AC 2007-2291: DEVELOPING CURRICULUM ON RESEARCH ETHICS FOR ENGINEERS: GATHERING THE DATA

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Introduction

For the past several years, faculty at the University of Texas at Austin have been developing web-based educational modules designed to help Engineering faculty integrate the teaching of ethics into their existing courses. These undergraduate educational modules, known collectively as PRiME (Professional Responsibility Modules in Engineering), cover topics such as Professional Ethics, Ethical Leadership, and Credibility of Sources and are already being used by faculty at UT and elsewhere: http://www.engr.utexas.edu/ethics/primeModules.cfm. Inspired by the success of these undergraduate modules, several faculty have outlined a plan to expand the educational offerings by creating, with the help of a grant from the National Science Foundation (NSF), web-based educational materials that prepare graduate students for the ethical issues they will encounter as academic and professional researchers. This paper describes the first stage of this project:

1. assessing the need for graduate education in research ethics
2. determining the appropriate issues to address and pedagogical techniques to employ in teaching graduate rather than undergraduate students.

Gathering the data to proceed with this project entailed reviewing the literature on teaching graduate engineering research ethics (especially our four focus topics), working with our multi-disciplinary team to identify appropriate issues and pedagogical techniques for graduate students, and reviewing the assessment we performed on the undergraduate modules.

Literature Review – Engineering Research Ethics

The research on engineering ethics education has focused, largely, on the undergraduate curriculum.\(^1,2,3,4\) For instance, in 1989, faculty and practitioners participated in an NSF-sponsored workshop at The University of Texas at Austin (UT Austin) in 1989 to examine how topics of professional responsibility can best be introduced into the undergraduate engineering curriculum.\(^4\) The workshop identified and examined limitations on integrating these topics into the classroom, including lack of faculty exposure to the topics, lack of faculty time to introduce the topic into the classroom, lack of space in the curriculum, and lack of support material. In the last 16 years, driven by accreditation requirements\(^5\) and other factors, faculty have better defined the need, developed materials, and introduced these topics to undergraduate engineering students across the United States. Much less material, however, is available to assist in developing an engineering graduate student’s understanding of “academic” ethics involved in teaching and research.

Researchers, such as Steneck,\(^6\) stress the importance of including topics of engineering ethics in courses across the curriculum, but few researchers have outlined specific suggestions for including ethics at the graduate level (there are exceptions – see Vollmer and Hall’s work\(^7\)). Yet, graduate students, who stand at the doorway to future careers as high-level engineers and researchers, have a real need for exposure to these subjects. Studies suggest that ethical development continues before and during graduate school.\(^8\) Graduate students themselves are sometimes the recipients of harsh, if not ethically questionable treatment by their research
advisors. Herkert (1999) reports that graduate students seem unaware of the importance of ethics, and Koehn observes that graduate students at Lamar University ranked ethics as only 5th out of 11 most important “educational attributes”. Undergraduates actually ranked “the impact of engineering solutions in a global and societal context” higher than did graduate students (4th as opposed to 7th); this result may reflect the increased exposure of undergraduates to topics of professional responsibility.

Many students do not appear to have internalized the importance of research ethics. Along with an article by Whitbeck on “Responsible Authorship,” as of March 2006, the Online Ethics Center for Engineering and Science presents several essays, including one by Eugene Tarnow on authorship status, as well as scenarios and resources, such as the Federal Policy on Research Misconduct. But in a survey of students in a graduate class at the UT Austin’s Department of Civil Engineering, not one had ever heard of the site or of the Federal Policy. Much less are students aware of material on research-paper plagiarism, presentation of data, and intellectual property.

Despite the thoughtful work that has been published on problems with presentation of data and publication of research results, most students remain unaware of the guidelines available for constructing responsible, informative graphics. Edward Tufte has been particularly influential in exposing the potential distortion in decisions about how to display data graphically. The Visual Display of Quantitative Information includes five informative pages on various kinds of distortion, along with guidelines for avoiding them. His principle of providing clear labeling on the graphic itself has been taken up by several Engineering faculty at the University of Texas at Austin, but the number of UT students educated or mentored to provide such labeling seems vanishingly small. William S. Cleveland has provided useful insight on how to design graphics for clarity and to eliminate distortion of data, but his work is not generally cited in Engineering publications and courses.

Problems with publishing research (questions about anomalous data, duplicate publication, authorship status, plagiarism, and copyright violations) have been addressed by numerous researchers. Much of this work, however, has come out of the medical community, which has developed ethical codes in response; as an example, see the explanation of applicable codes on publication and authorship developed by the American Psychological Association. Responsible Conduct of Research (2003) uses biomedical case studies exclusively, and even the helpful guide for administrators published by the Council of Graduate Schools in 2006, Graduate Education for the Responsible Conduct of Research, was developed from a project to train graduate students from the behavioral and medical sciences. Whitbeck has recently presented guidelines on authorship and encourages the development of “field-specific and institution-specific” ways of working out differences on publication questions. And Loui’s discussion of plagiarism (2002) has focused attention on what constitutes plagiarism in various fields. Loui presents guidelines for defining plagiarism, including the finding that “quoting oneself is not plagiarism,” but he also observes that “[d]ifferent disciplines have different conventions, styles, and expectations for citing previous work.” Compounding the problem is the fact that academic rules on plagiarism are often at odds with the actual publishing practice of scientists and engineers, and the literature offers conflicting views about what knowledge is in the public domain and what is specialized knowledge.
policies also seem to confuse “intellectual property” and the concept of “academic property” or fair use. As a result, theorists, such as Lawrence Lessig, have called for a reexamination of our definition of intellectual property, copyright, and fair use.

Identifying the Critical Issues in Research Ethics

As the review of the literature of the past 20 years on research ethics shows, the research to date has focused largely on investigation and definition of research misconduct; with notable exceptions, little of that work has addressed how to teach emerging researchers – our graduate students – about responsible conduct and dissemination of research. This failure represents a serious disservice to our graduate students because in fact ethical problems lurk at every stage of engineering academic life – from preparing proposals, to designing and conducting experiments, to reporting and publishing the results. In the initial stages of research, researchers face temptations to fabricate, falsify, or manipulate data (see, e.g., Bird and Dustira). In later stages of research, researchers may inadvertently distort results by incomplete explanation or inadequate selection or faulty visual display. And in the final stage, problems may arise in the assigning of authorship, giving proper credit to others, publishing essentially the same paper in different forms or places, or unintentionally plagiarizing (see Loui and Pimple for examples).

The NSF project described here will respond to this undeniable gap in graduate engineering education by creating effective materials that use the Web to incorporate research ethics into graduate courses and programs. The new project utilizes the expertise, talents, and energies of a multi-university team of researchers to plan the most effective methods of presenting and teaching four new graduate topics:

1. Falsification and Fabrication of Research
2. Plagiarism
3. Presentation of data
4. Intellectual Property

The goal of the project is to develop web-based lessons on each of these topics. The initial step in the process is to determine the most crucial issues involved in each of these topics. Our experience and research has shown us that the dilemmas engineering researchers face in these areas are complicated and trickier than might be expected. The answers to questions that arise are not cut and dried. For instance, the internet, as much as it facilitates research, multiplies the problems associated with research by blurring the boundaries of publication and authorship. It is inevitable that as our capabilities and forms of research change so will our practices and standards of conduct. Caroline Whitbeck suggests that previous standards for ethical conduct may no longer hold, since “[a]s long as research continues to flourish, the conditions and collaborations necessary to further it will continue to change.”

Whitbeck points to the ambiguity that makes ethics instruction an exercise in analysis for both students and instructors, rather than the clear and clean delivery of a body of knowledge that can be conveyed in a series of lectures and readings. Thus, our research will be guided by thorny questions and points of investigation. For instance, we must ask whether engineering research is anchored in practices and standards of behavior that vary significantly from the practices and standards of behavior in humanities? Rules of conduct that fit well in one discipline may not translate fluidly to another. If the translation is not fluid, how do engineers adjust to the
difference? In conjunction with those questions, we may also investigate whether the weight and value assigned to the concept of authorship is different in engineering than in humanities? Should the standards that have been developed to protect authors in humanities-based disciplines be applied wholesale to authors in engineering? Moreover, could there be legitimate reasons for having different standards regarding specific practices such as the use of direct quotations in engineering than the standards that are traditionally applied in humanities-based disciplines? For instance, when authors are writing about objective data, such as the design of a truss, is the originality of language something that should be guarded with the same vigilance as the originality of prose in an essay, newspaper article, or piece of fiction should be guarded? We might also ask where do the boundaries between intellectual property protected by copyright and intellectual property protected by patent intersect? Where do those boundaries diverge?

To adequately address our target topics and allow students and instructors room to confront questions such as these, it will be necessary to identify the most appropriate and fruitful case studies to use as a foundation for the lessons on each topic. Although participating faculty have already developed and piloted material on ethics for undergraduate courses, we are well aware that the audience for these lessons is different. To correct for any biases or mistaken assumptions, a central challenge for the new graduate-oriented project is to create materials and draw from resources that are sophisticated enough to appeal to engineering graduate students, many of whom have had significant work experience. Our multi-disciplinary engineering team members will be critical in helping us develop meaningful case studies that foster examination of real-world issues in the workplace (whether industry or consulting company or national lab) and in academia (for those students going on to academic careers).

**Identifying feasible, practical, and effective ways to tackle those issues in the classroom**

The lessons we develop for graduate students will build on materials we have already created for undergraduates as part of the PRiME project. The PRiME modules are a series of web-based educational materials that can be integrated into existing engineering courses. The cycle-structure, described below, and the electronic method of delivery allow for functional modularity: any engineering faculty member can use any stage of the “lesson” (and accompanying materials) in combination with other stages or on its own, depending on the amount of time available.

All of the existing modules use a web-based platform developed in the UT College of Engineering (and in the university consortium called VaNTH). The goal was to design educational materials and processes that use the principles provided in the watershed work, *How People Learn.* Bransford and the National Research Council committee set forth a model for developing “environments that can optimize learning.” Elaborating on the HPL model, the College’s Faculty Innovation Center created the Challenge-Based Instruction framework to support web-based teaching. The six stages in the Challenge cycle are represented in Figure 1. This visual design, which is used for all the PRiME lessons, represents a six-step series of exercises, readings, or tasks. The Challenge Cycle leads students through the steps of reflecting, investigating, analyzing, and making judgments. Although the content, depth, and length of the lessons differ, the actual structure, reflected in the image, is constant. The consistency of the web platform is purposeful and is intended to facilitate use of the material in the lessons for both students and instructors. The flexibility of the medium serves instructors hard-pressed to create
new materials, and, of course, web-based materials are potentially engaging, as Herkert and Steneck have both noted in their discussions of the effectiveness of teaching ethics using web-based materials. Thoughtful use of “educational technologies,” as Michael Loui points out, also accommodates different learning styles and fosters student-centered and active learning. Even more importantly, technologies that enhance collaboration and provide shared workspace are especially appropriate for exploring the “open-ended” nature of “significant ethical problems.”

As our assessment results described below show, the modules developed for undergraduates have been shown to be not only engaging to students but also user-friendly for faculty; each is accompanied by a web-based Instructor’s Guide. We propose to use substantially this same framework to develop and deliver materials and instructional activities aimed at the needs of graduate students, but we remain open to suggestions from our multi-disciplinary team on the format and usability in a graduate classroom. To demonstrate this framework and to describe how the modules work in the classroom, we present in this section examples from several of the PRiME modules we have developed so far.

The Challenge Cycle

The cover page of every module (see Figure 1) spells out the purpose and the educational objectives of the module and introduces students to the Challenge Cycle which, as noted above, defines the sequence and structure of each lesson.

### What to Report?

**Purpose:**

The purpose of this lesson is to give you experience in and resources for deciding which data should be reported and which data are not relevant or necessary to report.

**This lesson will help you to:**

- Make decisions regarding what are credible and non-credible sources of information
- Decide which sorts of information can be, and which cannot be, ethically disregarded
- Realize your responsibilities as an engineer when communicating information in a professional capacity

**Introduction:**

Diane, a young engineer is faced with a decision regarding whether or not to consider reporting hearsay in an engineering study to a client. She wants to do the right thing but comes under a lot of pressure from her manager and the client’s attorney.

![Figure 1. The Challenge Cycle.](image)

The introductory page shown here is from a lesson (What to Report?) that explores the credibility of hearsay information. Designed for upper-division undergraduates, this module explores the communication dilemma a young engineer faces in research for a client.
From that cover page students can begin their navigation of the lesson by clicking on the word “Challenge” at the top of the cycle. Each lesson begins with a Challenge that presents a case study or a scenario prompting students to consider some difficulty or dilemma in engineering or professional behavior. For instance, in *Introduction to Professional Ethics*, a module designed to make students aware of the impact engineers can have on society and the codes of ethics that guide professionals, the Challenge (see Figure 2) involves an historical event as the foundation of the first lesson. In other lessons, such as *Plagiarism* and *Defining Ethical Leadership*, the Challenge is based on original hypothetical scenarios that were written by the PRiME developers.

The subsequent steps in the cycle, which are linked to iconographic buttons at the bottom of each page, allow students to progress through the stages of learning: demonstrate previous knowledge (Generate Ideas, see Figure 3), learn new information (Gather Multiple Perspectives, Figures 4 and 5), develop tools for analysis (Research and Revise, Figure 6), demonstrate what they have learned (Test Your Mettle, Figure 7), and adapt newly-acquired knowledge to new situations (Go Public, Figure 8).

**Figure 2. The Challenge.** The 1972 failure of an impoundment dam in West Virginia which left 125 people dead and 4000 homeless is the foundation for the module on *Introduction to Professional Ethics*. The Challenge gives students resources to read about the Buffalo Creek Flood to get them thinking about issues of responsibility.

**Figure 3. Generate Ideas.** This phase of the cycle allows students to record their initial reaction to the scenario or case study they have just read by answering open-ended questions that can be submitted electronically and/or used as a foundation for class discussion.
Figure 4. Gather Multiple Perspectives.
This phase presents several sources from a variety of media to help expand students’ knowledge. This example includes links to video clips from a documentary on the Buffalo Creek flood as well as an original article on the role of Pittston Coal engineers by Dr. Theresa Jones.

<table>
<thead>
<tr>
<th>Gather Multiple Perspectives</th>
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<tbody>
<tr>
<td>Read more about the disaster and those involved: the residents who survived, Pittston Coal, and the governmental agencies and officials who were responsible for establishing and enforcing laws to prevent such a disaster.</td>
</tr>
<tr>
<td>Details of the Disaster</td>
</tr>
<tr>
<td>• A. Buffalo Creek (From the West Virginia State Archives)</td>
</tr>
<tr>
<td>• B. A Chronology of the Buffalo Creek Dam (From Special Collections, Morrow Library, Marshall University)</td>
</tr>
<tr>
<td>Engineers and Buffalo Creek</td>
</tr>
<tr>
<td>• C. The Role of Engineers at Buffalo Creek by Theresa Jones, PhD., PE</td>
</tr>
<tr>
<td>Design of Impoundment Dams</td>
</tr>
<tr>
<td>• D. What is an impoundment? (From Mine Impoundment Location and Warning System Website)</td>
</tr>
<tr>
<td>Survivors of the Buffalo Creek Flood Tell Their Stories (Video Clips from Buffalo Creek: 30 Years Later)</td>
</tr>
<tr>
<td>• E. Survivor Shirley Marcum: “At 8:30 sharp my house lifted up off its foundation...” (running time 1:32)</td>
</tr>
<tr>
<td>• F. Survivor Interviewed at Man High School shelter: “This is the most tragic thing I’ve ever seen in my life.” (running time 1:43)</td>
</tr>
</tbody>
</table>

Figure 5. Gather Multiple Perspectives. For What to Report we video-recorded an interview with attorney, Gretchen Hoffman, which has been broken into two-minute segments, posted on the website, and linked to questions on the Gather Multiple Perspectives page for that lesson.
Research and Revise

1. Codes of Ethics
   Many professions, including engineering, have codes of ethics providing guidelines for members of the profession. Read the NSPE Code of Ethics and think about how NSPE’s guidelines for practices and behaviors could guide engineers working at companies such as Pittston Coal Company.
   To learn more about the value of codes of ethics for engineers, read the following article by Michael Davis of the Center for the Study of Ethics in the Professions (Illinois Institute of Technology) Thinking Like An Engineer: The Place Of A Code Of Ethics In The Practice Of A Profession
   Watch a lecture by Dr. Steven P. Nichols of the University of Texas at Austin to find out what one engineer has to say about professional responsibility.

2. According to Dr. Nichols there are seven dimensions of Professional Responsibility. Find out more about what is involved in each dimension.
   - Health, safety, and welfare of the public
   - Professional ethics
   - Liability
   - Intellectual property
   - Environmental responsibility
   - Communications
   - Quality

Test Your Mettle - Essay

Consolidate some of your ideas about leadership the essay specified by your instructor:

- **Essay 1:** AN ANALYSIS OF CORPORATE MANAGEMENT PRACTICES
  After examining a code of management practices (issued by an engineering professional association), you describe how the code conforms to principles of ethical leadership (as you define the term).

- **Essay 2:** MY RESPONSE TO AN ETHICAL LEADERSHIP PROBLEM
  After reading a scenario that depicts a difficult situation for your management and followers, you describe your approach to leading the company to a better future.

Go Public

Please choose the appropriate button as assigned by your instructor. Each link will direct you to a different assignment option under the “Go Public” heading.

- **Option 1:** Short Presentation
- **Option 2:** Oral Progress Report
- **Option 3:** Finding Credible Sources

Figure 6. Research and Revise. At this point in the cycle, students begin to grapple with analysis of more complex issues and readings such as Davis’s scholarly article “Thinking Like an Engineer: The Place of a Code of Ethics in the Practice of a Profession” (1991).

Figure 7. Test your Mettle. Students can demonstrate, in this step, what they have learned by taking a test or writing an essay (as in this lesson on Ethical Leadership) or making a presentation.

Figure 8. Go Public. In this final stage of the cycle students are asked to apply what they have learned.

The overall approach of the modules can be adapted to many levels of education from first year to graduate school. For instance, in some lessons, such as Evaluating Web Sources, shown in Figure 7, alternative assignments enable instructors to select an assignment appropriate for their specific needs. Our plan has been to develop the graduate modules using the same framework; however, our assessment of and experience with existing modules may necessitate some structural changes.

The PRIME Learning Modules: Assessment, Revision, and New Challenges
Before developing new materials, we will “close the loop” on our previous assessment of the undergraduate modules and build relevant findings into the content, pedagogical techniques, and instructional delivery methods of the new modules.
Six PRiME lessons were piloted and assessed at UT Austin in the spring of 2005. Results of the assessment, reported in “PRiME: Integrating Professional Responsibility into the Engineering Curriculum,” show that the undergraduate modules were successful in engaging students in the exploration of ethical issues. Most of the participants in the student focus groups said that the PRiME pilots were the first time they had explored ethics and professional responsibility topics in their engineering courses. The self-reporting questionnaire revealed that most students felt the lessons enhanced their “understanding of professional responsibility”; the mean response to this question, across all six lessons, was 3.8 (out of a maximum positive response of 5). The students also rated the lessons as relevant to their needs. Student focus-group critiques did indicate that two lessons needed revision, and those critiques then informed our revision of the lessons and creation of the Instructor’s Guide.

Faculty usability assessment of the lessons was positive. The four faculty who used the modules noted that the material engaged students and provoked passionate and reasoned discussion. All four faculty members involved in the pilot have continued to use the modules in their courses. Because the goal of PRiME is to help faculty and administrators train students in ethics and professional responsibility by developing material on those topics that can be integrated into core engineering courses, the success of the material with instructors seems as important as the success of the material with students. We are thus heartened by the positive results of piloting one of the PRiME modules at Virginia Tech.

Based on the 2005 assessment, we revised the modules to improve usability and effectiveness. We also created an extensive on-line Instructor’s Guide to support faculty adopting the PRiME modules in their engineering classes. The Instructor’s Guide is delivered two ways on the web: through a stand-alone document (see the table of contents in Figure 9) or via interpolated notes to guide instructors on ways to use the materials on the student-view pages (Figure 10). These notes are viewable only by instructors who have logged in with their own password.

To enable faculty to adapt the lesson to whatever amount of class and homework time they have available, we created four Quick Start teaching options for each lesson; instructors can choose the option that best fits their schedule and syllabus. Quick Start enables instructors teaching different courses to make use of any or all of the PRiME lesson materials quickly and easily. The Quick Start teaching options give step-by-step lesson plans, ranging from having students work through the material on their own outside of class to engaging the students in various ways over multiple days in and outside of class. In between those two extremes are other options for fewer or more days in class and fewer or more assignments.
In spite of our careful structuring of the lessons to be able to be broken apart, however, in the year and a half since the assessment, issues have arisen about the amount of material incorporated into each lesson. Even though instructors do not have to use all of the stages in each lesson, there is anecdotal evidence that students (and faculty) find it confusing to be faced on the screen with all the stages and then have to bypass some. We are in the process of rethinking the visual design of the lessons to provide users a way to “enter” a narrower portal that will show on the screen only those stages to be taught. Additionally, since the pilot, few faculty (even the developers) seem to have actually used all of the material in the lesson they are teaching. Along with our new project team, we intend to explore more carefully the ways to do what Michael Davis has suggested: insert into an existing course an “ethics moment” that arises organically from the design, practice, or research issues at hand. ³⁶ Davis teaches a workshop to help faculty develop their own ethics moment; with that goal in mind we plan to develop with our engineering partners a series of discrete problems or writing assignments specific to individual disciplines: environmental, industrial, electrical, etc. The more we can customize examples and materials for graduate researchers and the smaller we can make them (in Davis’s sense of “micro-insertion”), the more success we may have at integrating ethics into engineering graduate curricula.

Research Ethics for Graduate Engineers: Conclusions and Next Steps

As our literature review demonstrates, the lack of pedagogical research on and educational materials for teaching research ethics to graduate students is a serious gap in U.S. engineering curricula. To fill that gap, we are creating a curricular package that covers research issues encountered by engineering graduate students as academic and professional researchers. It is
possible, however, that there exist curricular or pedagogical innovations in graduate research ethics that have not yet made it into the literature. Our multi-disciplinary team of researchers will help us explore other university curricula and probe beneath the titles of courses. The team will also help us structure real-world scenarios that incorporate critical issues in research ethics, from gathering the data to publishing the results. The team will meet in February 2007, so results of that planning clinic will be available at ASEE 2007.

Our experience creating and developing the undergraduate modules for the undergraduate PRIME project gives us a conceptual, pedagogical, and technological foundation for developing these new modules. Our goal is to create four modules that can be taught as part of an intensive short course or as free standing units in individual graduate courses. The results of our own assessment indicate, however, that we may need to make structural adjustments in the design and breadth of lessons for the graduate modules. The free standing units may need to be even smaller and more flexible, so that graduate faculty may use them more readily as a small (in terms of teaching time taken) but powerful (in terms of effective learning) add-on to existing courses.

References


