gradually, as discussion proceeds, tensions can lead to energetic, productive exchange and new direction, and that is what happened at the conference. To get past gaps in understanding and develop ongoing programs we cannot have one meeting and be done with the job. The tensions among people with different priorities and different languages have to be faced again and again. This Report will make a difference if people follow up and begin doing things.

Engineering Ethics Teaching: Concepts and Content

Approach to Problem Solving

A guiding idea for teaching is that many engineering ethics problems are like design problems.[1] Typically, there are no uniquely correct answers for either design problems or ethical problems. Some answers are clearly wrong, but most solutions are better or worse. Occasionally, there will be a brilliant solution. Sometimes there is one clearly right thing to do, but the problem is to get past obstacles in the way of doing it. Formulating and revising options for dealing with these sorts of problems requires practical wisdom and the exercise of judgment.

Many engineering ethics problems require the exercise of engineering judgment. Technical mastery is a necessary foundation of engineering judgment, as is a full awareness of the concrete situation, but ultimately, engineering judgment will go beyond technical mastery. However, not all ethical problems for engineers require a technical solution; conflict of interest problems are examples.

Engineering ethics problems are also like design problems in that the starting point is a concrete situation. The question to be confronted looks to the future: "How should we deal with this situation?" For both sorts of problems, solutions must be constructed.

The chief tasks in teaching engineering ethics can be characterized as follows. First and most important is to make students aware of ethical problems and help them learn to recognize them. A second task is to help students understand what it means for engineers to be moral agents as engineers. They are agents in that they make things happen. Their projects affect people for good or ill. Engineers are therefore moral agents who need to understand and

[1] *This is a notion advanced by Caroline Whitbeck and embraced by all the participants at the conference. For a fuller account of Whitbeck's ideas, see "Ethics as Design: Doing Justice to Moral Problems," Texas A & M Center for Biotechnology Policy and Ethics, 1692-1.*

anticipate these effects. A third task is to help students see that, being moral agents, they are responsible for helping to work out solutions to ethical problems they encounter. A corollary is that they are responsible for the reasons they give for their responses to problems. It is part of this task to help students develop the skills for mobilizing resources to resolve problems.

To accomplish the first task, teachers should present realistic problems. Students can learn how to approach them step by step. An engineering problem already in the course can be converted to a problem with ethical dimensions. For example, a problem of figuring what should be the thickness of a truck's partition that separates a driver from the load will concern the physical effects of bringing the truck to a sudden stop.[2] A related task will be to choose a design for the brakes. Depending upon the force and speed of loaded boxes striking the partition, sudden application of the brakes could result in injury, even death, for the driver. The ethical dimensions of the problem can be highlighted so that students can discuss the ethical implications of different technical choices.

The second task (helping students to understand moral agency) comes down to enabling engineering students to see that engineers are not hired guns. Areas of responsibility go with the body of knowledge they have mastered. This means that engineers should be oriented to look ahead to consequences of their choices and imagine themselves in the positions of those affected by their choices.[3] Engineers are to be concerned as well about their own characters and their personal traits as professionals, realizing that their characters are formed by the choices they make in their work and, in turn, are reflected in those choices.

A third task, helping students recognize their responsibility to deal with ethical problems, means preparing students for the way engineers function in the workplace. Engineers have to make judgments in conditions of uncertainty. They use rules of thumb, standards of practice, or other heuristic devices to manage in such conditions. Inevitably, they have to exercise judgment which is more than technical. The point is not to focus on assigning blame or making moral judgments retrospectively, but to identify problems ahead of time and learn to resolve them well.

Engineers should seek solutions, as individuals, yet not just as individuals. They are members of a profession which extends beyond their place of employment and has formulated ethical codes, and they have to interact with others, not only engineers, to construct solutions. They have to figure out to whom to go with a problem, for they work in situations where individual responsibility connects with doing things collectively. They have to learn to negotiate the pathways by which to investigate and get support.

[2] *This example was provided at the Conference by Taft Broome.*
[3] *Judith Perrolle emphasized this approach.*

Familiar steps to follow in problem solving are:[4]

1. Recognize and define the ethical problem and be ready to revise as you go along.
2. Investigate and check facts.
3. Formulate alternatives and continue to check facts.
4. Analyze the alternatives in terms of resources they require and their likely outcomes.
5. Construct desired options and persuade or negotiate with others to implement options.
6. Anticipate pitfalls or undesirable consequences of the desired options and take steps to forestall them.
7. Go back to steps 1. and 2. to review the ethical problem and check whether any facts were missed.

Reflection and deliberation about what to do are based on comparison of cases and agreed upon moral standards, as well as engineering codes of ethics. A vocabulary of moral terms, such as 'right,' 'wrong,' 'good,' 'responsibility,' 'obligation,' 'ideals,' 'virtue,' 'autonomy,' 'justification,' and 'excuse,' is needed to provide a baseline level of understanding. In reasoning about cases, it is advisable to identify central clear cases on which there is general agreement, but not to neglect less clear cases, once it has been shown that there are sometimes right answers.

The problem of the loaded truck coming to a sudden stop will serve to illustrate this approach to engineering ethics problems. The ethical problem begins with the question about what degree of protection should be provided the driver. The process of fully laying open the problem brings additional questions to the fore. What about the responsibility for loading properly? What is the driver's responsibility? What is the company's responsibility for training, for not over- or under-loading? What is the responsibility of government for appropriate regulations and enforcing regulations?

Alternatives of partition design and brake design will have to be generated within constraints of time and resources as well. The more careful one is to consider and compare a variety of alternative designs in the wider context brought out by these further questions, the greater the likelihood of coming up with a feasible, defensible solution. Likely consequences for affected parties, as well as constraints of time and resources, will suggest criteria for comparing solutions.

What constitutes a morally responsible solution is not simply a matter of legal liability. Legal liability is a different consideration. In this example, one can show that the legally liable party incurs greater costs for causing injury than for

[4] *A model for such a set of steps was emphasized by Steven Nichols.*

causing death. Moral responsibility and legal liability actually diverge here. A responsible solution should reflect our common view that killing is generally worse than injuring, and it should be guided by applicable provisions in engineers' codes of ethics.

Understanding the Context

In addition to an approach to problem solving, students need understanding of the context with its organizational, social, and political constraints. They need to learn about the work environment in business organizations and about the recent history of engineers as professionals employed primarily in large organizations. They need to learn about society's expectations.

Taking features of the context into account helps, for example, in dealing with the problem of accepting gifts. Should an engineer employed by a consulting firm accept a gift from a contractor with whom he has done business over the years? The engineer has to consider not only his relationship with the contractor, but also the implications for his employer, and for third parties, such as private developers to whom the firm recommends contractors. In this broader context, he may see the practical and ethical advantage if gifts are made openly and acknowledged openly. It is an indication that the gift is unacceptable if these conditions trouble the giver or the receiver. Engineers may find it useful to seek to make such a solution a matter of policy in a firm and in this way change the context.

To fully understand the current context of engineering, it is necessary to look at the past. An introduction to the history of the profession over the last 125 years can convey how the profession grew, with its emphasis on science-based education, in tandem with the rise of the modern corporation. It will bring out how, from the outset, engineers established professional societies and early on promulgated codes of ethics, in spite of the fact that many engineers had employee status. They sought professional status even as employees.

It is also necessary to look backward in solving particular problems, to try to understand the antecedents of the particular set of circumstances at hand. In carrying out the steps of problem solving, engineers have to take into account their roles in organizations which employ them. When they assess options, engineers have to bear in mind the contours and constraints of their roles, the likely need to negotiate with their managers and even outsiders over the desired option, and the obligations to the public that they have accepted as members of a profession.

In summary, participants agreed that the appropriate starting point for ethics teaching is in real, concrete problems of engineering. The governing question is, "What are we going to do?". Among the traits engineers should bring to problem solving is sensitivity to consequences for affected parties. They should become acquainted with the context of their work, as well as with heuristics for problem solving. Being alert to the roles of others in the workplace is essential for implementing effective responses. Engineers and engineering managers can and should awaken others in the organization to their responsibilities and to the implications of decisions, educating them to what collective responsibility means. Ultimately, individual engineers have to be willing to make a judgment and justify it to others with reasons. This is what those who fund their projects and those who have to live with the results have a right to expect.

Methods of Teaching

Engineering ethics teaching relies on careful and thorough discussion of concrete situations. An appropriate teaching method will help students imagine themselves in actual circumstances and stimulate them to devise and deliberate about options, assessing them from the perspectives of those who would be significantly affected, even those at a distance. There are a variety of ways to do this. Case studies, films, role playing, computer simulations, and group projects are vehicles that engineering educators and ethics specialists have used successfully. Presentations by invited practitioners and students, as well as lectures by the instructor, can be used to stimulate discussion. Discussion can proceed in the class as a whole, in small groups, as debates, or in other formats that allow the airing of differing views.

Cases of several kinds have been found appropriate: narratives of actual episodes (e.g. the Challenger and Hubble telescope failures), detailed vignettes of ordinary, everyday problems, the outcomes of which are still in doubt, and schematic hypotheticals. Narratives make vivid the pressures which engineers encounter and sharpen students' sense of society's stakes in having engineers practice responsibly. Detailed vignettes of less dramatic or extreme situations realistically capture problems, conflicts, and uncertainties of daily work. Discussion emphasizes a search for feasible solutions that satisfy engineers' proper moral concerns. Even schematic hypothetical problems can be useful when they are presented as templates of common problems and with an emphasis on problem solving. They can be used to illustrate the technique of brainstorming options. Problems already in use in technical courses can, often with small changes, be made into effective ethics problems. Assigned problems dealing with fluid flow can be fleshed out to refer to fluids containing toxic substances that flow into receptacles people use. Familiarity with a range of cases is valuable for learning to reason by analogy across cases, identifying clear central instances and distinguishing so-called gray area examples. Instructors should look for case situations detailed enough to help students appreciate the delicate balance in acting to force attention to a problem without alienating colleagues by pushing them to take a stand before they are ready or by failing to consult them in good time and thereby removing them from "the loop."[5] Situations that pose forced choices between highly undesirable alternatives can be used to expose students to those unusual occasions and to point up the need for looking ahead to prevent them.

Classroom Techniques

Several films mentioned in the bibliography in Appendix B have often proved useful in teaching, especially *The Truesteel Affair* and *Gilbane Gold.* Computer simulations allow students to make choices in situations, and then learn to respond to the consequences. Students can assess choices they have made and change course or take corrective action when necessary. Two of the ethics specialists who participated in the Conference, Michael Pritchard and Kathleen Waggoner, are developing such simulations. Role playing involves assigning roles and making up an improvisation from a case.

Group projects are desirable because they mimic group situations in the workplace and can give students a taste of what it is like to respond actively and cooperatively to a problem. Often a group project can grow out of a case.

Consider the case of an engineer with responsibility for the documentation supplied to the Food and Drug Administration for the marketing of her company's medical instruments. She is concerned that her company has fallen behind in supplying documentation. The student group can find out about the role of documentation in assuring safety and effectiveness of medical devices. The students should be encouraged and helped to contact people in appropriate firms to learn about options for facilitating documentation when new products are introduced or existing products are altered. They should also talk to people in settings where the reliability of medical devices is critical. The product of the group's efforts might be suggestions about how the engineer struggling with a firm's lagging documentation can use available resources to help the firm do its part in assuring the safety and effectiveness of medical devices it produces.

More work is needed to develop materials that support and expand the range of techniques for teaching. The work is well begun; suitable cases are not hard to find. However there is not a profusion of materials of other kinds or of reports on effective use of cases, simulations, films, role playing, or group

[5] *This is a point in Caroline Whitbeck's discussion in "The Engineer's Responsibility for Safety: Integrating Ethics Teaching Into Courses in Engineering Design," 1987, Winter Annual Meetings, American Society Mechanical Engineers, Boston.*

projects. Material on the use of role playing is particularly scarce, although many engineering educators and ethics specialists say they find it a useful device.

Skills for Teaching

The foregoing account of the concepts and methods for teaching points to the skills teachers need. The requisite skills and knowledge of subject matter are available to people from a variety of disciplines inside and outside engineering. In addition to skill in handling basic concepts of ethics, perhaps the main skills are those for conducting productive class discussion in a climate of trust and fostering in students skills for persuasion and negotiation. Teachers need to exercise with students the skills of applying what they know to real situations in order to make sound judgments and then to explain their judgments convincingly, even to people who lack their technical understanding.

Teachers need skills for helping engineering and science students cultivate sensitivity to language, exploit their competence for making careful distinctions in discussion, and develop patience with problems that can't be solved with an "equation." Even when engineering educators have become intrigued with engineering ethics problems and won over to teaching, they may need patience to bring students around. A willingness to try things in teaching, assess how they worked out, and make adjustments is therefore highly desirable.

As important as particular skills is the understanding that acting responsibly in situations of uncertainty or conflict is not a matter of merely gaining more technical certainty. It involves learning how to make judgments within constraints of information, time, and resources. With that understanding, teachers can help students learn techniques for following through on a problem.

Support from Institutions

Several institutions have roles to play in fostering ethics teaching in engineering and creating a new educational environment. These include engineering schools and programs, professional societies, industry, and government agencies. Engineering deans and educators can help faculty with stipends for attending short courses and workshops on ethics and for purchasing published modules, other printed materials, and software. They can provide release time. They must address the problem of appropriate recognition for participation in ethics education. If deans and engineering program directors provide adequate back-up and share with faculty an understanding that this is not a one-shot affair, a faculty effort can succeed. Deans and program directors can then proceed with their faculties to the next major task, devising ethics components for doctoral programs to prepare the next generation of engineering faculty.

For all these efforts, engineering educators need support from other institutions. The Accreditation Board for Engineering and Technology, Inc. offers general direction and suggestions in its *Guide on Professionalism and Ethics in Engineering Curricula.* The National Institute for Engineering Ethics (NIEE) of the National Society of Professional Engineers (NSPE) recently published *Professional Ethics and Engineering: A Resource Guide*, which lists books, articles, films, key resource professionals, and engineering ethics organizations and centers of special value to those undertaking the teaching of ethics in engineering.

Other professional societies should accept responsibility for increasing support of new efforts in engineering ethics education. They can assist with such projects as collecting cases or producing films. NSPE's NIEE has set an example with the film, *Gilbane Gold.* By such measures as strengthening their ethics committees, conducting ethics workshops in continuing education, and encouraging local chapters to be available to engineering students, professional societies can become visible resources for students, as well as for practicing engineers.

The Association for Computing Machinery is well launched on ethics activity through its Special Interest Group on Computers and Society (SIGCAS). Other active societies are the IEEE Computer Society, American Engineers for Social Responsibility, and Computer Professionals for Social Responsibility. Some sections of the American Society of Mechanical Engineers, the American Society of Civil Engineers, and other societies have struggled to foster similar work. A resource for these societies is the Professional Society Ethics Group (PSEG) of the American Association for the Advancement of Science.

Companies that employ engineers can include ethics components in company training and continuing education, with a view toward upgrading the organization. The Conference Board in New York City is a resource for new initiatives on this front. The Center for the Study of Ethics in the Professions of Illinois Institute of Technology is producing a program for corporate training, with support from a Hitachi Foundation grant. The program is in the testing stage.

The National Science Foundation can play a key role in the advancement of research and the development of educational innovations to be implemented by engineering faculty. By its support, NSF can help to create a comfort zone for faculty who are gathering resources to proceed. A number of projects have resulted from cross-directorate ethics management. The pros and cons of this approach can be debated. However, there would be clear advantages in more involvement by the Engineering Directorate through such programs as Research Experience for Undergraduates (REUs) and REUs at Engineering Research

Centers. These latter programs offer interesting settings for introducing engineering ethics. Cooperation between the Engineering Directorate, the Education and Human Resources Directorate, and the Ethics Program is needed for encouraging and developing projects in graduate training and research. Remaining open to a variety of approaches, NSF can continue to encourage the growth of the field of engineering ethics.

Appendix A

NSF Conference on Engineering Ethics in Engineering Education

Conference Participants

Taft Broome, Jr.
Civil Engineering
Howard University
2400 Sixth Street, N.W.
Washington, DC 20059
202 806 6570

James Eifert
Vice President for Academic
Affairs & Dean of Faculty
Rose-Hulman Institute of Technology
Terre Haute, IN 47803
812 877 8222
812 877 9925 fax
JAMES.EIFERT@Rose-Hulman.EDU Internet

Willliam J. Hall
University of Illinois
2106 Newmark Lab.
205 N. Mathews Ave.
Urbana, IL 61801
217 333 3927
217 333 9464 fax

Kathryn Harrison
(Effective 9-1-92)
Graduate School of Public Affairs
University of Washington, DC 13
Seattle, WA 98195
206 543 4900
206 543 1096 fax

Rachelle Hollander
Ethics and Values Studies
National Science Foundation
1800 G Street, N.W., Room 312
Washington, DC 20550
202 357 9894
202 3577568 fax
rholland@nsf.gov Internet

James A. John
President, GMI Engineering
& Management Institute
1700 W. 3rd Avenue
Flint, MI 48504-4898
313 762 9864

David T. Kao
Dean, College of Engineering
104 Marston Hall
Iowa State University
Ames, IA 50010-2150
515 294 5933
515 294 9273 fax

Wilbur L. Meier, Jr.
College of Engineering
North Carolina State University
Box 7901
Raleigh, NC 27695-7901
919 515 2311
919 515 7951 fax

Steven P. Nichols, P.E.
The Center for Energy Studies
University of Texas at Austin
10100 Burnet Road
Austin, TX 78758
512 471 3565
512 471 7682 fax
STEVE_NICHOLS@memail.me.utexas.edu

Judith Perrolle
Department of Sociology
and Anthropology
Northeastern University
Room 500 Holmes
Boston, MA 02115
617 437 2686

Rosa Lynn Pinkus
School of Medicine
University of Pittsburgh
Presbyterian University Hospital
190 Lothrop Street, Room 166
Pittsburgh, PA 15261
412 648 3243
412 648 3126 fax
Pinkus@med.pitt.edu Internet

Michael Pritchard
Department of Philosophy & Center
for the Study of Ethics in Society
Western Michigan University
Kalamazoo, MI 49008
616 657 5083

Harold Salzman
University of Louisville
Urban Research Institute
Louisville, KY 40292
502 588 6626
502 588 7386 fax
h0salz01@ulkyvm Bitnet
h0salz01@ulkyvm.louisville.edu Internet

Roland Schinzinger
Electrical and Computer Engineering Dept.
University of California at Irvine
Irvine, CA 92717
714 856 6738 office
714 786 7691 home
714 856 4152 fax

Larry Shuman
Associate Dean, School of Engineering
University of Pittsburgh
Pittsburgh, PA 15261
412 624 9815
412 624 1108 fax

Carol Ann Smith
Department of Philosophy
G5 Humanities and Social Sciences Bldg.
University of Missouri - Rolla
Rolla, MO 65401
314 341 4869

Kathleen Waggoner
Department of Civil & Construction
Engineering
380 Town Engineering Building
Iowa State University
Ames, IA 50011
515 294 2872

Vivian Weil
Director, Center for the Study
of Ethics in the Professions
Illinois Institute of Technology
3101 S. Dearborn St.
Life Sciences Bldg, Room 166
Chicago, IL 60616-3793
312 567 3472
312 567 3493 fax
CSEPWEIL@IITVAX Bitnet
csepweil@karl.iit.edu Internet

Caroline Whitbeck
Mechanical Engineering
Massachusetts Institute of Technology
Room 1-104A
Cambridge, MA 02139
617 253 1631
whitbeck@Eagle.MIT.EDU

Carl Wolgemuth
Associate Dean for Undergraduate
Studies
College of Engineering
Pennsylvania State University
University Park, PA 16802
814 863 3750
814 863 4749 fax
CHWI@PSUADMIN Bitnet

Appendix B

Resources for Teaching

Guides

Accreditation Board for Engineering and Technology. *Guide on Professionalism and Ethics in Engineering Curricula*, New York: ABET, Inc., 1989

National Institute for Engineering Ethics, NSPE. *Professional Ethics and Engineering: A Resource Guide*, Alexandria, VA: NIEE, NSPE, 1990

Educational Films

1. *The Truesteel Affair, 1983*
   24 minute/color, 16 mm/video
   Fanlight Productions
   47 Halifax Street
   Boston, MA 02130
   617 524 0980

2. *Gilbane Gold: A Case Study in Engineering Ethics, 1989*
   24 minute/color, VHS video tape
   National Society of Professional Engineers
   1420 King Street
   Alexandria, VA 22314
   703 684 2800

3. *Company Loyalty and Whistleblowing: Ethical Decisions and the Space Shuttle Disaster: A talk by Roger Boisjoly, Engineer, Morton Thiokol, 1987*
   2 hours/color, VHS video tape
   Dr. Mark Maier
   School of Education & Human Development
   State University of New York
   Binghamton, NY 13901-6000
   607 777 6723