PRiME: Designing Challenge-Based Ethics Instruction for Undergraduate Engineers

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Abstract

Engineering Communication faculty at The University of Texas at Austin (UT Austin) are developing web-based educational modules designed to infuse the teaching of engineering ethics into the engineering curricula. To accomplish this, the College of Engineering has developed an instructional framework to embody the principles of Challenge-Based Instruction deriving from the work of Bransford et al. in How People Learn. The Challenge cycle has worked very well for developing a series of interactive, learner-centered materials and activities, but the HPL model, which includes four "lenses" that used together create a successful learning environment, may be problematic when applied to the teaching of ethics. This paper discusses the design of the modules, including self-assessment strategies, and the particular problems facing instructors of engineering ethics as they attempt to create an environment that is learner-centered, knowledge-centered, assessment-centered, and community-centered. The first two principles, especially, may be difficult to fulfill.

Keywords: *engineering ethics*, *learner-centered, assessment, learning environment*

Introduction

One of the most profound challenges to engineering programs, set by the Accreditation Board for Engineering and Technology (ABET), is the requirement that students master professional as well as technical skills. According to Criteria 3, the "education outcomes" expected of engineering graduates now comprise 11 skills, six of which are professional skills such as possessing "an understanding of professional and ethical responsibility."[1] From an academic point of view, such criteria require a department's core engineering curricula to extend beyond math, sciences, and technical problem-solving into the domain of the humanities and social sciences, a boundary that faculty from all disciplines have traditionally been reluctant to cross.[2] Moreover, the field of engineering education must expand in depth as well as scope. The foreword of a recent special issue of *The Journal of Engineering Education* calls on readers to raise the standards of the field by, among other things, taking into account cognitive and educational psychology and the best practices in assessment.[3] An article in the same issue highlights a number of engineering programs that teach professional skills in effective and innovative ways, but the authors conclude that there is "much work to be done" in assessment.[4] In this paper, we introduce Professional Responsibility Modules for Engineering (PRiME), an initiative at The University of Texas at Austin that brings together humanities-trained and engineering faculty to help infuse engineering ethics into existing curricula, and to do so making use of recent research in educational psychology. PRiME is funded by the Chair of Free Enterprise and the UT College of Engineering, and it will offer teaching modules in topics like "Professional Ethics," "Credibility of Sources," and "Leadership and Ethics."

The PRiME project is part of a larger effort in the College (and in the university consortium called VaNTH) to design educational materials and processes that use the principles provided in the

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watershed work, *How People Learn*.[5] Bransford and the National Research Council committee set forth a model for developing "environments that can optimize learning." The model (what we will refer to as the "HPL model") has four overlapping lenses: learner-centered, knowledge-centered, assessment-centered, and community-centered. The College's Faculty Innovation Center elaborated on the HPL model to create the Challenge-Based Instruction (CBI) framework to support web-based teaching. The PRiME faculty, in turn, are making use of this framework to produce their modules.

PRiME, then, aims to apply the most advanced educational theory and teaching technology to a pressing problem in engineering education. Yet in the process of creating the modules, we are formulating two sets of questions: first, we question how well our educational materials fit the HPL model and adhere to its principles; second, we question the practical applicability of the HPL model itself for our particular purposes. How well does it work for training engineering students in ethics and professional responsibility? This presentation begins with a brief overview of the HPL model and UT's Challenge-based Instruction framework. It then focuses on the development of one lesson in PRiME's "Credibility of Sources of Information" module, of which a pilot was designed and tested during the academic year 2004-2005. Much of the presentation focuses on how the PRiME developers adapted the HPL-derived, web-based framework created at UT Austin to the pedagogical requirements and materials of the ethics module. We conclude with some preliminary questions about how well the HPL model will work in the teaching of engineering ethics.

The "How People Learn" Model

The HPL model was created to address a crisis that educators faced at the end of the twentieth century: human knowledge had expanded at such a rate that its "coverage" was an "impossibility." HPL deliberately reset the goal of education from helping students acquire discrete elements of "knowledge" to helping them develop a "fundamental understanding about subjects, including how to frame and ask meaningful questions about various subject areas." [5] The book *How People Learn* also adopts that goal for itself, drawing from the abundant advances in the science of learning, and synthesizing research from cognitive and other fields of psychology to formulate the underlying principles of genuine, in-depth learning. *How People Learn* isolates three principles: (1) students bring to a classroom topic various understandings and misunderstandings that need to be revealed before the students can learn new knowledge; (2) students learn best when new knowledge is presented in a "conceptual framework," allowing them to apply that knowledge to different situations; and (3) students need to develop "metacognitive" skills, or skills in which they monitor their own learning. Of course, students can and do learn material quickly without these principles in play—as, for instance, when they cram for exams—but what they learn may not be retained or easily applied outside the classroom.

From these three principles, Bransford and the National Research Council committees devised a model "learning environment," which uses an earlier model from Bransford: four interrelated "lenses," or perspectives, as illustrated in Figure 1.

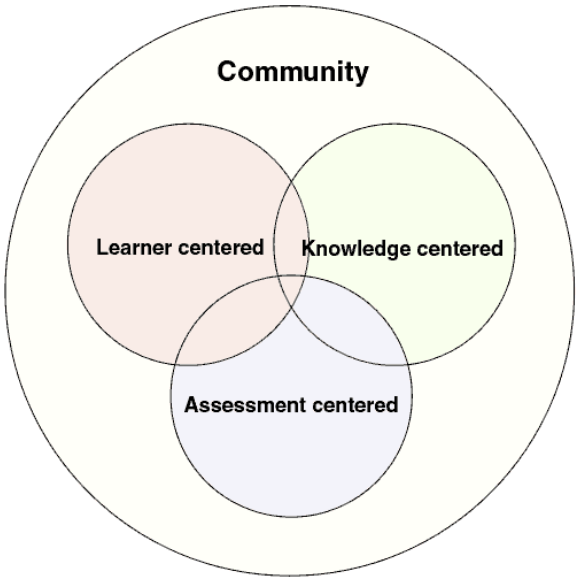

Figure 1. The four interrelated lenses of the HPL learning environment. (Adapted from Bransford in Soraci and McIlvane, p.134.) [6]

Model learning environments are "learner-centered" in that they attempt to elicit and clarify the knowledge that students bring to the classroom. The teachers avoid imposing a "middle-class, mainstream" norm on the classroom, incorporating instead a "sensitivity to cultural practices of students and the effect of those practices on classroom learning." Bransford uses the metaphor

of "bridge building" to illustrate what a "learner-centered" teacher tries to accomplish. Such teachers not only invite the students to cross the bridge of learning, but they "keep a constant eye on both ends of the bridge."

The "learner-centered" activities become "knowledge-centered" as the students build on or correct their prior knowledge. Ideally, teachers aim to impart not a thin array of facts and formulas, but a "deep understanding" of the field, and conceptual knowledge that the student can recall and access long after the class is over. Bransford et al. admit that creating "knowledge-centered classrooms" can be difficult if the students bring vastly different literary and computational skills to the classroom. The teacher may need to reconcile the emphasis on "deep understanding" with more practical concerns to "promote the automaticity of skills necessary [for the students] to function effectively."[5] In other words, some students lacking skills basic to the discipline may need time to develop fluency and, eventually, an automatic practice of those skills before attending to the "deeper understanding" of a subject.

The "Assessment" lens overlaps with those of the "Learner" and "Knowledge" because the HPL model assesses both the knowledge that students bring to the class, and what knowledge they gather as the course progresses. *How People Learn* recognizes two types of assessment: formative and summative. Formative assessments treat an assignment as a "work in progress," conveying information about the quality of the work so that the student may improve it. Summative assessments take place at the end of a class or unit, measuring students' mastery of material. Formative assessment is particularly important to the HPL learning environment because it cultivates the students' ability to assess their own learning, or to become "metacognitive."

These three lenses are themselves "centered" in the larger "community." *How People Learn* recognizes several levels of community, beginning with the classroom and school, and extending to the neighborhood, town, or region, and beyond. HPL learning environments acknowledge and make explicit the classroom and school's position in those multiple worlds.

How People Learn stresses that these four lenses should be "aligned," to take advantage of points in which they overlap and to prevent discontinuities. Schools should be "aligning goals for learning with what is taught, how it is taught, and how it is assessed [].Without this alignment, it is difficult to know what is being learned."[5] At the University of Texas, a group of developers and faculty have created an instructional format that attempts to ensure this alignment.

Challenge-Based Instruction

The Challenge-Based Instruction (CBI) framework was developed by the Faculty Innovation Center at the UT College of Engineering to provide a structural, web-based format for incorporating HPL principles in the delivery of instruction. The Biomedical Engineering Department at UT had already cast some of its ethics materials in the CBI framework, which stresses interactive, group-oriented learning and student self-assessment. The six stages in the Challenge cycle are represented in Figure 2.

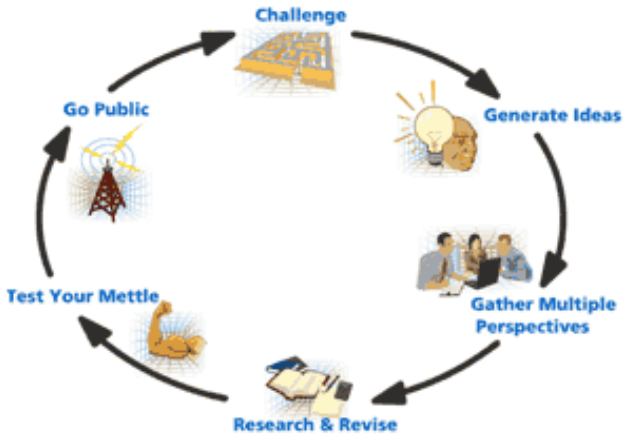

Figure 2. Stages of learning in ethics modules, based on the principles in *How People Learn.* [5] Developed by the Faculty Innovation Center at the College of Engineering, UT Austin.

These six stages allow students and the instructor to assess pre-existing knowledge about the subject matter, to embark on a series of explorations of that subject, and to pursue various lines of inquiry and test them against existing resources and knowledge bases. The goal is to enable students to use their new knowledge in new problem situations. The framework incorporates the four "lenses" described in *How People Learn* and embraces the "metacognitive approach to instruction" described above, an approach that lets everyone –students and the instructor –witness

his/her own learning as well as the learning of peers and others.

The Challenge stage is supposed to get students thinking, to make the subject matter *matter* to them, and to create a sense of identity with the issues. It usually consists of a story, a set of questions, or some other narrative device. Having set the overall "stage," the Challenge leads into any of five other stages, each of which privilege at least one of the four HPL lenses. Generate Ideas allows students to articulate their own pre-existing ideas about the issues raised in the Challenge. As such, it is learner-centered, making clear the "conceptual and cultural knowledge that students bring with them to the classroom." [5] Gather Multiple Perspectives is an initial research activity that gathers relevant information from experts; similar, real-world stories, news items, etc. This stage brings the knowledge-centered lens into play. Research and Revise continues the research, delving into more scholarly and in-depth works and prompting students to revisit their initial ideas. As such, this stage is assessment-centered as well as knowledge centered. Test Your Mettle engages students in some sort of production based on their acquired knowledge. The "assessment" could be an actual test or a written product or presentation of some kind. And the Go Public stage ensures that students can adapt their thinking to new situations in the world. Examples of specific activities for the Credibility of Sources module are given below.

Since all the PRiME ethics modules are designed to be flexible enough to be used by instructors of many different engineering courses with differing amounts of time to devote to the material, we have adapted this framework to those needs by ensuring that these six stages are recursive and non-linear rather than rigidly sequential. For instance, once the challenge has been given to students –typically in the form of a complex scenario or case study in which ethical courses of action are not obvious or unilateral –the subsequent steps could be followed in any order or repeated. For instance, if students were not generating many ideas in the Generate Ideas stage, the instructor might want to return to the scenario given in the Challenge and change the way students responded –in class, perhaps, instead of simply online as an e-mail thread. For some lessons the path through these stages would branch in different directions, depending on what the instructor felt would be most helpful to students.

The following section presents an example of the adaptability of the CBI framework, through a description of an ethics lesson that proceeds through all the stages in sequence. What may be more problematical, however, is the notion that all four of the HPL lenses can be incorporated fully into instruction in ethics.

Credibility of Sources: "What to Report?"

The Credibility of Sources module offers education in evaluating sources in both academic and professional practice. One lesson, "What to Report," examines a case study in which a young engineer considers whether to use hearsay evidence in an engineering report. This lesson is appropriate for juniors and seniors or graduate students. In another lesson, "Evaluating Web Sites," lower-division students develop criteria for evaluating online sources for writing a research paper. Although the two lessons address problems from different stages of an engineer's training, they both aim to stimulate the critical judgment necessary for responsible professional practice.

To illustrate how the stages of challenge-based instruction were adapted for the ethics lessons, here is a description of the What to Report lesson. The Challenge sets out the scenario of a young engineer who hears some potentially damaging information about former pollution of a site, but who is directed not to report the hearsay information. (We call this person "you" in the scenario and in direct questions to students; we call her Diane in interviews with our legal expert). This scenario, called "Hearsay: What's it Worth," was posted as a case-of-the-month on what is now the Online Ethics web site. [7] The case is no longer archived, however. The attorney for Diane's client company (Americorp) makes five pronouncements to her, all of which attempt to prevent her from including the "hearsay" information in her environmental report to Americorp.

The next three stages move students from thinking about their own initial responses to this situation through phases of research in which they gather more information, to a "Revise" stage in which they revisit their earlier ideas. In Generate Ideas, students are asked to respond to the attorney's five statements by answering five questions in text boxes on the web site. These answers may be e-mailed to the instructor only or may be posted on a class bulletin board, according to the desire of the

individual instructor. Multiple Perspectives then offers students descriptions of other similar, real-life cases involving research and investigation: what information is credible and what is not? What information must be included even though it is ambiguous or unproven? These real cases are accompanied by the National Society of Professional Engineers (NSPE) Board of Ethical Review's discussion of their judgment of each case. Students also watch short video segments in which a "real" attorney discusses her perspective on the Americorp attorney's pronouncements. Class discussion becomes particularly useful at this point, but it is not necessary if there is no time. Then, in Research and Revise, after being directed to relevant rules of practice in the NSPE Code of Ethics, [8] students return to the five questions asked in Generate Ideas and answer them again, with new information and perspectives under their belt. At this stage, the instructor may also want to introduce readings from various ethical philosophers and engineering leaders on the duties and responsibilities of professionals who hold public safety in their hands.

Test your Mettle asks students to decide exactly what they would do in Diane's shoes. The site presents the ten possible courses of action originally published on the University of Washington site (no longer available) and then asks students to prepare a short (five-slides) presentation on their proposed course of action. This presentation could be planned in small teams or individually.

Finally, Go Public asks students to present their proposed action (individually or in teams) to the rest of the class and respond to whatever feedback they receive. This final stage is where students show they can apply their new knowledge in some public forum. Some instructors may wish to bring in volunteers from industry at this point to give their feedback. The final button on the web site prompts students to fill out a short survey on their satisfaction with the format and content of the lesson.

Fitting the HPL Lenses to the Ethics Lessons

The "What to Report?" lesson clearly can be made to work within the challenge-based instructional framework, and it clearly incorporates the four HPL lenses of a successful learning environment. Generate Ideas gathers students' preconceptions and allows the instructor to teach to those, at least to some extent. As such, the lesson is certainly learner-centered. Self-assessment opportunities are built in, especially when comparing the results of the questions asked in the Generate Ideas stage with those of the same questions asked in the Research and Revise stage, so the lesson is also assessment-centered. Because many activities take place in a communal space, either online or in the classroom, the lesson is community-centered. And because the Multiple Perspectives and Research and Revise stages provide expert testimony, expert discussion, and published codes, the lesson is knowledge-centered. Yet although the "What to Report?" module appears to successfully work with the HPL lenses, a closer look raises questions about how well the HPL model fits the teaching of engineering ethics. Here we will outline two gaps in the fit that have presented themselves thus far.

The first gap presents itself in the idea of a "Learner-centered" environment for engineers learning ethics. Because ethics, as a subject, is a collection not only of facts and professional "best practices," but also of personal values and experiences, instructors will have a difficult time gathering and assessing all the pre-conceptions and misconceptions of their university students. What particular misconceptions will these students have? *How People Learn* insists that "[t]eachers who are learner centered recognize the importance of building on the conceptual and cultural knowledge that students bring with them to the classroom," and cites, as an example, a school in Hawaii that integrated native Hawaiian "talk story" into reading instruction . Yet that example appears relatively simple to us in that the teachers worked with children from (what appears to be) only one distinctive ethnic group.

By contrast, in the College of Engineering, our classrooms bring together young (and sometimes mature-aged) adults from five continents, who may together speak a total of twelve languages. Many students speak English as a foreign language. Even more students enter our classrooms with life and work experiences in foreign countries that practice different codes of ethics from those considered standard in the United States. Students preparing for careers in the oil and gas industry, for instance, may spend time working in countries in which "bribery" and "kickbacks" are common cultural practices. Students from such countries often can—and do—argue that what Americans may

consider a "bribe" is, in certain contexts, a "gift" that cannot be refused without giving offense. Other students from other continents may chime in with challenges or variations to the argument. We offer this example not to defend bribery, but to show a fraction of the staggeringly complex "prior knowledge" that engineering students bring to their ethics classrooms. Of course, such classrooms offer spectacular pedagogical opportunities, but we have to pause at the implications of developing a "learner-centered environment" in such classrooms.

The second gap appears as we aim to design a "Knowledge-centered" environment. A key finding of the committee that produced *How People Learn* is that students need "a deep foundation of factual knowledge" and need to "understand facts and ideas in the context of a conceptual framework." Certainly the Credibility of Sources module can provide a conceptual framework composed of professional codes of ethics, prior legal judgments, and (more problematically) historical philosophical strands of thought. But the point of having this "factual knowledge," as *How People Learn* points out, is to enable students to use this knowledge in the real world by being able "to quickly identify what is relevant" in the mass of detail and facts that make up any particular situation. Can scenarios and case studies really give students this kind of discriminatory power? Everything is relevant in a case study, but in real life . . . well, it's a lot messier, certainly when it comes to making ethical decisions. Ethics seems in fact to go beyond facts and may even be said to resist a "conceptual framework."

Conclusion

The "What to Report" lesson is included in six PRiME modules that will be piloted and assessed in the spring of 2005, so we will present an update to this paper at the July 2005 IPCC conference. Our ultimate aim is to create web-based educational materials on ethics and professional responsibility that any engineering faculty member can use in his or her course. The CBI design breaks the lessons down into stages that not only engage the HPL model of optimum learning environments, but also make it possible to integrate the lessons into different lesson plans, homework assignments, and classroom discussions. After the first modules are assessed and revised, PRiME plans to develop further modules on other topics needed by UT Engineering faculty. We expect that PRiME will collaborate with technical-based faculty to design modules on such topics as Design Ethics, Environmental Safety, Patents, and Global and Social Responsibility.

The *How People Learn* educational model, and the CBI framework derived from it, promise to be powerful tools to help PRiME relocate the teaching of Ethics and Professional Responsibility from a much-maligned corner of the engineering curriculum to a dynamic position center-stage. Yet we know that the problems of teaching Ethics to engineers will not entirely disperse with the latest and most sophisticated educational theories. This paper presents two perceived gaps between the HPL theory and the practice of teaching engineering ethics: more will undoubtedly appear as we test and assess the modules. Perhaps, indeed, the difficulties in applying HPL theory to engineering practice may cultivate a fruitful "learner-centered" environment for both fields.

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