# Short, Instructional Modules for Teaching Ethical and Societal Issues Within an Engineering Curriculum

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## Abstract

Engineering employers and academic accreditation agencies are now insisting that societal and ethical issues be included in the standard engineering curriculum. We have developed and tested short (3 class-hour) modules on three of these issues – engineering ethics, an awareness of the societal impact of engineering, and knowledge of contemporary issues. These modules have been designed for simple integration into standard technical courses, effectively introducing key concepts and promoting student awareness, showing directly how the issues relate to the practice of engineering, and minimally impacting the existing curricula. This paper provides details of each of the modules – objectives, outlines for each class, in-class exercises, assignments, assessment guidelines, and techniques for bridging the material into specific engineering disciplines. We have tested each of the modules on a group of students, and the data from our tests show that students who complete the modules increase their awareness of ethical, societal, and contemporary issues and significantly increase their self-confidence with respect to these issues, feeling more capable of addressing them in their professional practice.

## The Need to Include Societal and Ethical Responsibilities within the Engineering Curriculum

Since an engineer's work can have significant impact on society, the practice of engineering carries certain obligations and responsibilities. Engineers need to assess both positive and negative impacts of particular engineering solutions, to inform society of these impacts, and to gain informed consent before a particular solution is implemented. Engineers need to act ethically, to recognize and resolve potential conflicts of responsibilities to society, to employers, to fellow workers, and to self. Engineers need to keep abreast of current events and to assess how these events may relate to their practice. Academic institutions, engineering employers, and accreditation agencies are all recognizing that these societal and ethical responsibilities need to be included within the engineering curriculum, along with the traditional technical material. ABET requires that the engineering program of an accredited institution must demonstrate that their graduates have "an understanding of professional and ethical responsibility [Criterion 3(f)]", "the broad education necessary to understand the impact of engineering solutions in a global and societal context [Criteria 3(h)]", and "a knowledge of contemporary issues [Criterion 3(j)]" [1].

We have developed and tested three short educational modules – one each on engineering ethics, awareness of the societal impact of engineering, and knowledge of contemporary issues. Each module requires 3 class-

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hours plus appropriate homework and can be integrated simply into a standard technical course. In addition to minimally impacting the existing curricula, integrating the modules into standard technical courses shows the students how the issues relate to the practice of engineering. As far as possible, we have designed the material to be discipline-non-specific. In addition to the 3 class-hours of general instruction, the instructor has the option of giving a discipline-specific assignment at some time later in the course.

Each module has been designed to require minimum advance preparation by the instructor – the modules include an instructor's guide containing justification, objectives, prerequisites, assignments, grading rubrics, suggested in-class student exercises, reference materials, and classroom requirements. The modules also include the requisite audio-visual material for the three class-hours of instruction, complete with instructor's notes. The AV material is most often PowerPoint slides and URLs to appropriate World Wide Web pages. In the remainder of this paper we describe each of the modules and provide test results showing their effectiveness. Interested readers can preview our modules at http://www.ece.ua.edu/faculty/rpimmel/public_html/ec2000-modules[3] and can receive electronic copies of the modules by directly contacting the authors.

# ***Three Modules to Teach Ethics, Societal Impact, and Knowledge of Contemporary Events***

## ***Ethics Module***

An engineer must recognize his/her responsibilities to society, to an employer, to fellow workers, and to himself or herself. Ethical dilemmas arise when a situation produces conflicts in responsibilities to two or more of the above groups. Engineers need to understand their ethical responsibilities, to recognize that conflicts will exist, and to know how to satisfactorily resolve these conflicts. Satisfactory resolution involves knowledge of an appropriate code of ethics, an understanding of how to apply ethical principles to professional situations, and the ability to pursue additional resources if the problem appears novel, beyond the grasp of the individual, or if the individual desires corroboration. Students completing the Engineering Ethics module should be able to do the following:

1. Discuss an engineer's professional responsibilities.
2. Discus various engineering ethics codes.
3. Discuss the importance of engineering ethics in the career of an engineer.
4. Discuss the need for a professional code of ethics.
5. Discuss what an engineer should do when the employer's interest conflicts with the public.
6. Discuss resources and contact points that would be helpful in dealing with ethical dilemmas.
7. Given a scenario, identify ethical concerns, describe the appropriate behavior, and discuss the ethical basis for these choices.

The Engineering Ethics module is structured into three 50-minute sessions. The first session is a case study of the Ford Pinto. Prior to the first session, students are placed in 3 or 4-person groups and are assigned to read [2, 3], view a QuickTime movie showing a Pinto collision and the subsequent fire (accessible through [2]), and discuss a series of questions within their groups. The first few questions concern the ethics involved in companies performing cost-benefit analyses when human lives are involved (noting that society

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[3] This URL provides previews for a total of 15 modules developed by various educators as part of the Foundation Coalition, with support from the Engineering Education Program at the National Science Foundation under award number EEC9802942. The other twelve modules are computational skills, design skills, experimental skills, modeling skills, problem solving, project management, lifelong learning, teaming, time management, graphical communication, oral communication, and written communication.

performs such analyses and asking how the societal analyses are different from a company analysis). The next series of questions ask whether the students feel that upper management at Ford was properly informed and understood the engineering issues involved, noting that Mr. Iacocca has an engineering degree from Lehigh University. A hypothetical question is then posed concerning what the students would do if they detected safety-related defects within a product they were designing. Students are finally asked to justify whether or not they feel ethical obligations are needed above and beyond legal requirements.

During the first class-hour of the module, the instructor leads a discussion using the above questions as a guideline. Key concepts during the class discussion include an engineer's responsibility for public safety, cost-benefit analyses when public safety is involved, and the issues of informing management and the public of possible safety hazards. The need for a code of professional ethics is also introduced. Additional concepts include an engineer's responsibility to his or her employer, gauging a company's culture to determine its commitment to public safety, and determining when whistleblowing is acceptable or even imperative.

As a pre-assignment for the second session, each student group is tasked with developing its own engineering code of ethics. The students are specifically told NOT to read any professional organization's codes prior to doing their work, but to develop their own codes based on the first session's case study (concerning large, societal issues) and based on their own experiences (concerning smaller personal issues). During the second session the instructor leads a 35-minute discussion to develop a class-wide consensus for a code, using contributions from each group. The instructor then summarizes the discussion, noting that all the suggested items can be divided into classes of responsibilities — responsibilities to society, to an employer, to fellow workers, and to self, and that ethical problems arise when there are conflicts between responsibilities to two or more of the above classes. These observations provide a general structure for ethical codes and give students a way to analyze and resolve ethical problems. The instructor then provides copies of ethical codes from appropriate professional societies, reinforces the observations about how codes are organized, and relates the professional society ethical codes with the code developed in class. The instructor also discusses resources (web pages, journals, books, and hotlines) which can help engineers when they are confronted with particular ethical issues (these resources are listed in the instructor's guide).

The third session is a case study involving Wernher von Braun, with students having read a series of web pages and a book review [4] as their pre-assignment (the instructor's guide provides URLs and a synopsis of the contents for each of the web pages). Key concepts include the significant impact which an engineer's work can have on society and the ethical responsibility of an engineer to know *and care* about how a product or technology which he or she develops can be used (there is much evidence to support an argument that von Braun did not care how the technology he helped develop was being applied). Observations can also be made on how decisions concerning ethical issues can snowball. Additional concepts include an engineer's responsibility to promote fair labor practices (again, there is much evidence that von Braun knowingly used slave labor in WWII), the obligation of an engineer to be a good human being in addition to being a good scientist, and how politics can motivate governmental and individual behavior that may not be ethical.

## ***Societal Impact Module***

Students completing the Societal Impact module should be able to do the following:

1. Identify global, societal, and environmental implications of various technological issues within their engineering discipline.
2. Create a comprehensive list of questions concerning global, societal, and environmental impact of a *particular* engineering implementation within their engineering discipline.
3. Identify fora (journals, websites, newspapers, etc.) where global, societal, and environmental issues of engineering are discussed.
4. Find websites or other public domain material concerning global, societal, and environmental impact of a *specific* engineering solution within their discipline.

5. Prepare an oral or written report concerning global, societal, and environmental impact of a *specific* engineering implementation within their discipline.
6. Identify appropriate governmental regulatory bodies and appropriate general regulations concerning global, societal, and environmental impact of engineering within their specific discipline.

The first 50-minute session begins with the instructor asking, "What is an engineer and what does he or she do?" The ensuing class discussion should produce a satisfactory definition of an engineer (one such candidate: "an engineer applies the principles of physics and the tools of mathematics to nature and materials to produce devices, processes, and systems which serve mankind"). Examining the definition, the instructor concludes that an engineer is essentially an *applied scientist*. From this observation, the instructor can persuasively state that what we do as engineers has a profound impact on society. The instructor gives many examples, such as the Internet, nuclear power, and biomedical advances, and observes that each example has had positive and negative societal impact (particular examples are provided in the instructor's guide and AV material for this module). The instructor then breaks the class into groups and asks each group to provide three real-world examples of proposed engineering solutions that have had a significant impact on society. For each example, the group is asked to briefly discuss the original problem that inspired the solution, to describe the solution, and to examine positive and negative impacts of the solution. 15 minutes is provided for this exercise.

The groups then share a few of their examples with the class, after which the instructor collects the lists (they will be used in the third session), summarizes, and observes that engineering solutions involve tradeoffs (that is, they have both positive and negative effects). When these solutions impact society, the general populace should be informed of the tradeoffs and should, somehow, give its approval.

The instructor next discusses how solutions can have unintended consequences, giving appropriate examples. As a memory aid for the students, the instructor calls this problem the Law of Unintended Consequences – "No matter how good a proposed solution seems to be, it will have some unintended side effects" [5]. The instructor briefly discusses how and why certain consequences can be unanticipated, and concludes the session by giving the following assignment to the groups:

> "Before the next class, develop a set of specific procedures which practicing engineers can use to ensure, as best as possible, that unintended consequences are limited, that society is informed of the tradeoffs involved in an engineering solution, and that society gives approval before a solution is implemented."

The second session begins with the instructor asking the groups to share the highlights of the procedures they developed as their assignment. Responses are written on a board or overhead projection slide, and similar responses are grouped together. When all responses have been recorded, they should include at least the following five steps, which are summarized for the instructor in the AV material:

1. Study similar problems, previous solutions, and their societal impact.
2. Identify technological trends associated with the proposed solution and project possible societal impact of these trends so that unintended consequences can be anticipated.
3. Research any laws and regulations that may exist concerning a proposed solution.
4. Perform extensive testing of your proposed solution.
5. Determine appropriate ways to inform society and solicit an informed consensus.

After the above steps (and any others suggested by the class) have been enumerated, the instructor asks, "What resources are available to help with these steps"? Resources for each of the steps are discussed individually, with the instructor first asking the class for their suggestions and then providing any additional information necessary. (PowerPoint slides with this information are, of course, provided in the module for the instructor.)

In the first session the instructor collected an assignment from each group in which they provided three real-world examples of proposed engineering solutions which have had a significant impact on society. By the second session, the instructor will have examined these assignments and selected one of the three examples in each group's assignment. The instructor now concludes the second session by telling the groups that in the third session they will each make a 15 minute presentation concerning their selected example, discussing its positive and negative impacts and its intended and unintended consequences. The groups are told that during the presentations, the group and the rest of the class will be asked to "second guess" and discuss what they would have done to anticipate unintended consequences and to improve the solutions. The third session of the module consists of these presentations and should be delayed long enough after the second session to provide sufficient time for the students to research and prepare the presentations.

## *Contemporary Issues*

Students need to know how breaking developments affect the practice of engineering, how they can stay on top of developments, and how to plan for the future when one doesn't know what the future will be. Students completing the Contemporary Issues module should be able to do the following:

1. Name 3 sources of breaking news in their discipline.
2. Apply their search skills to find recent developments impacting their discipline.
3. Make initial applications of breaking news items to the likely future development of their discipline.
4. Suggest implications of these new developments into their engineering practice.
5. Track some form of technical advance over a timeline, then predict developments 2 - 5 years into the future.

The first session begins with the instructor identifying some contemporary issues related to specific disciplines, which, hopefully, students will recognize from recent headlines. Possible issues include California's power crisis, bringing down the MIR space station, the continual increase in speed of computers coupled with decrease in price, the destruction related to the September 11$^{th}$ terrorist attacks, and hackers defacing government and e-business sites. The instructor selects one of these issues and discusses it in depth (again, information is available in the instructor's guide), then asks the students for possible and probable implications of this issue to the practice of their discipline. The instructor then discusses the accelerating increase of information and asks the class "Assuming that the information in our discipline grows at roughly the same pace as general information, what do you think the implications of this growth will be for you after you've been practicing engineering for 10 years?" Class answers may emphasize the need for increased specialization and the concurrent need for greater communication in a company.

The instructor then asks the class "What have you learned today? How do you need to adjust your training and plans because of what you've learned? How can you find out about contemporary issues and their implications when an instructor is not there to help you?" This should produce a discussion in which the students and instructor identify information sources which can help them stay abreast of current events and which can help them analyze the effects of these events on their professional lives. The session concludes with the instructor assigning the class to scan the sources which have been listed, to write two paragraphs describing two recent developments that could affect engineering, and to name two additional news sources that would probably have information on these or similar developments.

The second session concentrates on finding and evaluating sources which provide information and analysis on contemporary events and how they impact the practice of engineering. The instructor selects five students and has them individually summarize the work from their first-session homework, reporting on the issues they found, their sources, and the implications for engineering. Other students in the class are asked if there are other implications and how long it might take before the implications occur. After the reports, the instructor asks the class "Where can we go to find more information about these issues?" During the ensuing discussion, new sources are introduced by the students and the instructor (the instructor's guide provides a list of sources). Hopefully the students will have discovered that not all sources are equally good and reliable (if not, the instructor needs to observe this fact and discuss it). The instructor groups the sources into categories: World Wide Web sites, technical/scholarly journals, news headlines, and popular press. The instructor then identifies appropriate technical/scholarly journals and some of the better websites, better news headline sources, and better popular press sources. Handouts are provided to the class.

The instructor now poses the question "Once you have the information, how do you determine the implications?" After discussion, the instructor forms groups of 3 - 4 students and makes the following in-class assignment:

> "Consider one of the issues from this session's student reports. What implications do you expect from this issue for your engineering field? You may wish to trace out a time line of developments related to this issue over the last 3 – 5 years and then project 2 years into the future. Be creative, but limit flights of fantasy."

The remainder of the class is spent on the in-class assignment. At the end of the module, the instructor assigns each group to research and write a report and prepare a 3 – 5 minute talk on the implications of the contemporary issue they've just been discussing. The talks will be presented in the third in-class session, followed by questions from the instructor and class.

The third in-class session begins with the reports. The instructor then summarizes by asking the class to identify elements common to most or all of the reports and to discuss what they have learned about the importance of keeping abreast of contemporary developments in their field.

## ***Testing the Effectiveness of the Modules***

Each of the modules was tested by having an instructor who was NOT the module developer teach the module to a test group of 9 – 12 students (paid volunteers)[4]. The modules were taught in three 50-minute sessions, one each on a Monday, Wednesday, and Friday of a particular week. The students were chosen from a pool of 20, based on their availability. The overall group was 65% seniors, 25% juniors, and 10% sophomores, with 45% of the group having a GPA above 3.0 while the remaining 55% had GPAs between 2.0 and 3.0. Twelve of the twenty students had co-op or intern experience.

Before each module, the selected students filled out a survey designed to measure their confidence in being able to achieve each of the module's objectives. For example, concerning the sixth objective listed above for the ethics module (Discuss resources and contact points that would be helpful in dealing with ethical dilemmas), students were asked to rate, on a scale of 1 – 5, the statement "I am confident that I can discuss resources and contact points that would be helpful in dealing with ethical dilemmas". A "1" rating meant "I strongly disagree", a "2" rating meant "I disagree", a "3" rating meant "no opinion", a "4" rating corresponded to "I agree", and a "5" rating meant "I strongly agree". Students were also asked to use the same 1 – 5 scale to rate their opinion of the importance of each objective in the module to a graduating engineer (the question, for example, for objective 6 in the ethics module was "It is important that graduate engineers can discuss resources and contact points that would be helpful in dealing with ethical dilemmas.") After the module was completed, students were again asked to rate their confidence in being able to achieve each of the module's objectives and their opinion of the importance of each objective. The data for the ethics module, social impact module, and contemporary issues module are shown in Figures 1 – 3. The numbers on the y-axis in each figure correspond to the numbering used to list the module's objectives earlier in this

[4] We acknowledge that this is a small group of students and we advocate further testing.

paper. For example, in their pre-module test for the contemporary issues module, the students gave a 3.9 rating to the statement “I am confident that I can name 3 sources of breaking news in my discipline”, corresponding to module objective #1. As a final comment, note that the social impact module was tested using a control group (a separate group which did not take the module) instead of obtaining pre-module scores from the students about to take the module. As a whole, the test data in Figures 1 – 3 show that students who complete the modules increase their awareness of these issues and significantly increase their self-confidence with respect to the issues, feeling more capable of addressing the ethical, societal impact, and contemporary issues in their professional practice.

## Conclusions

We have developed and tested three short educational modules – one each on engineering ethics, awareness of the societal impact of engineering, and knowledge of contemporary issues. Each module requires 3 class-hours plus appropriate homework and can be integrated simply into a standard technical course. Each module has been designed to require minimum advance preparation by the instructor; the modules include an instructor’s guide containing justification, objectives, prerequisites, assignments, grading rubrics, suggested in-class student exercises, reference materials, and classroom requirements. The modules also include the requisite audio-visual material for the three class-hours of instruction, complete with instructor’s notes. Our tests, using independent instructors and student volunteers, show that students who complete the modules increase their awareness of these issues and significantly increase their self-confidence with respect to the issues, feeling more capable of addressing the ethical, societal impact, and contemporary issues in their professional practice.

## Acknowledgement

This work was supported by the Engineering Education Program of the National Science Foundation under Award Number EEC-9802942.

## References

[1] Accreditation Board for Engineering and Technology, Inc., *Criteria for Accrediting Engineering Programs*, effective for evaluations during the 2000-2001 accreditation cycle, November 1, 1999.

[2] http://www.mojones.com/mother_jones/SO77/dowie.html, *Pinto Madness*. This article and the article referenced in [3] are, of course, also available in hard copy but they are much more easily accessed via the World Wide Web.

[3] http://www.motherjones.com/mother_jones/SO77/larsen.html, *Safety Last*.

[4] Piszkiewicz, Dennis (1995), *The Nazi Rocketeers, Dreams of Space and Crimes of War*, Praeger, Westport, CT ISBN 0-275-95217-7.

[5] Ivins, Molly, syndicated columnist for the Fort Worth Star-Telegram. Ms. Ivins developed the Law of Unintended Consequences in a political context, but it is equally valid in an engineering context.

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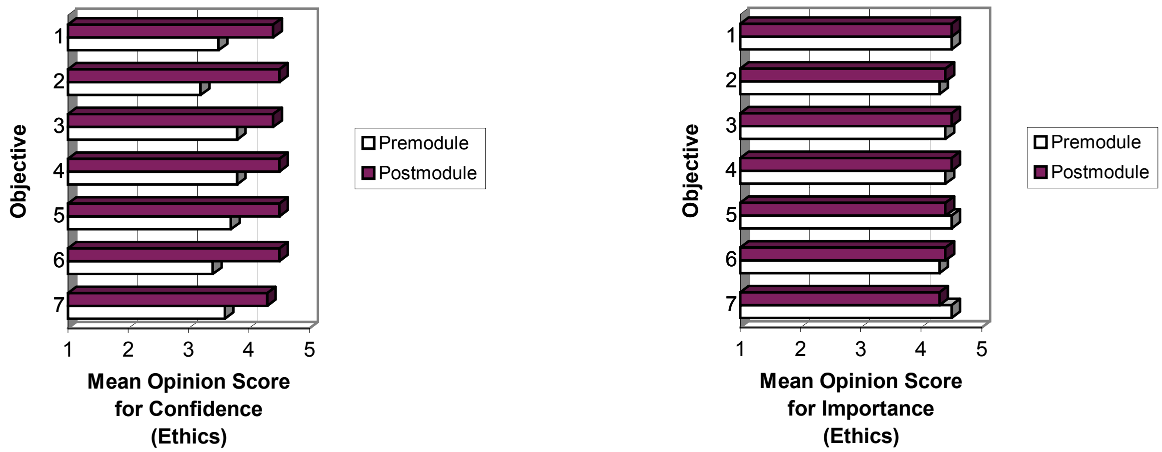


**Figure 1. Pre- and Post-Module Mean Opinion Scores for Level of Confidence and Importance; Ethics Module**

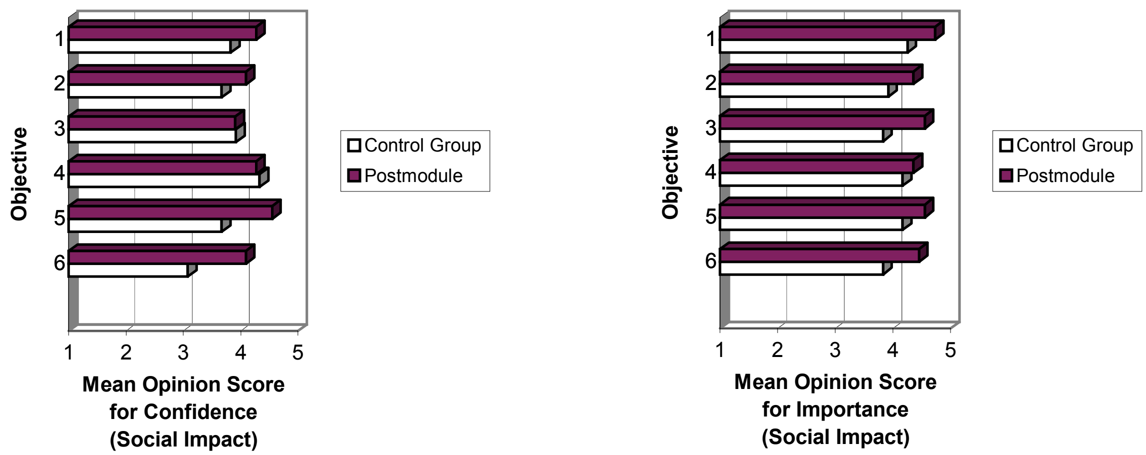


**Figure 2. Control Group and Post-Module Mean Opinion Scores for Level of Confidence and Importance; Social Impact Module**

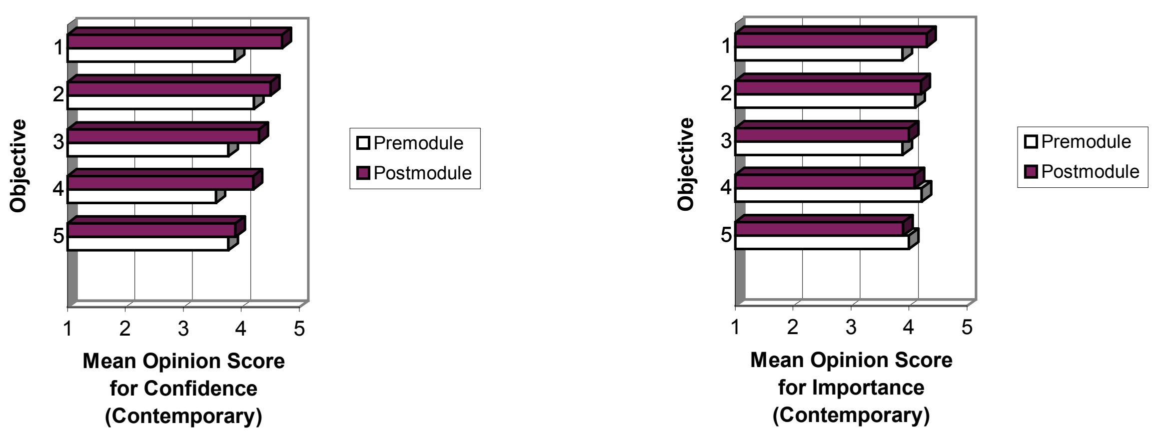


**Figure 3. Pre- and Post-Module Mean Opinion Scores for Level of Confidence and Importance; Contemporary Issues**