Teaching and Assessing Graduate Ethics in Engineering, Science, and Technology

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***Abstract*— Educating scientists and engineers with respect to the ethical implications of their professional actions is an increasingly urgent, demanding, and complex task, and we do them and society a disservice if they inadequately grasp the ethical significance of the work they do. Education in ethics in engineering and the sciences has been recognized as intrinsically important. The Institute for Science, Technology, Ethics, and Policy at The University of Texas at El Paso brings together scientists, engineers, and philosophers from the academic, industrial, and public policy domains to focus on training both graduate students and faculty in ethical theory related to science and engineering. This training will focus on the rigorous development of ethical thought as applied to current topics in the science, engineering, and technology sectors. Because education in ethics necessarily involves subjective as well as objective factors, in order to evaluate the efficacy of this approach, an innovative assessment of student development that integrates both quantitative and qualitative approaches needs to be made. This paper describes such an experimental method that will be used to assess students for an ethics in engineering course.**

***Index Terms*— Ethic in Engineering, Ethic in Computer Science, Ethic Education, Ethical Theory Training, Assessment of Training**

I. Introduction

Ethical issues frequently arise in the practice of engineering and science, and ethics educators at both the undergraduate and graduate levels have been struggling to keep pace with the rapid changes in science and technology [3, 18]. A number of institutions host web sites with down-loadable modules and case studies. (See for example [19].) One of the standard methods for educating graduate students and faculty in the ethical concerns associated with engineering and scientific research and professional practices has been (and continues to be) to rely on testing students and teachers for their ability to apply professional ethical codes associated with a particular discipline. Any instructor can then pick up a module, test their students on applying the appropriated material to a set of well-established, empirical case studies and be done with the requirement to cover ethics. The merits in adopting this pedagogical approach have to do with the ease of integrating such teaching modules into already overburdened curricula and understaffed departmental units. But this particular practice is one of the many controversial methodological issues involved in how training in a system of ethics is conditionally linked to the quality of research in ethics as it is related to an individual disciplinary system. The problem is that while in theory, certain standards of practices can be codified for general applicability to any research or professional project; in practice the ever-changing material dealt with by scientists and engineers is precisely of the sort that pushes the limits of ethical guidelines. Moreover, ethical decisions necessarily take the form of subjective judgments; thus, pre-packaged teaching modules often only graze the surface of the ethical considerations and capabilities intended in an undergraduate science or engineering program.

Even with readily available modules and case studies, an additional impediment to the inclusion of ethics education in science and engineering course is the opinion that ethics should be taught by faculty with degrees in ethics, and not by scientists and engineers [6]. The mass-production of such modules and case studies in the last few decades to complement the discipline-specific codes of ethics indicates the noble attempt by engineers and scientists to remedy on their own the real need to address the growing problem of the need for a more nimble and comprehensive approach to educate engineers and scientists in the ethical issues involved in their professions.

Complicating this endeavor is the unavoidable condition that “exploring ethical presuppositions” also entails familiarity with both the dominant ethical paradigms, such as virtue (or character) ethics, deontological (or duty) ethics, and utilitarian ethics but also the many contemporary ethical orientations that have emerged in the last century. Orientations such as cultural relativism, emotivism, pragmatism, intuitionism, and discourse ethics have emerged, in large part, precisely as a response to not only the unprecedented nature of advances in technology and the computer sciences in particular, but advances in engineering and the natural sciences in general. See, for example, [10].

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II. Institute for Science, Technology, Ethics, and Policy

The Institute for Science, Technology, Ethics, and Policy (ISTEP) at The University of Texas at El Paso (UTEP) seeks to provide an alternative vehicle for teaching and research focusing on ethical dimensions involved in the related fields of engineering and the sciences for groups of graduate students and for faculty, including the active participation of industry professionals and policymakers. Moreover, an organizing principle that sets ISTEP apart from others is our desire to institutionally cultivate the dimension of systematic embededness of ethical concerns and practices that occur across these interrelated knowledge, production, and socio-political policy domains. Research at ISTEP brings to bear precisely the sort of work that philosophers do in exploring the ethical presuppositions of any authoritative or scientific domain to stimulate the kinds of research and activities in the field of teaching in ethics, engineering, the sciences and public policy that global developments in the twenty-first century demand.

Clearly there are already a number of good sources for ethics information and support relating to engineering, science, and public policy [4, 7, 9, 13, 16, 20, 21, 22]. We believe that ISTEP can establish a program that builds on past efforts that will also have unique and timely aspects. For instance, to address the ethical challenges that multiculturalism and internationalism present to the engineering profession, as the top engineering graduate school for Hispanics [11], UTEP can readily involve minority students in its activities [1]. Since UTEP is located on the Mexico-U.S. border, it had to develop working relationships with Mexico, Mexican professionals, and policy makers. Many of UTEP's students, especially in engineering, are Mexican nationals and will return to their country after graduation. Such students provide an excellent chance to understand the consequences of different professional ethics and to test the extent to which training in ethics, as understood in the United States, can and should be related to ethical issues in other countries. As an example of how international considerations affect societal issues, the College of Health Sciences has a primary research focus on minority health and how the health system as a whole responds to minority and early generation immigrants. Many UTEP students and community professionals come from a tradition of suspicion and mistrust of the government and its rules. Making a case for following (the sometimes flawed) professional and educational practices in the United States is not trivial [19].

III. Goals of graduate engineering Ethics education

One of ISTEP's primary goals is to establish practical structures to better educate graduate students to not only become more aware, but also to become more actively engaged in the work being done within the various groups working at the Institute. The global and international consequences of better attending to ethical dimensions in the ever-more tightly interwoven practices of academics, industry engineers and scientists, and public policymakers is becoming increasingly evident. Thus, we have initiated collaborative and interdisciplinary research projects originating from the relationships that we hope to foster between graduate students, resident and visiting scholars, and invited professionals and policymakers. Our research brings to bear the often-competing perspectives and intentions of various practitioners from disparate but related disciplines and members from within those disciplines in varying levels of training or expertise, from novices to experts. Such multidisciplinary and intra-disciplinary projects are essential for not only better understanding, but also for improving the quality of relationships with each other in the world.

In theory, if the small group of researchers and associates already connected with ISTEP directed their efforts toward improving the kind and quality of research and information technology practices at the UTEP site alone, there would be work enough for decades to come. This is one compelling reason why we are so invested in our students. Indeed, our goals are much broader in so far as we recognize that the changes in educational praxes that we are attempting to institute can only be accomplished by educating students to become better aware that the world in which they are already living and will be working is radically pluralistic with an international and multicultural context.

Our initial goals include introducing our graduate engineering and computer science students to the challenging ethical complexities that are part of every research agenda and project assignment that they will soon be undertaking as members of the workforce. In other words, ethics education for graduate engineering students should be recast as arguably the most pragmatic and pressing dimensions of their preparation.

IV. Example Issues

An example of a contemporary scientific practice that has substantial ethical implications was recently encountered by an ISTEP associate teaching a bioethics course. At issue is the practice of splicing or dividing research results. Suppose a researcher has received funding from a government agency such as the National Science Foundation (NSF) or the National Institute of Health (NIH). The proposal specifies the bounds of the research to be conducted. At the end of the contract, the researcher publishes most, but not all of the results that were derived from the research effort. The researcher then writes another proposal that overlaps the original proposal. The issues include the support of researchers in the laboratory, the potential benefits of the

community interested in the results, and the deception of the funding agency. The situation is further complicated if the laboratory is supported by several related research grants that may or may not be overlapping in scope. To gauge the depth and extent of this problematic area, see [15] and [2].

As this paper indicates, one of the specific goals of ISTEP is to advance the ethical thinking of engineering students so that they can analyze matters such as this in terms of ethical points of view as opposed to relying on erroneous or misinformed patterns of behavior. To accomplish this for an engineering student could entail engaging her in the relatively simple task of setting up a Web page for the class within which she is working or revising one of the many Departmental Web pages at UTEP that are in constant need of updating. As a matter of course she would have a limited time-frame to accomplish this task with instructions that the Web page has to include at least 50% new material and that it has to have elements of at least three other model Web pages that she has found through her research on the internet. In this way, she will be confronted with the practical demands of ethical issues in her own discipline, such as copyright laws that apply to internet-published material. For instance, under pressure to create 'original' content, she may be tempted to copy-and-paste lists of resources (en bloc), already published images, or this or that series of html, xml, or other unique markup language sequences. We would expect her to be able to articulate the ethical reasoning behind why such an action is or is not ethical.

Other examples of issues associated with engineering ethics include:

- Can, and do, engineers make a difference to the degree to which technology leads to morally desirable outcomes? What role does professional autonomy play here, and what are its limits? And secondly, what should be the scope of an engineer's responsibility; that is to say, on which issues are they, as engineers, morally obliged to reflect?
- Researchers in the natural and physical sciences, the social and behavioral sciences, and engineering all grapple with privacy issues in their research. The issue of privacy arises in field studies of populations and laboratory studies of individuals. It arises in the design of computer systems and engineering artifacts. How has graduate education incorporated, or how might it better incorporate, attention to privacy concerns? How do graduate students, postdoctoral fellows, and faculty identify the relevant questions and address them? Are there examples of best practices?
- What is the relationship of standard codes of ethics to new developments in technology and the sciences?
- What role do or should cyber-communities have with academic and professional communities, with industry, political, and religious communities, and with intercultural communication?
- How can educators, industry professions, and policy makers provide for bio and cultural diversity through providing clues for building credible and sustainable design alternatives that will not hurt others?
- What is the nature and function of intellectual copyright law, the patent system, outsourcing, reverse engineering (in the context of taking an existing design and producing it for cheaper), and the fluctuating parameters and standards of scientific publishing?
- Should one work on a new version of software knowing that the reason there is a new version is to sell more copies?
- Should one embed code in a software program that identifies the purchaser?
- Should one use or modify a program that is the best that you can do, but that you know will be misused by others?

Of course, a long list of many other issues in these rapidly changing fields could go on for several pages. Among those many others, the following concerns could also eventually be taken up in one way or another through the research and teaching functions of the proposed Institute: computer security, technological obfuscation, piracy, computer viruses, bioethics/bioengineering, nanotechnology, neuroscience, tracking devices such as RFID, biometric analysis and identification, genetic screening, open-source software (Linux, Java, the GNU public license software, to name a few), digital rights management, or form/function distinctions involved in liability, infringement, and other issues such as access-control technology associated with the Digital Millennium Copyright Act or the European Union Copyright Directive.

V. ISTEP's Approach to Ethics and Assessment

Our approach to teaching ethics is, in the first place, dictated by our choice to work together as colleagues from different disciplinary backgrounds but with investments in each other's professional commitments. Secondly, it is just as strongly motivated by our desire to generate new and relevant approaches to educating students in better understanding the ethical challenges that they will inevitably face as professional engineers and scientists in a world that will remain culturally, economically and nationally diverse.

We are convinced that teaching ethics is a profoundly personal phenomenon that has broadly public consequences. Thus, it is imperative that the context for teaching ethics becomes one that takes into account the need for demanding very different sorts of teaching practices than the typical engineering student may encounter in a highly structured program of study. What this means in practical terms is that students will be asked to provide more reflective and philosophical accounts for their choices in making a judgment, enhancing their awareness of the complexity and demands of their involvement in the project at hand.

Typically, they will be asked to objectively define the terms that they use in the arguments that they propose for justifying a judgment in a given situation.

Minimally, they will be expected to demonstrate a working familiarity of ethical concepts and conceptual relations within the written context that they establish for their arguments. This approach depends upon our success in developing an awareness of the ability to not only recognize the ethical components of issues, but also the ability to express and defend a position with respect to an issue. What is more difficult to measure, however, is the subjective impact of this course of study because, in fact, teaching ethics unavoidably entails a subjective element of decision-making. Our recognition of this unavoidable subjective element and attempt to integrate that element in an institutional teaching context is one of the significant aspects of what sets our approach apart from others. This accounting for the role that subjectivity plays in ethics is necessarily closely related to how we understand the role of more formal vehicles for assessment.

Assessment is the systematic collection of data by the providers of a particular graduate course in Engineering Ethics that will be offered through the interdisciplinary aegis of ISTEP. Standard methods for measuring students' abilities for mastering a variety of modes of ethical reflection, conceptualization, and expression will be administered in the form of series of writing, speaking, and testing exercises. However, in order to establish a measure for determining enduring efficacy of the educational experience, data will be collected as part of the regular, annual delivery of the course. Numerous existing approaches are available (see for example [5, 8, 14, 17, and 23].) Given the subjective nature of what is being taught, we plan on establishing a follow-up vehicle to track the students that pass through the courses over the interval of three to five years. Such a systematic vehicle will provide evidence to:

- develop an understanding of how elements of the graduate experience impacts participants and enhances the effectiveness of such programs (understanding);
- improve program activities, processes and outcomes in successive cohorts (improvement);
- and render judgment about the overall merit or worth of the learning experience.for meeting the needs of students as they become workers facing ever-new ethical challenges in their workplaces.

The overarching questions that guide the evaluation of the project are: "What long-term impact does participation in the graduate engineering ethics course or the faculty training course have on students' ability to make informed, ethical decisions in both the academic and industrial setting?" and "How have activities and the structure of the engineering ethics project increased the number of students successfully trained in and using ethical methodologies in their work?

Another ancillary but significant target of our assessment is faculty, in particular assessing the extent that they use the program; their faithfulness to the model; and their feelings about barriers and enablers. Faculty who attend workshops and training will also be tracked over time to assess the changes in their attitudes and approaches to teaching ethics in their courses.

Again, we want to be clear that formative evaluation measures will be used to determine students' progress on an ongoing basis. A summative evaluation will be administered at the end of each course by accumulating overall data from a variety of sources which could include pre- and post- tests, focus group and/or individual interviews, and journals/portfolios. Quantitative and qualitative data analysis will identify evidence of positive effects on students' abilities to make informed ethical decisions and positive effects on faculty members' abilities to train students at the graduate level in these areas. Specifically, we will create:

A student questionnaire that is designed to systematically gather student self-ratings of their skills and knowledge level in a field of interest and knowledge and skills needed to make ethical decisions or to teach ethics in the context of engineering and technology.

We also intend to develop a formative evaluation instrument that compares the approach to "best practice" [8, 23]. This is intended to determine how well the program is meeting objectives related to student participation and program quality.

A proposal has been submitted to UTEP's Institutional Review Board to ensure proper protocols are followed during this research.

VI. Conclusions and Future Work

The need to address the ethical implications of scientific, engineering, and technological advances is ongoing and will continue to increase exponentially as the impacts of these advances continues to determine the conditions of the interrelated spheres of academia, industry, and social life. Therefore, the need for improved training in ethics and a greater consideration of the consequences of personal choices in shaping professional actions will also continue to grow. The fellows and associates involved in ISTEP are developing pedagogical programs linked with relevant research intitatives in order to design more dynamic (and less mechanical) techniques for enabling faculty to better prepare students and each other for a future that will require the ability to reason about and impact policy decisions that cross socio-political boundaries. Teaching graduate students in engineering, who will become the academics, professionals, and policy makers in the future, to better understand and to apply ethical reasoning in their professional settings is one step in that development.

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