The PRiME Project: Developing Educational Materials to Train Responsible Engineers

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Introduction

Engineers have a profound impact on society and a resultant responsibility to society. Statements in codes of conduct for engineering professionals support this position. The Code of Ethics for the National Society of Professional Engineers states that "Engineers shall hold paramount the safety, health and welfare of the public." Specific codes for mechanical engineers, electrical engineers, and chemical engineers (inter alia) clearly express an engineer's obligation to others. One can divide these obligations as 1) obligations to society, 2) obligations to employer, 3) obligations to clients, and 4) obligations to the profession, which includes obligations to students, trainees, and colleagues. Certainly, these obligations include a requirement for technical abilities (the codes stipulate an obligation to practice only in areas of the engineer's competence), and most engineering courses in higher education address these areas of technical strength (engineering science, engineering analysis, and engineering synthesis—or design).

Although the need for technical competence or scientific knowledge is fundamental, there is more to being a engineer. An engineer uses tools of analysis and creativity to apply scientific knowledge to social needs. Figure 1 presents a graphical representation of these domains: scientific knowledge, analysis, creativity, and societal need. The intersection is the realm of engineering practice. Not all specific engineering activities require analysis (area "C"); nor do all specific engineering activities involve creativity (area "A"), but the authors argue that all engineering activities inherently have societal impact (area "B"). Proper preparation for the practice of engineering requires not only an understanding of technical strengths but also an understanding of and appreciation for the professional obligations of engineers. The Accreditation Board for Engineering and Technology (ABET) recognizes the need for educating engineers whose competence includes analytical abilities, creativity, and an awareness of the social impact of engineering, as well as technical skill. Collectively, these qualifications, which should be developed and sustained by professional engineers, can be grouped under the concept of professional responsibility. ABET has expressed the need for educational programs that address those elements of the profession.

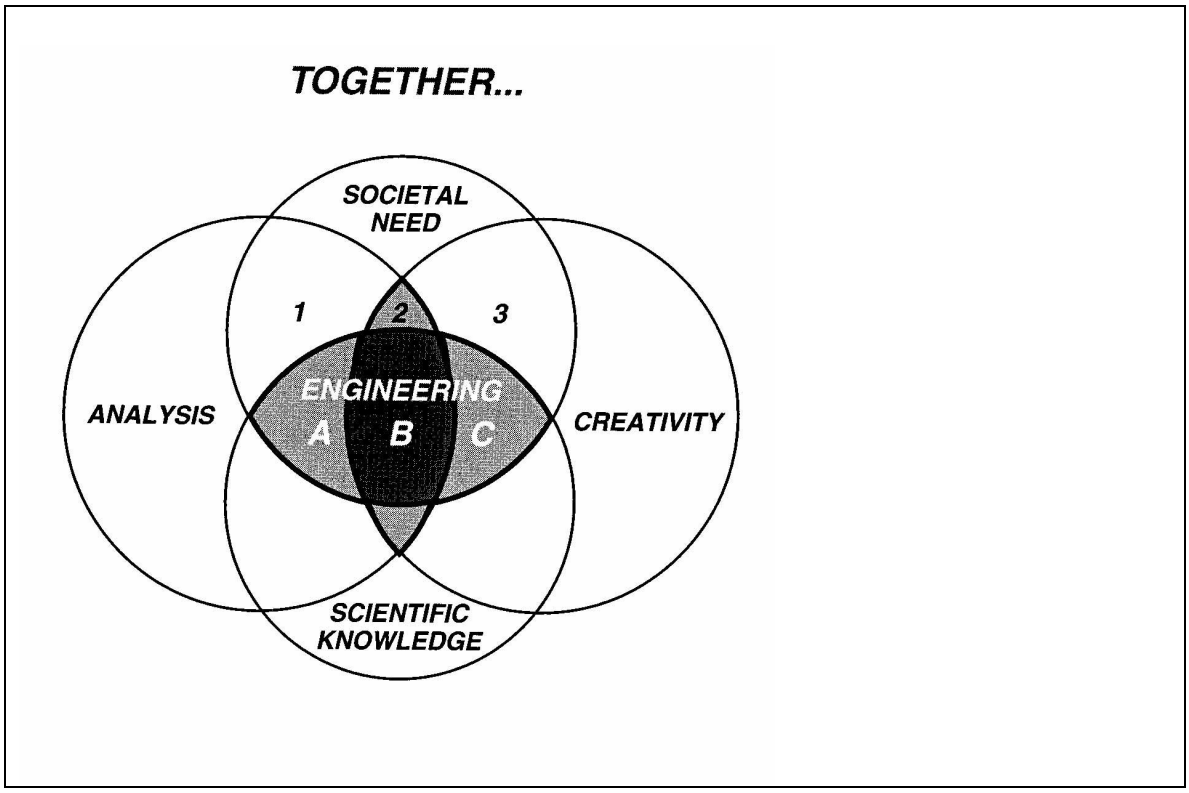

Figure 1. Graphical Representation of Engineering Activities

Academic institutions take several approaches in addressing the areas of professional responsibility. This paper describes the PRiME Project, (**P**rofessional **R**espons**i**bility **M**odules in **E**ngineering) a program developed in the College of Engineering at The University of Texas at Austin to include topics of professional responsibility in the engineering curriculum.

Origins of the PRiME Project

In the summer of 2004, faculty teaching Engineering Communication from five departments in the college of engineering began meeting to explore ways to improve the ways that professional responsibility is addressed in the College. The committee began by conducting a curriculum review of courses offered to undergraduate engineering students at the University of Texas and several peer institutions that include topics of ethics, technology and society, professional responsibility, and leadership. The goal of that preliminary investigation was to establish a better sense of what pedagogical materials exist in the field and what sorts of material would be helpful.

As a result of those explorations, the PRiME Project was conceived. The practical aim of the project, which is funded by the Chair for Free Enterprise, is to compile and develop web-based teaching modules that tackle the complex issues involved in training engineers to be responsible professionals, ethical leaders, and dependable contributors to society. The PRiME committee, whose members teach Engineering Communication in the College (see Table 1 for a list of members), developed modules during the fall of

2004 on several topics and piloted them in the Spring of 2005. The initial assessment of the existing modules will be completed in the summer of 2005. The committee undertook modules on five topics: *Introduction to Professional Ethics*, *Ownership of Information*, *Credibility of Sources*, *Ethical Interpersonal Communication*, and *Ethical Leadership*. Once these initial modules are evaluated and revised, the committee plans to develop additional modules.

Table 1
Members of the PRiME Committee

Faculty	Department	Title	Topics of Modules Developed
Christy Moore	Mechanical Engineering	Sr. Lecturer	*Introduction to Professional Ethics* *Ownership of Information*
Hillary Hart	Civil Engineering	Sr. Lecturer	*Credibility of Sources*
D'Arcy Randall	Chemical Engineering	Lecturer	*Ownership of Information* *Credibility of Sources*
Randi Voss	Biomedical Engineering	Lecturer	*Ethical Interpersonal Communication*
Mark Carpenter	Electrical Engineering	Lecturer	*Ethical Leadership*

The Objectives of the Modules

The overall goal of the project is to compile and develop teaching materials that address the topics of leadership and professional responsibility. Although all of the modules have been developed by communication instructors and piloted in the College of Engineering's required Engineering Communication courses, the larger goal of the project is not simply to create materials for communication courses. Effective communication is one aspect of professional competence, and communication courses are an excellent arena for critical discussion of the complex issues involved in analyzing responsible professional decisions. But it is clear that engineering professional responsibility involves more than effective communication. The long-term goal of the PRiME Project is to create modules that will include topics on the following categories which are the essential elements of professional responsibility:

-Technical competence
-Safety (health, safety, and welfare of others)
-Professional ethics
-Legal liability
-Intellectual property
-Environmental responsibility
-Quality

The initial modules undertaken by the members of the PRiME committee begin to address these topics. The modules on *Ownership of Information* and *Credibility of Sources* are the first of a series of modules on the topic of intellectual property. The committee plans to develop modules on the patent process and research ethics in addition. The modules on *Introduction to Professional Ethics* as well as the modules on *Ethical Interpersonal Communication* and *Ethical Leadership* are the first on the topic of

professional ethics. Ultimately, the committee will develop modules on the other topics listed above. For instance, a module on environmental responsibility is currently in the planning stage.

All of the modules are designed for and intended for use in engineering core courses, not just communication courses. Each module contains a variety of materials, including readings, exercises, and assignments, that can be adapted to different classes in the engineering curricula. The materials are, in fact, designed to be flexible so that they may be used in a variety of engineering courses. For instance, some of the modules offer several possible final assignments at the conclusion of the material. One of those assignments might be designed for a first-year introduction to engineering course; another would be more appropriate in a design course. Depending on the topic and the portions of the module an instructor chooses to use, each module can be completed in anywhere from one to four class periods.

The modules themselves will be supplemented by instructor's site which will give instructors guidance on techniques for using the material in the module, PowerPoint slides to use in lectures, and lists of additional material.

The Design of the Modules

The modules are designed to guide students through an analytical evaluation of the topics, a process that is as important to professional development as the actual data provided in the content of the modules. In *How People Learn: Brain, Mind, Experience, and School* [1], Bransford, Brown, and Cocking note that the goal of educators is no longer to simply teach students how to remember and repeat information. "[T]he goal of education is better conceived as helping students develop the intellectual tools and learning strategies needed to acquire the knowledge that allows people to think productively about history, science and technology, social phenomena, mathematics, and the arts." [*How* 1999] Using the theoretical model set forth in this book, Dr. Kathy Schmidt of the Faculty Innovation Center in the College of Engineering has developed a web-based format for the Challenge Cycle which was created by Bransford and colleagues. The format leads students through educational material in a sequence that will help them to develop their analytical skills. This six-step series of exercises, readings, or tasks allows students to explore complex issues in a way that engages their critical responses rather than simply drills data into their brains. Figure 2 shows the Challenge Cycle which is the design used for all the PRiME Project modules.

Each module begins with a Challenge which involves a case study or a scenario that prompts students to consider some difficulty or dilemma in engineering or professional behavior. The subsequent steps in the cycle allow students to explore their initial response to the problem, research the problem further, and ultimately demonstrate what they have learned in the process.

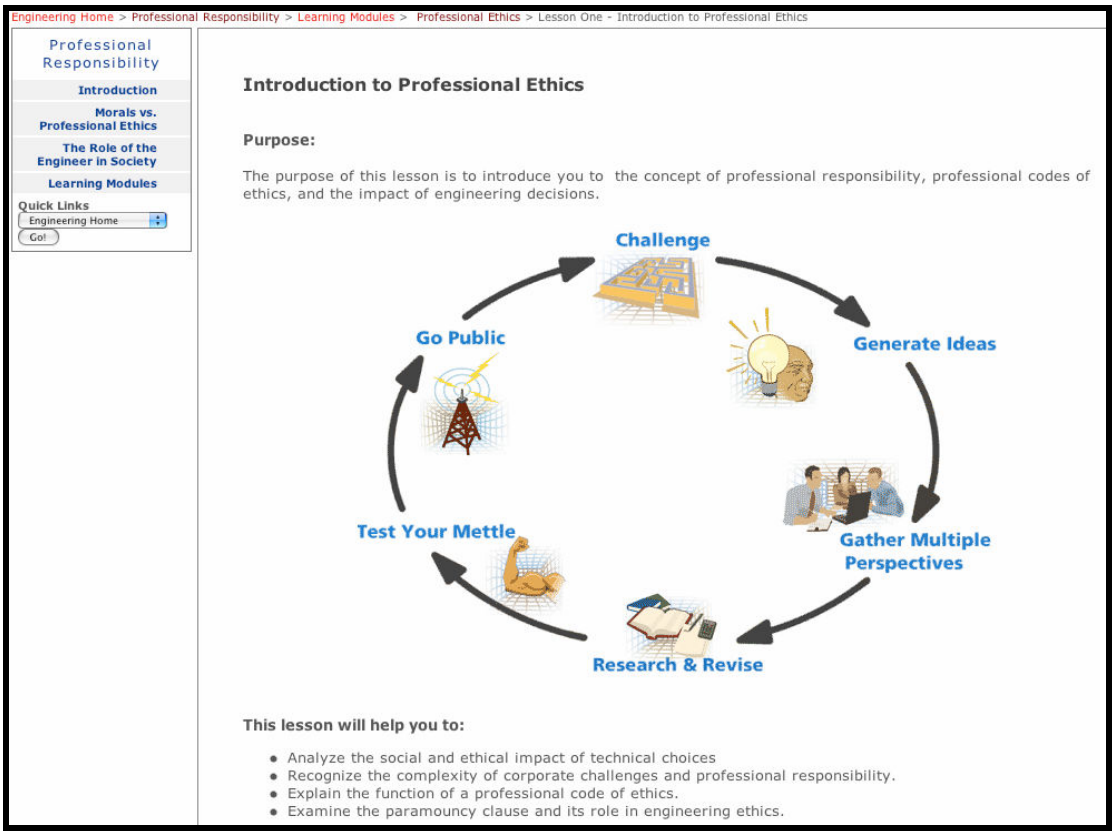

Figure 2. The Challenge Cycle. The introductory page to a lesson that uses the failure of a series of dams in Logan County, West Virginia in 1972 as a case study to investigate issues of personal, professional, and corporate responsibility.

Description of Example Module: *Introduction to Professional Ethics*

The Challenge cycle allows students to go through the iterative steps of reflecting, investigating, analyzing, and making judgements, a process that prepares them to be responsible professionals as much as the actual information they acquire. Although the content, depth, and length of the modules differ, the actual structure is so similar that a review of one of the modules will serve to explain the function of all of the modules. The following sections demonstrate this process using one module as an example.

Introduction to Professional Ethics is a module designed to make students aware of the impact engineers can have on society and the codes of ethics that guide professionals. Using the 1972 Buffalo Creek flood as a case study, the module requires students to grapple with the difficult question of responsibility. The flood, which resulted in over 100 deaths and incalculable damage, occurred as a result of the failure of an impoundment dam operated by a coal mining company – Pittston Coal. It makes for an interesting case study because there is evidence that the impoundment dams had a history of design and maintenance problems and that Pittston managers withheld information from the residents of the Buffalo Creek Valley shortly before the failure of the dam.

The Challenge. The Challenge step (see Figure 3) in the cycle starts students off with a simple description of the flood, which was preceded by days of heavy rainfall, and the damage it caused. There is, at this point, no mention of Pittston Coal Company.

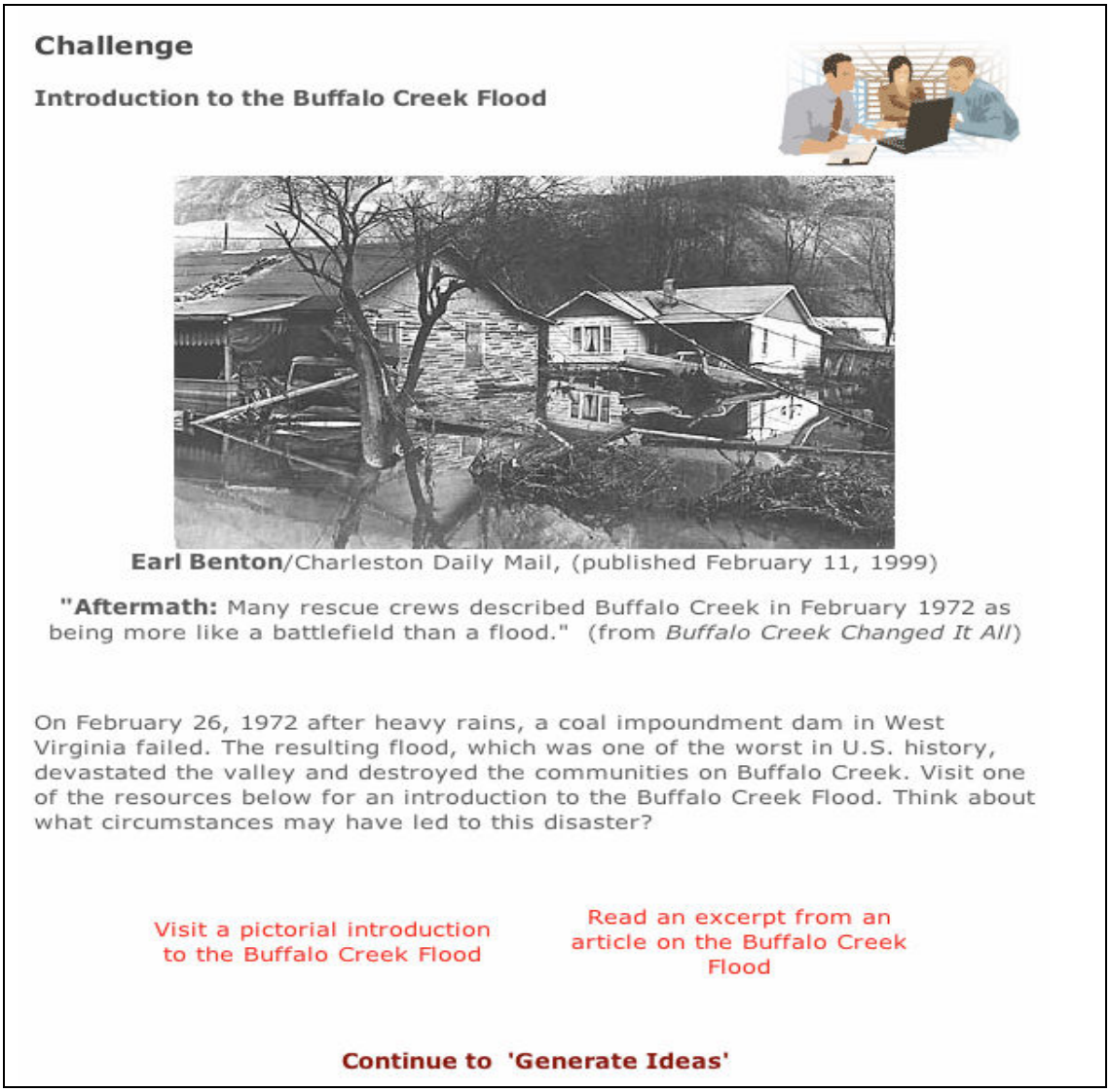

Figure 3. *Introduction to Professional Ethics*: The Challenge.
Instructors can use one of two possible paths on this page. One takes students to an excerpt of an article by Tom Price about the flood; the other takes them to a web site operated by the West Virginia Archive Society that describes the flood using both photographs and text.

Generate Ideas. The next step in the Challenge Cycle, "Generate Ideas" (see Figure 4), gives students the opportunity to record their initial reaction to learning about the disaster. Students are encouraged to generate their won ideas by offering open-ended questions about the flood, what sorts of people might have lived in a coal-mining community in West Virginia, and who or what might be held responsible for this disaster.

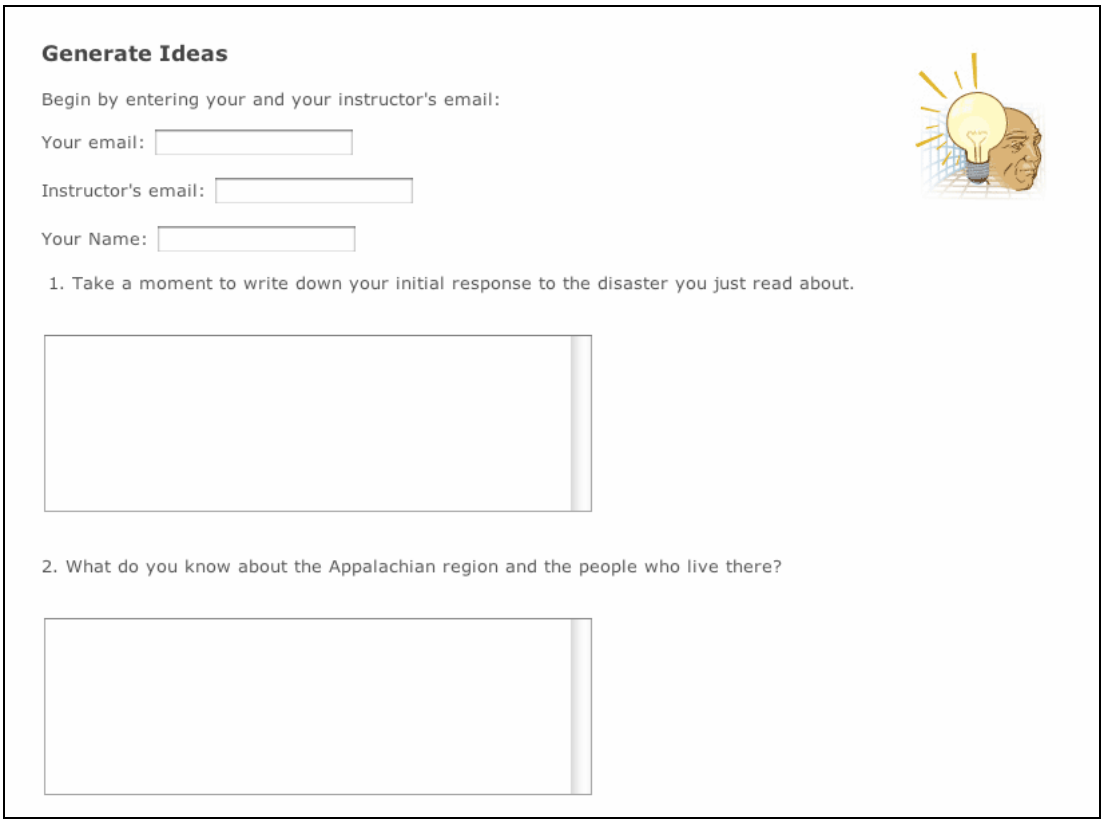

Figure 4. *Introduction to Professional Ethics*: Generate Ideas.
This phase of the cycle asks students to respond to a series of open-ended questions.

Gather Multiple Perspectives. In the next step in the sequence -- "Gather Multiple Perspectives" (see Figure 5) -- students are introduced to Pittston Coal Company. This section of the module directs students to web space containing the full text of the resources that were abridged for the Challenge. Both the article by Tom Price and the West Virginia Historical Archives Society describe the problems with the impoundment dams and the questionable decisions made by Pittston management regarding disclosure to the public. This page includes a chronology of recorded problems with the impoundment dams operated by Pittston Coal, a description of impoundment dams and their design constraints, and video excerpts from interviews with survivors of the flood, mine workers, and community leaders. The question of responsibility becomes most conspicuous when Tom Bethell, former United Mine Workers of America spokesman, accuses Pittston managers of knowing that the residents of Buffalo Valley were in danger and deciding not to warn them.

Research and Revise. From "Gather Multiple Perspectives," students go to "Research and Revise" (see Figure 6). In this phase of the cycle students are introduced to the ethical elements applicable to their professional practice: the concept of professional responsibility and professional codes of conduct. It is at this

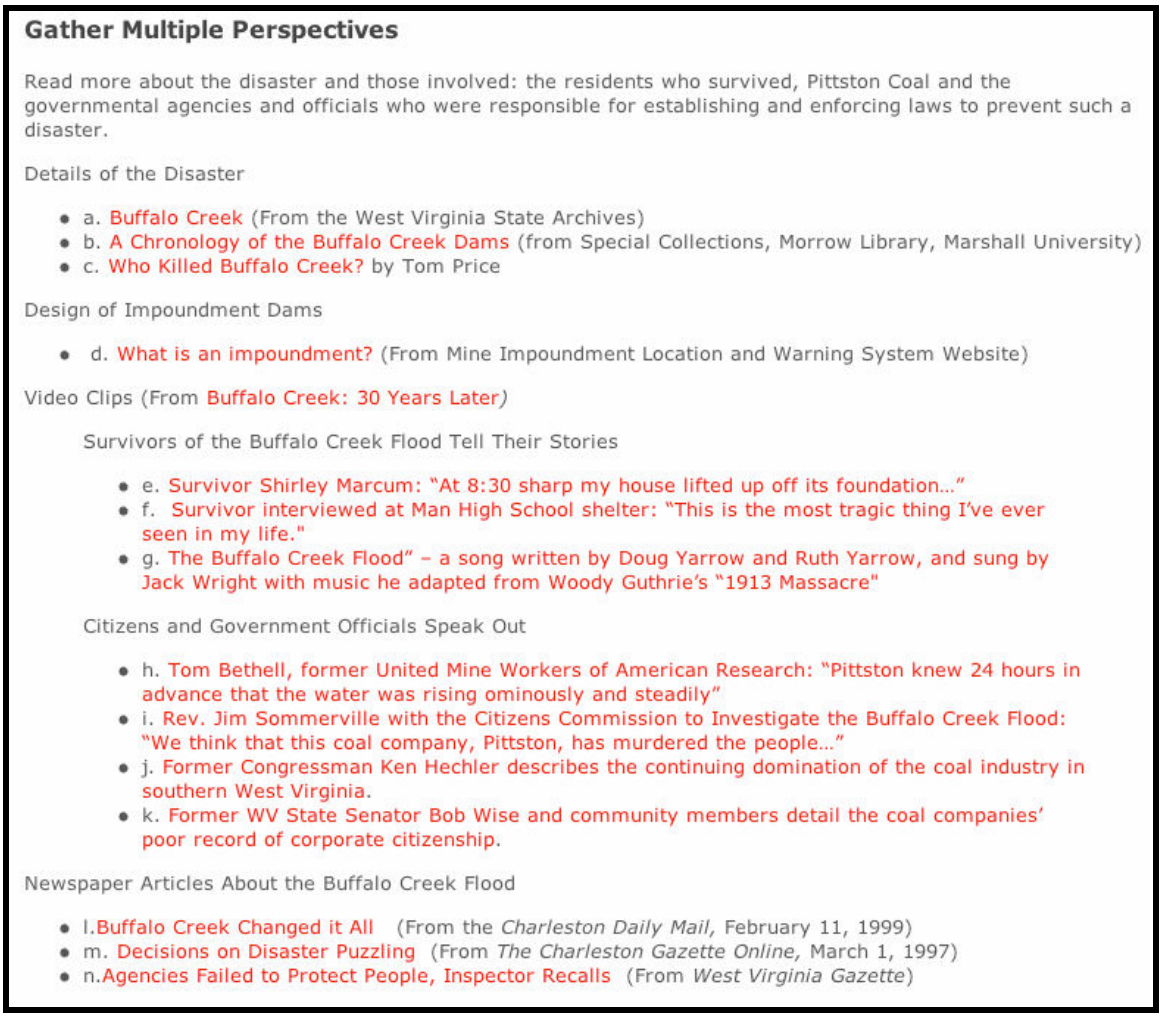

Figure 5. *Introduction to Professional Ethics*: Gather Multiple Perspectives. In this step in the cycle, students are provided additional resources about Pittston Coal Company's role in the disaster.

point in the cycle that students learn about the theoretical precepts that govern professional behavior, such as the paramouncy principle. They are asked to apply such principles to this particular incident. This crucial step in the process encourages students to develop their own skills of analysis and judgment. This part of the cycle ends with an exercise asking students to consider the relationship and balance of responsibility between companies and the communities in which they are situated. The resources in Research and Revise challenge and provoke students in ways that prompt them to consider the assignment of responsibility for the consequences of the disaster.

Test Your Mettle. The penultimate step in the process – "Test Your Mettle" (see Figure 7) – gives instructors a tool to assess what students have learned so far in the module. This particular module offers students two possible tests. One is the NSPE Code of Ethics Examination, a 25-question test over the provisions of the Code of Ethics; the other is a seven-question short answer exercise that could be used either as a test or a series of discussion questions in class.

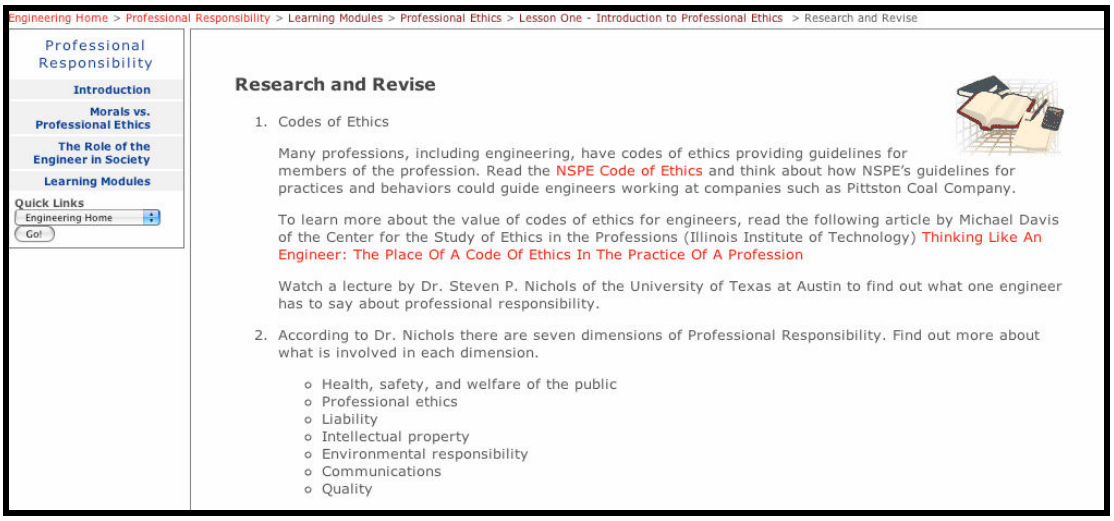

Figure 6. *Introduction to Professional Ethics*: Research and Revise
These resources introduce students to important philosophical concepts.

Figure 7. *Introduction to Professional Ethics*: Test Your Mettle
Two options are given to instructors. The option on the right is a series of short-answer questions that could be used as discussion questions in class instead of as a test.

Go Public. The final step in the Challenge Cycle, "Go Public" (see Figure 8) allows students to apply what they have learned. This module offers instructors four possible paths. The first, "Propose a Research Project," is designed specifically for the Engineering Communication course in which the module was piloted. In that course, this module is used as a foundation for a semester-long research project into corporate behavior. The assignment asks students to "do some research and find an instance of another company that has faced a problem" and then propose a research project on that company and its problem. Two other options ask students to discuss the concept of professional responsibility either in an essay or in an informal presentation. These

assignments could be adapted for a variety of courses, most notably a freshman introduction to engineering course. The final assignment which asks students to evaluate the dams on Buffalo Creek could be used in a variety of technical-content courses including a design course.

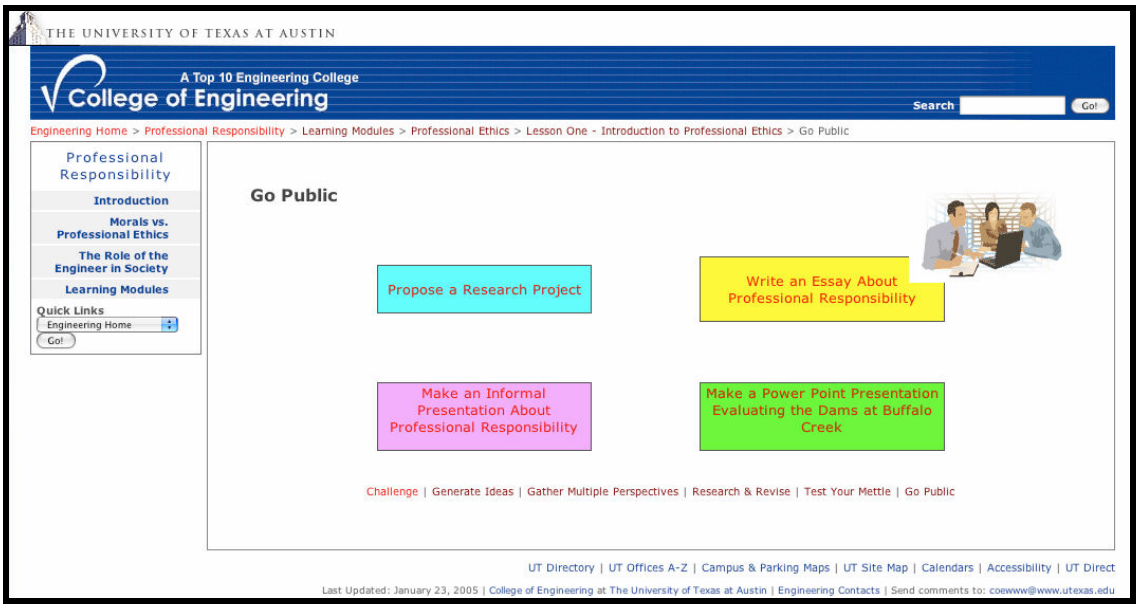

Figure 8. *Introduction to Professional Ethics*: Go Public

Each of the assignments is designed to elicit students' analytical responses to question of professional responsibility.

Piloting and Assessing the Modules

All of the modules developed in the fall of 2004 were piloted in two separate Engineering Communication courses by different instructors in different departments in the spring of 2005. In the fall of 2005 one of the modules will be piloted in two first-year introduction-to-engineering courses. The effectiveness of the pilots have been evaluated using assessment tools which use both qualitative and quantitative data. Although the committee understands the value of quantitative data, it also recognizes that pedagogical initiatives such as the ones undertaken by this project must be evaluated qualitatively. For the qualitative assessment, the project is using comments collected in focus groups with students from each course involved in the pilot, written evaluations of each class in the pilot completed by research assistants acting as observers , and faculty feedback forms completed by each instructor teaching any portion of a lesson. The quantitative assessment is based on an on-line, anonymous student survey developed specifically to evaluate these modules. The combination of these assessment tools will be used as the foundation for the revisions of the modules and plans for future modules.

Conclusions

As Colleges of Engineering endeavor to find effective ways to teach undergraduates the foundations of professional responsibility, administrators and faculty

must invent tools to fit the task. The PRiME Project is one of the ways the University of Texas is meeting that challenge. The goal of the project is to offer pedagogically sound resources that will encourage students to develop their analytical skills and teach them some fundamental strategies for approaching professional responsibility. The modules that have been developed are on-line and available to all faculty within our own college as well as other colleges.

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Christene Moore is a Senior Lecturer in the Department of Mechanical Engineering at the University of Texas at Austin. Ms. Moore's current research is focused on ways of expanding the undergraduate engineering curriculum to better incorporate topics of professional responsibility and ethics. In that endeavor in 1999, she worked with Ted Aanstoos and Dr. Steven P. Nichols to redesign and improve ME 204, a two-hour course in professional responsibility. In 2001, she partnered again with Steve Nichols and with Dr. Hillary Hart to design teaching modules in communication ethics. In 2003, Ms. Moore began collaborating with Dr. D'Arcy Randal on the topics of academic honesty and plagiarism. In the summer of 2004, Ms. Moore in collaboration with Dr. Billy Vaughn Koen implemented curricular modifications in the Mechanical Engineering writing course that emphasize corporate leadership and ethics. She is also a member of the PRiME (Professional Responsibility Modules in Engineering) Project which is funded by the Chair for Free Enterprise. The objective of the PRiME project, begun in summer 2004, is to create flexible teaching materials to help engineering faculty incorporate units on professional responsibility, leadership, and engineering ethics into their courses. In addition Ms. Moore developed the curriculum for a Freshman Seminar entitled "Production, Consumption, and Citizenship in a Post-Industrial Community" which focuses on the impact of technology on society and the influence of consumers and citizens on technology.

Ms. Moore works with College of Engineering's Engineering Communications Committee on initiatives that will help the College's Engineering Communication program continue to expand and improve. She is interested in developing ways to address the needs of non-native speakers in the College, increasing engineering undergraduates' opportunities to give oral presentations, and exploring the value of collaboration in the writing classroom. From 1997 to 2001, Ms. Moore was the faculty editor of the *Undergraduate Engineering Review (UER),* an electronic journal which is written, edited, and published by undergraduate engineering students.The quality of the *UER* was recognized with an award from the University of Texas Department of Academic Computing and Instructional Technology.

STEVEN P. NICHOLS, Ph.D., J.D., P.E.
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Dr. Nichols' research interests include topics in engineering design and manufacturing, technology commercialization, and professional aspects of engineering practice. He currently serves in two administrative posts at The University of Texas at Austin.

As the Associate Vice President for Research, Dr. Nichols supports the commercialization of the knowledge base of The University of Texas at Austin and supervises the activities of the Office of Technology Licensing and Intellectual Property. As the Associate Vice President for Research, Dr. Nichols advocates that the knowledge base of a university has potential to more broadly benefit society, and he believes that commercialization activities at universities must support the education, research, and service missions of a university. He initiated the Texas Alliance for Technology Commercialization and hosted the Alliance's first Technology Forum in May of 2002.

As the Director of the Clint Murchison Chair of Free Enterprise, Dr. Nichols focuses on creating and nurturing a culture of technology innovation, creativity, leadership, and entrepreneurship in the College of Engineering. As part of his activities, Dr. Nichols organized the Roden Scholar program and supported the start-up of the Engineering Entrepreneurship Society, and the Idea to Product (I2P) technology competition. I2P has grown from 9 teams at UT-Austin in 2002 to 72 teams in 2003. The University of Texas at Austin will serve as the host for the first International Idea to Product Competition in the Fall of 2003. Dr. Nichols has also initiated multidisciplinary research and classroom activities that encourage collaborative learning environments for students, faculty, and staff from the College of Engineering, the College of Natural Sciences, the McCombs School of Business, and the School of Law.

Dr. Nichols previously served as the Associate Chair for the Department of Mechanical Engineering. He coordinates with faculty and industrial representatives. He also prepared proposals for industrial support for Departmental Activities. Dr. Nichols also serves as a designated contact for alumni. As part of his responsibilities, Dr. Nichols has raised more than $8 million in industrial support for educational activities.

Dr. Nichols previously served as the Director of the Design Projects Program. (Department of Mechanical Engineering) Dr. Nichols taught the Department's capstone design courses (ME 466K and ME 279M) for 14 years, supervising approximately 200 students each year in approximately 60 industrial sponsored projects annually. He emphasizes design methodology and has introduced material on engineering ethics, and engineering professionalism. While serving as Director for the program, Dr. Nichols has raised more than $3,920,000 in industrial and government support for undergraduate engineering design education. Dr. Nichols coordinated an interdisciplinary (collaborative) design experience among students and faculty in the Department of Mechanical Engineering and the Department of Electrical and Computer Engineering. He also organized a cross-disciplinary course in entrepreneurship in cooperation with the College of Natural Sciences, the School of Business, the College of Pharmacy, the School of Law, and IC^2.

Dr. Nichols also previously served as the Director of the Center for Energy and Environmental Resources (formerly the Center for Energy Studies). CES research includes faculty in separations research, process energetics, energy economics, and environmental engineering. Dr. Nichols also serves on the board for a state agency, the Texas Energy Coordination Council. The Council recently completed a study of Market Based Methods for Encouraging Renewable Resources for the State of Texas.

Dr. Nichols served as the Acting Director of the Center for Electromechanics for five years. CEM research focuses on rotating machines, but Center researchers also work in areas including resistance welding, electro-spray, and hybrid electric vehicles (suspension, control, and energy requirements). During the 1997-98 Academic Year, the Center introduced a new research program both in power quality applications and in space applications for flywheel technology developed at CEM.

Dr. Nichols is a member of the New York Academy of Sciences, is a Fellow of the American Society of Mechanical Engineering, and has received the Fred Merryfield Design Award from the American Society of Engineering Education. Dr. Nichols received his Ph.D. in Mechanical Engineering in 1975 and J.D. in Law (with honors) in 1983.

STEPHANIE J. BIRD, PH.D

Dr. Stephanie J. Bird is co-editor of the journal *Science and Engineering Ethics*, an international journal that explores ethical issues of direct concern to scientists and engineers related to both the practice and application of science and technology. In its tenth year of publication, the journal is widely abstracted and indexed and was recently cited by the National Academy of Sciences as a leading resource for scholarly articles on research integrity. Recent special issues of *Science and Engineering Ethics* have focused on various topics including "Whistleblowing and the Scientific Community", "Scientific Misconduct", and "Communicating Science".

Dr Bird is former Special Assistant to the Provost and the Vice President for Research at the Massachusetts Institute of Technology (MIT) where she worked on the development of educational programs that address ethical issues in science and engineering, professional responsibilities, and ethical issues in research practice and science more generally. She is a laboratory-trained neuroscientist whose research interests now focus on the ethical, legal and social policy implications of scientific research, especially in the area of neuroscience. Her theoretical and laboratory training have been complemented by work in areas of ethical and legal philosophy.

Dr. Bird has taught in her areas of expertise at M.I.T. including both courses designed to examine various aspects of the responsible conduct of research, and those that consider the ethical and social policy implications of technology. Dr. Bird has written numerous articles on issues in the responsible conduct of research and on mentoring and other responsibilities of science professionals.

In 1990 and 1991, Dr. Bird served as President of the Association for Women in Science (AWIS), a national organization with 5000 members and over 80 chapters across the US. She was Director of the first AWIS Mentoring Project which was designed to encourage and support undergraduate and graduate students in their pursuit of careers in math, science and technology.

Dr. Bird is an active member of the Society for Neuroscience and currently chairs the Social Issues Committee. In 1983, she initiated the annual Social Issues Roundtable which examines ethical and policy ramifications of various aspects of neuroscience research. She is an active member and Fellow of the American Association for the Advancement of Science (AAAS).

Dr. Bird is an internationally-known speaker, giving talks and workshops at professional societies, conferences, medical schools, and research and teaching institutions on teaching research ethics, on various aspects of professional standards and ethical values in science including mentorship, and on neuroethics.