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Ethics Training for Engineers in Emerging Technologies and Fieldwork in Developing Communities

PROJECT DESCRIPTION

OVERVIEW

This project develops a graduate Engineering Ethics Program in the School of Engineering and Applied Science (SEAS) at the University of Virginia (UVA) and in the Department of Civil, Environmental, and Architectural Engineering (CEAE) at the University of Colorado-Boulder (UCB). The Engineering Ethics program will emphasize integrative ethics training in the areas of nanotechnology, materials engineering, tissue engineering, human computer interaction, and fieldwork in water and sanitation infrastructure in developing communities for engineering students in a rich environment with students from the sciences and liberal arts, and prominent speakers from a broad range of relevant interests. The goal will be to integrate ethics training with students' thesis work. Average enrollment in the Engineering Ethics Program (EEP) at UVA is expected to be 8 students per year over the course of this project. The project is expected to result in a permanent graduate option in Engineering Ethics available to students from all departments in the school of engineering, instead of the limited option now only available to graduate students in Systems and Information Engineering. The permanent option will include topics pertinent to all the participating engineering disciplines and expects an average enrollment of 15 students per year. The program at UCB is expected to average 6 enrolled students per year, and eventually include all incoming students in the Engineering for Developing Communities graduate program in CEAE. The result will not only be new graduate experiences at these two campuses, but also a model for others to follow, one that will be widely disseminated and shared.

UCB has an established seminar series in Earth Systems Engineering, (http://ese.colorado.edu/seminars.htm), which will be the forum for speakers from the Engineering Ethics seminar series. Seminar speakers will talk at both schools. Fieldwork for students at UCB is funded through the work of Bernard Amadei and his Engineers Without Borders program. Thus, additional funding is not requested in this proposal for the Engineering Ethics program at UCB.

1.0 INTRODUCTION

It is now widely accepted that engineers need training in ethics at the undergraduate level, and that they need professional codes to guide their conduct.[1] However, Daws argues that the National Society for Professional Engineers (NSPE) Code of Ethics for Engineers leaves students with only a minimalist, dogma-based approach to professional ethics, with no insight into the underlying principles of the Code. Alternatively, in a micro-ethics approach, students can be exposed a priori to the underlying principles and taught to use heuristics to resolve ethical issues in their practice. A macro-ethics approach goes further by teaching students to construct principles for resolving ethical issues by working through case studies, but this approach does not engage students in linking these constructed personal ethical principles to the larger social context. A meta-ethics approach moves students through the stages of moral development from dogma, through heuristics, case studies and finally to situations that require them to connect their personal ethical domain to the larger social context in which they practice engineering (Daws

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[1] The excellent science and engineering ethics web-site at Case Western provides a good overview (http://onlineethics.org/), as do textbooks (Harris et al. 1995, Johnson 2001) and books of case-studies (Gorman et al. 2000).

2004). Wareham and Elefsiniotis (1996) argue that environmental ethics should be a mandatory component of engineering education and should prepare students to see themselves as stewards of the environment with a mindset that is geared towards pollution prevention and remediation. Others argue that ethics education of engineers is needed because the standard curriculum does not prepare students to identify ethical conflicts when they arise in their work, or how to interpret the Code of Ethics for Engineers to define their personal moral responsibility when ethical conflicts arise. (McGinn 2003, White and White 2001, Vesilind 1988). This project will use a meta-ethics approach to take graduate engineering students through the stages of moral development, from a review of the Engineers Code of Ethics, through heuristics methods for resolving ethics dilemmas, to case studies of ethics in engineering, and finally to connecting their personal ethical construct to the larger social context in which they study and conduct research as engineers. This pedagogy will be realized through a combination of mixed seminars, professional workshops, and laboratory and fieldwork practice documented in personal logs that trace the development of their ethical thinking. The project considers the role of ethics in engineering education as improving learning through a holistic approach that provides a context for students to critique their learning at the university, and connect the micro-world of their research to the macro-world of broader social implications in issues of privacy, risk, equity, indigenous knowledge, and sustainability. This project sees ethics training as empowering engineering graduate students to carry forth their inventions and innovations to society, conscious of the ethical dimensions of such innovations, and proactive about measures to mitigate their potential adverse effects. A particular focus of this effort is technologies, like indigenous and low-cost water purification and wastewater treatment systems, that promise benefits for what are called Tier 4 markets—the poorest of the poor, mostly in the developing world (Prahalad & Hammond 2002). In the process of their development as scholars, these graduate students can be a bridge for true interdisciplinary research between the engineering and ethics communities, thereby enriching the knowledge within both communities.

1.1 Intellectual Merit

Emerging technologies are fraught with ethical dilemmas that arise from the tradeoffs of risks, costs, uncertainty, and benefits they pose to society. For example, the fabrication of nanomaterials exposes workers to risk from air pollution and has unquantified risks from accidents in transportation and manufacturing. (Cobb and Macoubrie 2004). Researchers in tissue engineers must wrestle with the issues of public acceptance of embryonic stem cell research, and the complex uncertainties about the social benefits and long term risks of the technology. (Daar et. al. 2004). Researchers in developing communities, from those collecting plant species for medical research, to those building infrastructure to supply water and sanitation services, must be sensitive to the indigenous knowledge regulating the ownership and use of local resources (Parsons 1996).

Despite these significant concerns, the public is generally optimistic, but uninformed about new technologies, like nanotechnology, and their potential impacts. Policy makers often adopt a risk seeking, rather than precautionary attitude about regulating technology at its emerging stages of research and development. (Cobb and Macoubrie 2004, Grandjean et. al. 2004). Furthermore, engineers and scientists engaged in research in emerging technologies usually are not trained in ethics, and have no framework for integrating concerns about risk, privacy, equity, indigenous knowledge, and sustainability, into their routine practice, and subsequently into proactive measures to mitigate the potential adverse impacts of technology on society. These engineers either do not see it as their responsibility, do not know how, or have no incentive to communicate issues of risk, privacy, equity, sustainability and indigenous knowledge to the public. (Haws 2004). Thus, they are largely inarticulate on these issues, to the public and in the channels of scholarly communication within their fields. Training engineers to integrate ethics into the way they think about and practice their craft, as well as to articulate ethical concerns in their scholarly communication and interaction with the public, requires education at the interface of engineering and philosophy, and raises such **intellectual considerations** as; curriculum content, pedagogy of instruction, the decision of whether engineers, ethicists, or both should present the educational material, and how the effectiveness of this training should be evaluated. (Magun-Jackson 2004). This project tackles all of these considerations by developing an integrative training program, which includes a new curriculum for educating engineers in ethics, by means of a series of seminars attended by engineering, science and philosophy students, taught by engineering, ethics, science, and policy experts, evaluated by means of student portfolios maintained throughout the training period, and requiring students to publish collaborative articles on the ethical dimension of their work in peer reviewed conference proceedings and archival journals.

1.2 Broader Impacts

The Engineering Ethics option makes graduate engineering education more attractive to students interested in the societal impacts of engineering, sustainability, and in engineering research in developing communities. Zimmerman and Vanegas (2005) report that women and racial minority students participate in engineering service organizations like Engineers Without Borders at rates that are 2 to 3 times the national average of enrollment for students from these groups in undergraduate engineering programs. Thus, the program provides an opportunity to recruit a more diverse body of students into engineering, particularly those from developing communities, which in the U.S. tend to be poor, rural, or populated by Native Americans and racial minorities. (Grasso et. al. 2004, Wigfield and Eccles 2000). As the program's students and faculty develop ways to identify ethical issues in their work, and present them to their peers and the public, they increase the chances of a broad dialog on the risks, costs, and benefits of emerging technologies and of research in developing communities, and the development of democratically negotiated guidelines for scientific and engineering inquiry in these areas. Students in the Engineering Ethics program at UVA and UCB go into developing communities to conduct research, better equipped to recognize, acknowledge, and incorporate local values and indigenous knowledge into the design of systems to benefit those communities. In the case of water and sanitation systems built by this research, the benefits are direct and tangible. In addition, these students serve as de facto ambassadors of goodwill between their privileged society, and the severely underprivileged societies in which, and for whose benefit, they conduct their research (Parsons 1996).

2.0 PROJECT GOAL AND OBJECTIVES

The goal of this project is to train engineering graduate students to integrate societal and ethical dimensions, including privacy, risk, equity, indigenous knowledge, and sustainability into their technical research in emerging technologies and fieldwork in developing communities. This will be achieved by four objectives; i) to educate students about the ethical issues associated with their work in emerging technologies and fieldwork in developing communities; ii) to integrate ethics into the way students think about their work as evinced by the explicit mention of ethical issues in their experimental design, expected results, and analysis; iii) to make students articulate in dialogue on issues of ethics in the professions of science and engineering, as evinced by their participation in a rich, integrative graduate seminar series with science and philosophy graduate students, invited presentations in ethics, and concluding with the publication of at least one article in a related peer reviewed journal or conference proceeding; iv) to document, evaluate, and disseminate the results of the project to educators and practitioners in science and engineering.

3.0 RESEARCH HYPOTHESIS

Specialized training, beyond complementing the standard engineering code of ethics, can get students to integrate ethics into their research and practice of engineering. The best training avoids the problem of compartmentalization by integrating ethics training with engineering research. Compartmentalization occurs when engineers do well on ethics units, but do not see

that there are ethical issues in their design and discovery activities.
At the University of Virginia, PIs Gorman, Werhane and Louis created a graduate option in Ethics, Policy and Systems Engineering (M. Gorman et al., 2000). Two students have obtained PhDs through that option, and six Masters students. All of these students published case-studies (M. E. Gorman et al., 2000) that show the way in which technical, social and ethical issues are linked in practice, and all had an ethical component to their technical project. For example, Matt Mehalik contrasted a standard systems-engineering life-cycle analysis with one that made different assumptions about how to measure environmental intelligence. (Mehalik, 2000a,b).

Our hypothesis is that this option can serve as a model for integrating ethics and engineering in other engineering disciplines besides Systems Engineering, and that it will be possible to create a community of students pursuing ethics and engineering at the University of Virginia and at the University of Colorado-Boulder, that could be modeled elsewhere. Gorman and Groves have shown that it is possible to introduce ethical issues into a materials science thesis related to nanotechnology (Gorman et al., 2004). But it is hard for such a student to work in isolation. Students learn a great deal from each other. Therefore, we propose to combine students from engineering and science backgrounds with those from ethics and social sciences.

4.0 RESEARCH PLAN

4.1 Overview of Research Plan

The project will focus on PhD students in the School of Engineering and Applied Science at the University of Virginia, and at the University of Colorado – Boulder, School of Engineering. There are two options for testing the hypothesis. The first would be to divide the cohort of participating students at each collaborating institution into two isolated groups, one that receives the specialized training, and one which does not (Campbell et al. 1966). The groups would then be tested at the end of the project to determine the extent to which specialized training produced a measurable difference in ethical thinking and practice between the two groups of students. This option is unfavorable because the PIs wish to expose all students in the program to the specialized training in ethics, and it would be impractical to isolate the two groups of students since they take classes together, work in the same laboratories, and share extra-curricular activities. Also, previous research suggests the training is of substantial benefit (Gorman et al. 2000), and it would therefore be unethical to withhold it from participants.

The second option is to test all participating students at each collaborating institution on their integration of ethics before they receive the specialized training. The students would then be retested after the specialized training program to assess the effects that the specialized training had on their integration of ethics into the practice of engineering. This method faces the difficulty of separating the effect of the specialized training from other experiences the students have during the three year period of the project. By studying the effect on students at different institutions, the investigators expect to account for these environmental factors to the extent permissible by the number of participating students and the accuracy of the instruments used to record the effects of the training. More difficult is the appropriate metrics for assessing students' integration of ethics into their thinking and evaluating the effect this has on their practice of engineering. This project will use the portfolio method of evaluating students' integration of ethics into their practice of engineering (Olds 1997a, b). Details of student use of the portfolios, the assessment of information from the portfolios, and the evaluation of students based on the result of this assessment are discussed below.

Specialized training will be offered to PhD students in SEAS who apply for the Engineering Ethics program. At the University of Virginia (UVA) these students will be recruited nationwide. The current ethics and policy option in Systems Engineering attracts several applications a year from other institutions, without any systematic effort to advertise. Students will also be recruited from the laboratories of professors in Bio-Medical Engineering, Civil Engineering, Chemical Engineering, Electrical and Computer Engineering, Materials Science and Engineering, Systems Engineering, and the Science Technology and Society Program, who have agreed to participate in the program.. At the University of Colorado-Boulder, the program will be offered to students in the Civil, Environmental, and Architectural Engineering (CEAE) Department. It is expected that students from the undergraduate engineering programs at UVA will consider the Engineering Ethics program in CEAE at UCB, and that UCB undergraduates can be recruited to UVA, partly on the strength of the Engineering Ethics option at both institutions.

4.2 Curriculum

There are three main components of the program; **curriculum, laboratory and fieldwork**, and **workshops**. The **curriculum** will consist of a year-long, two-credit graduate seminar offered in the Fall and Spring of the students' second year in the graduate program, supplemented by graduate courses tailored to each students' thesis. The seminar will focus on privacy, risk, equity, indigenous knowledge, and sustainability as dimensions of emerging technologies and of engineering research in developing communities. (Roc and Bainbridge 2002, Young and Eristhee 2002). Students will be introduced to Earth Systems Engineering Management as a framework for evaluating the environmental context of technology and for examining the ethical implications of converging technologies, like the convergence among nanotechnology, biotechnology, information technology and cognitive science, (Allenby 2005, Engineering 2000). The coursework will be grounded in fieldwork in domains of relevance to the students' research. For example, in the environmental systems area, students will do fieldwork on the construction of water and sanitation infrastructure in developing communities.

At both UVA and UCB the Engineering Ethics seminars will be open to students from engineering, sciences, liberal arts/philosophy, education, and commerce, whether or not they are enrolled in the Engineering Ethics program. This multi-disciplinary makeup of the classes will enable a rich exchange of ideas, encourage students to see the issues from multiple perspectives, and to learn from each other. (Davidson 2004). Experts in the fields of ethics, and in technology areas related to the focus of the program, will be invited to speak in the seminar series at both the University of Virginia and the University of Colorado – Boulder. Thus, students at each institution will be exposed to much of the same content, which may mitigate some of the environmental differences experienced by students at the two universities. As a requirement of the seminar series, students from the ethics program will work in pairs to collect data on social and ethical implications related to their research, and prepare and submit a paper on an ethical issue from their work for publication in a related peer reviewed journal or conference proceeding. The paper will be a collaboration between an engineering and non-engineering student. The "Journal of the American Society of Engineering Education" (ASEE), the "Society for Risk Analysis" (SRA) Journal, "Science and Engineering Ethics", and "Water Policy" are some of the archival journals in mind. Conference proceedings include "ASEE" and the "IEEE's Systems, Man, and Cybernetics" annual conferences.

The graduate seminar at UVA will build on the series already hosted by the University's Institute for Practical Ethics (IPE), of which co-PIs Gorman and Louis are members. Thus, the Engineering Ethics seminars will adjust their schedule to take advantage of speakers visiting for IPE events, and will share speakers with IPE by arranging for the speakers to rotate through UVA and UCB. UCB has an established seminar series in Earth Systems Engineering, which will serve as the forum for the Engineering Ethics speakers. Patricia Werhane - Ruffin Professor of Business Ethics & Senior Fellow of The Olsson Center for Applied Ethics, at UVA's Darden School; Brad Allenby Professor of Civil and Environmental Engineering at Arizona State University and formerly the Environment, Health and Safety Vice President for AT&T, Amory Lovins, CEO of the Rocky Mountain Institute, and Buddy Huffaker Executive Director of the Aldo Leopold Foundation, are some of the speakers who have presented in seminars at UVA and UCB in the past, and are among the prominent speakers sought to present in the proposed series. Pat Werhane and Brad Allenby will constitute the core of a Review Board for the Engineering Ethics program at UVA and UCB. Bernard Amadei of UCB will be the third member of the review board for the UVA program, and Garrick Louis of UVA will be the third member of the review board for UCB. Students will send drafts of their articles for publication to the Review Board four weeks prior to the end of the seminar series. The board will review the student papers and meet with students at UCB two weeks after receiving their papers to discuss their reviews and comments from items in their portfolios. The review boards will hold a similar meeting with students at UVA the following week. In the final week of the first and second semester of the seminar series, all the senior personnel and consultants in the project will meet at UVA to review the student portfolios, assess the progress of and recommend modifications to the program. The Review Board will also consult with the lead faculty in the Engineering Ethics programs at UVA and UCB on program modifications recommended from the annual formative program evaluations and student portfolio evaluations.

After completing the seminar series in their second year, students in the Ethics Program will host a **workshop** on "Ethics in Science and Engineering" at the Sustainable Resources Conference held at the University of Colorado-Boulder and Naropa University each October. Thus, in the Fall semester of their third year, students from UVA and UCB will collaborate to organize and host a workshop on topics from their research and coursework. Louis hosted a workshop on engineering for developing communities at the Sustainable Resources Conference in October 2003, and plans to be a conference organizer in 2006. This will coincide with the workshop hosted by students of the Ethics Program. The workshop will invite speakers from the Ethics Program's seminar series in the previous year, their students, and other authors, to present papers during two 90-minute morning sessions, then engage in discussions on integrating ethics into science and engineering practice during two 90-minute afternoon sessions. Outcomes from the workshop will include a book of papers from the workshop, and an internet forum of colleagues engaged in Ethics in Science and Engineering Practice (ESEP) to be hosted on the Ethics Program Website at UVA. A summary of each cohort's progress through the program is included in Table 2.

While the Sustainable Resources Conference is planned as the major workshop at which students from the Ethics Programs at UVA and UCB collaborate and meet, students from each program will be encouraged to present related work at conferences in their individual disciplines. For example, Louis and his students will present papers on ethics in their work on community sanitation systems (including environmental justice, the role of indigenous knowledge in planning, and female participation in planning and management of community sanitation systems) at conferences of the International Water Association, and the American Society of Civil Engineers Infrastructure Conference. It is expected that faculty and students from the Earth Systems Program at UCB will also be presenting at these venues. Likewise, students and faculty from other engineering departments participating in the Ethics program will interact at conferences, exchanging ideas, learning from each other, and building a network for collaboration beyond the end of the funded research project. These interactions between students from the two universities participating in the project are not viewed as compromising the integrity of the test of effectiveness of the specialized ethics training on engineering students. Rather, it is a single experience shared by all students in the program and will provide a common base from which to compare the effect of environmental differences on students from different institutions.

4.3 Laboratory practice and fieldwork

The third component of the program **is laboratory practice, and fieldwork** for students working in developing communities. Here the students get the opportunity to implement ideas discussed in the classroom as they begin to integrate ethics into all phases of their research and practice. Each student applying to the Engineering Ethics program will be asked to maintain a logbook in which they record their thoughts and ideas during the course of their work in the classroom, laboratory or in the field. The student's logbook will be part of a portfolio that includes other evidence of their progress in the integration of ethics into their engineering practice. These additional items include written work outside the laboratory or ethics classroom, and documentation of significant encounters from which the students draw ethical inferences. (Olds et al. 1997a, b). Students will maintain portfolios from the start of their first year in the graduate program until their graduation. Since the students will not receive any formal ethics training in their first year of graduate school, the logbooks will record any changes in their thinking about their research and fieldwork, as they progress through ethics training in the second year, and the Sustainable Resources workshop in their third year. The logbooks will be collected and analyzed after the end of the Fall semester of the students third year. Thus, investigators will be able to compare student logbooks from their first year, to those from their second year and first half of their third year, and use these results to evaluate the effect of the ethics training program. Students will be asked to continue maintaining the logs after the research project is completed until they graduate from the PhD program in the fourth or fifth year. These longer term logs will be used to assess the persistence of the effect of specialized ethics training on student integration of ethics into their routine practice of engineering. Supervising faculty will also keep logs of student progress from their observation.

All logs will be reviewed by Jeff Shrager, at Xerox PARC, who has developed a method for creating and coding diaries (Shrager 2005). The goal will be to help students reflect on their own learning. The logbooks will not be shared with the faculty involved in the program, except as the students themselves choose to. Gorman et. al. used this methodology on a smaller scale, in a study of a nanotechnology Masters student (Gorman et al. 2004). The student provides a daily reflective diary via email, from which to analyze the student's developing expertise. So far we have collected over 150 entries in nearly 10 months. We have developed two coding schemes for these diaries. The first captures general sorts of events, using a set of keywords assigned to each diary entry, including: email interchanges, experiments, lab work, reading papers or literature search, meetings, decisions or considerations, methodological reflection, and points where the student noted specific things learned. The second coding scheme is more specific to the goals, acts, and decisions surrounding specific research, and takes the form of "content tags" assigned at points in the diary where important experiment-related events take place, including: experiments, inferences, changes in view, methodological considerations, theory change, and the setting or resolution of goals. These tags include contextual and content information. Analysis of these tags produces traces of the student's progress through her intellectual career along many interacting dimensions. In this project the method will be used to assess the students' development of ethics expertise.

4.3.1 Fieldwork for nanotechnology laboratory students

Nanoscale science is a much sought after technical graduate option in various departments at UVA and nationwide. Since technology enabled through nanoscale sciences is still at its earliest stages of deployment in society, integration of ethics within the curriculum for graduate students can have profound implications on its eventual application. While nanotechnology promises super-strong materials, faster microprocessors that use less power, and customized, targeted, and point-of-care biomedicine, there are numerous ethical issues that may gravely influence social acceptance of this technology. (Roco and Bainbridge 2001). In this fieldwork graduate students will examine environmental ethics, privacy, and equity issues in technological development enabled through nanoscience. Students in the Engineering Ethics program will conduct fieldwork in the rural, working-class community of Danville, Virginia to assess the awareness of and attitudes toward the environmental ethics dimension arising from nanomaterial exposure among workers at Danville's Luna Nanomaterials Carbon Nanomaterials Manufacturing plants. A similar survey will be conducted nationally of nanotechnology labs in which graduate students work. Several recent toxicology reports (Royal Society Report, Yu et. al. 2004, Wahi et. al. 2004, Sayes et. al. 2004, Oberdörster 2004) have concluded significant risks from exposure to nanomaterials by air pollution at doses greater than 10 microgramm/cubic meter. Attitudes towards environmental risk associated with the toxicology from workplace exposure to nanomaterials will be explored using an approach called "scenario-analysis" (Schwartz. 1998, van der Heijden. 1996) in which subjects help researchers to identify risks, assess exposure, and establish priorities for research into the environmental impacts of nanomaterials.

Nanoelectronics graduate students will use scenario analysis to characterize the privacy implications of pervasive, undetectable nanosensors based on the extant literature on deployment of these devices. (Warneke et. al. 2001). As a dimension of their fieldwork, both nanomaterials and nanoelectronics students will also survey the plant workers and their families about their perceptions of the equity issue associated with the distribution of benefits, costs and risks of nanotechnology on rural communities, like Danville, where fabrication plants are built. The critical questions are how residents view this budding industry, in terms of the training it provides to the workforce, which is very different from the requirements of their former agricultural and extractive mineral economies. (Fonash 2001, Roco 2003). Thus, this experience creates an option for nanotechnology graduate students wishing to integrate ethics into their dissertation research.

4.3.2 Fieldwork for Environmental Systems and Engineering for Developing Communities Students

Graduate students in Environmental Systems Engineering at UVA and Engineering for Developing Communities at UCB, work on the acquisition of water, sewage, and solid waste management systems by poor, rural, and indigenous communities. Students spend between three weeks and three months each year conducting community assessment, and assisting the communities in planning, building, and managing systems for their water and sanitation needs. The students document the process of systems acquisition, and use this for their research on sustainable infrastructure for developing communities. These students have no prior training in ethics or anthropology, and enter the communities with only discussions in their research group meetings on indigenous knowledge, the role of women in environmental health, and alternative value systems regarding private property and community resources, such as rivers and streams. (Geertz 2000, Gregory 1999).Yet an intimate knowledge of the community in which they work is firstly, a basic courtesy to that community, and secondly, a necessity for the acquisition of appropriate technology and management systems by the community. (Freudenberg 1999, OECD 1995, Parsons 1996, World Bank 1980). Students accompany the professor into the field in the summer after their first year and work there under his close supervision. In the summer of the second year they return to the site either without the professor or under much less supervision. Their second exposure will be bolstered by the Engineering Ethics seminar series, and the students will be required to maintain their logs to show evidence of their recognition of, sensitivity to, and integration of issues of risk, privacy, equity, indigenous knowledge, and sustainability in their assessment, design, and construction of water and sanitation systems in the community. The explicit enunciation of these issues in their logbooks, will be reviewed by the Engineering Ethics Review Board and the consultants for assessment and educational evaluation, and will be used as criteria in evaluating the student's research proposal for the Ph.D. in the Spring semester of their third year if the student chooses to integrate ethics into her dissertation.

This combination of curriculum, workshops, and fieldwork builds on existing strengths at the University of Virginia and the University of Colorado-Boulder. As mentioned earlier, the University of Virginia has an established Institute for Practical Ethics, chaired by James Childress of the Department of Religious Studies. The Institute is an association of faculty and students at UVA, engaged in issues of ethics that range from medicine to genetically modified organisms. Several of the speakers in the proposed Ethics Program will come from faculty in the Institute for Practical Ethics, and from speakers invited to the University by the Institute. The University of Virginia is host to a Multi University Research Initiative (MURI) in Materials Science, which, along with nanotechnology, is one of the areas of emerging technology included in the Ethics Program. Students from the laboratories of Professors Robert Hull and Robert Kelly will be invited to participate in the Ethics Program.

The Departments of Science Technology and Society (STS) and Systems and Information Engineering (SIE), have a long history of collaboration in research. Gorman (STS) and Louis (SIE) are co-PIs on an NSF grant (#0080400 – Moral Imagination, Invention, and Design), have been co-advisors for two PhD students (Matthew Mehalik 2001, and Michael Hertz 2004) and two Masters students, all of whom received degrees in Systems Engineering with a concentration in Ethics. Gorman and Louis are also co-authors on a paper on the ethics training of Engineering Students with students from the STS/SIE collaboration (Gorman et. al. 2000). Werhane was a co-advisor to Mehalik on his PhD dissertation, and also collaborated with Gorman and Louis in developing the ethics case studies under NSF grant#0080400. Werhane will be a member of the Review Board for the Engineering Ethics Program at UVA and UCB.

Louis has empirical research projects in developing communities in Central Virginia, on the Caribbean island of Tobago, the indigenous Chuj community of San Mateo Guatemala, the municipality of Bacoor Cavite in Metropolitan Manila, and the village of Agadir Morocco. Students in Louis' research are directly exposed to the ethical issues of indigenous knowledge, cross-cultural valuation of technological risk, and sustainability in the design of community-based infrastructure systems. Louis collaborated with Professor Bernard Amadei of the University of Colorado – Boulder, and with students at UVA to establish a chapter of Engineering Students Without Borders at the University of Virginia.

Prof. Amadei is the founder of Engineers Without Borders USA, which sponsors living classroom experiences for engineering students to volunteer in community development projects (water and sanitation) in developing communities around the world. Prof. Amadei also founded the Annual Sustainable Resources Conference, hosted each October by UC-Boulder and Naropa University. Louis hosted a workshop at that conference in 2003, and will collaborate with Prof. Amadei as a conference organizer in 2006. Amadei will be a member of the Review Board for the Ethics Program at UVA and Louis will be on the Board for UCB. Thus the participation of UC-Boulder in the Engineering Ethics Program extends an existing relationship.

Gorman has a long history of collaboration with Brad Allenby at Arizona State University. This relationship extends to Allenby's days at AT&T Bell Laboratories. (Gorman et al. 2003) and has continued to his present tenure at Arizona State University. Allenby will be a member of the Review Board for the Engineering Ethics Program at UVA and UCB, and the Earth Systems Engineering program at Arizona State University is a the next logical institution to adopt the Engineering Ethics Program. .

Swami will work with M. Gorman to be the primary driver on the field-work related to nanomaterials and devices. N. Swami is currently the Graduate Program Director in the Electrical Engineering department, and the Associate Director of the university's Nanotechnology Institute

(NanoQuEST), where he focuses on developing its research and graduate opportunities. Swami served as Director of Virginia's statewide nanotechnology initiative and worked closely with the state to establish the Luna Nanomaterials' nanomanufacturing plant at Danville. He also administered an NSF grant (CTS **#0335961)** that coordinated regional stakeholders around the nation in a workshop to analyze regional investments aimed at enhancing the region's research infrastructure, workforce programs, and technology commercialization programs (NNI/NNCO report due shortly) and testified in a recent Senate hearing on this matter in relation to Senate Bill S189 (Swami et al. 2002. He is also Co-PI on a current and pending RET site awards from NSF and has research interests in surface science of nanomaterials. (Swami et al 1999a, b, 2005).

5.0 EVALUATION

Formative evaluation of this approach will be done using student and faculty logs. Student logs from the first year in the graduate program to the second year onward. These differences are expected mainly to take the form of an increase in the incidence of references to privacy, risk, equity, indigenous knowledge, and sustainability. An absence of such an increase in references to ethics terms, does not disprove the hypothesis, but requires that any change in students integration of ethics into their practice, be measured by some means other than the student logs. To this end it is proposed to test Ethics Program students on their first day in the program, which will be at the first meeting of the Ethics seminar in the Fall of the students second year in graduate school. This test will be designed to set the baseline for students knowledge of the ethical issues associated with their studies and research. Students will then be tested at the end of the Fall semester of their third year, immediately after surrendering their logbooks for evaluation. Comparison of the results from this pre- and post-program testing of students will be analyzed to determine the effect of specialized training on students' integration of ethics into their engineering practice.
As mentioned previously, diaries will be complemented by complete portfolios of each students' work, including all papers, responses to readings, case-studies, thesis drafts and the final products. These portfolios can be analyzed summatively to chart the students' intellectual progression (Olds et al. 1997a,b). Students at UVA and UCB will be interviewed after each year of their experience by the ethics graduate student assigned to help with the core seminar. Interviews will be confidential and will be anonymous to the PIs. All students will be contacted after graduation to find out how this experience has impacted their career choices. This interview will be conducted by the PIs. We hope to make the contact semi-annual, via e-mail or phone, and encourage the students to contact us whenever they have an insight.

Joanne McGrath Cohoon of the Curry School of Education and Department of Science, Technology and Society at UVA will conduct **summative evaluations** of the program. The summative evaluation methods will be modeled on those used to evaluate the ethics option Gorman and colleagues created in Systems Engineering (Gorman et al. 2000). They will evaluate the effectiveness of co-advising as a means of integrating graduate students' understanding of the technical with the social and ethical aspects of engineering practice. The method involves comparing the experiences of students and faculty in co-advising teams with the experiences of matched sets of students and faculty in traditional advising relationships. Interviewers will conduct semi-structured interviews with students and faculty in the experimental and control groups to explore both their advising experience and students' developing understanding of the social and ethical aspects of nanotechnology. The interviews will explore how well the co-advising process works from the perspectives of faculty and students, and ask students about their mental model of their technology's societal impact, their understanding of stakeholders' mental models, the criteria and methods they are using for determining societal impact, and their ability to exercise moral imagination regarding the impact of technologies. Interview scripts will be developed by Cohoon in collaboration with the project PIs. With permission in the form of a signed informed consent form, interviews will be audio recorded and transcribed. Interviews will be conducted twice a year by Cohoon, who will also analyze interview data and report results to the project PIs annually.

We will ask the graduate students involved in interviews to submit portfolios of work related to the seed projects and their courses, and mine those portfolios for evidence that what they are learning about ethics is having an impact on their research. We will look for similar evidence in the publications and presentations of faculty associated with the project. Comparison interviews will be conducted with four graduate students at each university, matched as closely as possible with those in the project, except that they are not co-advised by an ethicists or a social scientist, to explore differences in the educational and research process. Any student or faculty member can decline to participate in this evaluation at any time by so indicating to Cohoon, who will keep this information confidential.

5.1 Evaluation of field experiences

Students at UVA and UCB who are involved in water and sanitation projects should demonstrate more sensitivity to indigenous knowledge, equity and sustainability in their fieldwork in developing communities. This difference will be inferred from observations made by their supervising faculty in the field and from later evaluation of their portfolios. Supervising faculty observations will be part of portfolios maintained by faculty and used in formative evaluation of the program. Students will also publish a peer-reviewed article on the main ethical issues in their work. This will demonstrate that students have achieved sufficient maturity to evaluate the ethical component of their work, and synthesize it into a reviewed discourse on the subject to their professional peers (Haws 2004).

Another expected indicator of student integration of ethics into their practice of engineering will be the results of evaluation questionnaires distributed to attendees at the Sustainable Resources Workshop hosted by the students. Attendees will be asked to comment on students' fluency with the ethical issues discussed, and their appreciation of the way ethics are integrated into the experiences of speakers and other attendees at the workshop. A Likert scale can be used for this questionnaire, with the results analyzed to determine the extent to which students integrated ethics into their dialog at the workshop, at least in the perception of the workshop attendees.

5.2 Evaluation of laboratory experiences

Similar methods will be used for field experience having to do with nanotechnology and the environment and research on privacy. We cannot guarantee all these students will go to workshops, but they will encounter peers and mentors in their field experiences, and we can ask these to help us evaluate student progress. The method is designed to provide sufficient indirect indicators of demonstrated effect or lack of effect of the Ethics Training Program, to serve as an illustrative model for subsequent training programs. As we get more process information, we can develop more focused questions and instruments to use on future evaluations, in consultation with colleagues like Joanne Cohoon of the STS department.

A significant expected result of the Engineering Ethics Program is the emergence of new ethics issues associated with engineering practice in emerging technologies and fieldwork in developing communities. The investigators expect that the rich multidisciplinary exchanges that occur in the seminar series, workshops and authorship of a reviewed manuscript, will result in new questions about the issues covered from privacy to sustainability, as well as new issues identified by the students or the reviewers of their work. To the extent that this occurs, the project would have made a significant contribution to the field of Ethics Education for Scientists and Engineers.

6.0 RESEARCH, EDUCATION, AND OUTREACH

The curriculum, workshops, and fieldwork components of this project each integrate elements of research, education, and outreach. Thus, the proposed Ethics Program incorporates both the cognitive (classroom, laboratory, scholarly writing) and affective (laboratory practice, fieldwork, workshops) aspects of their learning. In a revision of Bloom's taxonomy of educational objectives Anderson and Krathwohl (2001) note the importance of this balanced approach to student learning (Krathwohl 2002))

Table 1 summarizes the research, education, and outreach elements of the proposed Ethics Program.

Table 1. Research, Education, and Outreach Components of The Ethics Training Program

Program Component	Research	Education	Outreach
Curriculum	Content, Pedagogy, Assessment, Evaluation, Student publications	Student training: privacy, risk, equity, indigenous knowledge, sustainability, Multidisciplinary learning Students develop and maintain Ethics Program website, Critique their education	Across UVA SEAS Across UVA UC – Boulder Student/student, student/faculty, faculty/faculty networks
Workshops	Content, Structure Evaluation of students Publication of Sustainable Resources Workshop papers and discussion	Student training: learn from practitioners, collaborate across participating institutions	Presence in the participating professions at their conferences and to practitioners at the Sustainable Resources Conference.
Lab/Fieldwork	Student portfolios Supervisor observations, Assessment, Evaluation, Publication of Results	Student training: New ways to look at the lab and fieldwork (sensitization). Integration by observation of faculty and other experienced practitioners. Experienced graduate students train REUs,* students from ESWB and ESW	Across laboratories – students exposed to the work of their peers. Across institutions – students collaborate at the workshop. Faculty collaborate through the program and speakers Case study communities benefit from infrastructure projects by trained students

* REU – Research Experience for Undergraduates, ESWB – Engineering Students Without Borders, ESW – Engineers for a Sustainable World

7.0 SCHEDULE

Table 2 summarizes the quarterly schedule of project activities over the 3 years.

Table 2. Bi-Monthly Schedule of Project Activities

Semester	Research	Education	Outreach
Fall 1	Senior personnel meeting Cohort 1 starts portfolios	Core engineering courses begin	Arrange speakers and site visits for students
Spring 1	Develop curriculum	Core engineering courses Students begin laboratory work	Create Ethics websites at UVA and UCB
Summer 1	Lab work for lab students First fieldwork for cohort 1*	Students design experiments	Begin water and sanitation projects in case study sites
Fall 2	Senior personnel meeting	Ethics seminar part 1: Cohort 1	Speakers visit UVA, UCB

Semester	Research	Education	Outreach
	Cohort 2 start portfolios Ethics pre-assessment of cohort 1. Evaluate portfolios	Review board visits First education evaluation	Students prepare for Sustainable Resources Workshop on Ethics
Spring 2	Update & revise curriculum	Ethics seminar part 2: Cohort 1 Review board reviews students' publication drafts	Cohort 1 holds brown bag series to meet outside the classroom
Summer 2	Lab work for lab students Second fieldwork for cohort 1 First fieldwork for cohort 2 Student seminar publications	Students apply ethics learning in the lab and in the field	Continue project in the field Interview Danville workers Prepare for Sustainable Resources workshop
Fall 3	Senior personnel meeting Cohort 3 start portfolios Ethics pre-assessment of cohort 2 Evaluate portfolios	Seminar series part 1: Cohort 2 Review board visits Second education evaluation	Speakers visit UVA, UCB Sustainable Resources workshop for Cohort 1 Cohort 2 prepare for SR workshop
Spring 3	Cohort 1 prepares workshop proceedings for publication Ethics post-assessment for cohort 1 Update & revise curriculum	Ethics seminar part 2: Cohort 2 Review board reviews students' publication drafts	Establish ethics forum website Cohort 2 holds brown bag series to meet outside the classroom
Summer 3	Lab work for lab students Second fieldwork for cohort 2 First fieldwork for cohort 3 Publish Danville and SR workshop results Student seminar publications	Students apply ethics learning in the lab and in the field	Continue fieldwork Prepare for Sustainable Resources Workshop 2 (after project ends)
Fall 4	Senior personnel meeting Evaluate portfolios Review all results Prepare results for publication Student seminar publications	Final summative education evaluation Final formative education evaluation	Prepare to establish a similar program at Arizona State University

7.0 SUMMARY OF SENIOR PROJECT PERSONNEL

Table 3. Senior Project Personnel

Name	Affiliation	Responsibilities
Garrick Louis	UVA Systems Engineering	Main PI, Seminar leader, Environmental systems fieldwork, UCB Review Board member
Brad Allenby	ASU Civil Engineering	Seminar speaker, UVA & UCB Review Board member
Bernard Amadei	UCB Earth Systems Engrg.	Program director at UCB, Earth systems fieldwork, UVA Review Board member
Joanne Cohoon	UVA Sci. Tech. & Society	Educational evaluation
Mike Gorman	UVA Sci. Tech. & Society	Co-PI, Seminar leader
Jeff Shrager	Xerox, Palo Alto	Formative evaluation
Nathan Swami	UVA Electrical Engineering	Co-PI, Seminar leader, Nanotechnology laboratory and fieldwork lead
Pat Werhane	UVA Darden School	Seminar speaker, Review Board member

8.0 RESULTS FROM PRIOR NSF SUPPORT

M. Gorman
STS :Inventing for a Better Global Environment: A Comparative Analysis of Two Networks (SBR-9810200) Gorman and Mehalik developed portions of the theoretical framework that is used in this proposal and applied it to the team that created environmentally sustainable products.(Gorman and Mehalik 2002)
SDEST: Environmental Ethics and Invention: A Case Study (GBR 9319983) and Putting Ethics at the Heart of Design (SBR-9618851), Gorman, Werhane, and graduate students from systems engineering wrote a series of engineering ethics cases and notes on ethical reasoning that were published in the University of Virginia Darden School Case Bibliography, are available on the World Wide Web (http://repo-nt.tcc.virginia.edu/ethics/home.html) and in a volume (Gorman et. al. 2000)
SDEST: Moral Imagination, Invention & Design (SES-0080400) provides funding for more fine-grained, detailed case-studies with a stronger STS component. One of these case-studies is Monsanto and GMOs. To date, we have produced an intellectual property case on Monsanto and GMOs for the Darden business school and drafts of a case on the introduction of GMOs into Europe. This current grant also establishes the foundation for a book on knowledge, ethics and intellectual property, which will include material on nanotechnology if this proposal is funded. Results from an NER award, Societal and Ethical Dimensions of Nanotechnology (SES-0210452), are described in the text. Deliverables include one article and one book chapter and a preliminary patent application.

G. Louis
CAREER: Integrated Municipal Sanitation Systems (BES #9984318): This project yielded a model for evaluating the performance of community water systems as individual facilities, and as components of a regional system. (Rogers and Louis 2004). The concept of integrated municipal sanitation systems was developed and tested in Bacooor-Manila the Philippines and Agadir, Morocco. Community capacity assessment and appropriate technology selection models, as well as capacity-based approaches to sanitation system acquisition, and community-based implementation of infrastructure in developing communities were developed in the Self Help Virginia program in rural Virginia communities, and in the Philippines and Morocco case studies (Louis 2003, Louis 2004).
SDEST: Moral Imagination, Invention & Design (SES # 0080400, co-PI with Gorman)
In this project an Engineering Ethics option was developed for graduate students in Systems and Information Engineering in conjunction with co-PI Mike Gorman of the Department of Science, Technology and Society. Students produced case studies used for ethics training of graduate engineering and business students. Students involved in fieldwork in developing communities were introduced to ethical dimensions of indigenous knowledge and sustainability in their work. The program has produced 2 PhDs and 2 MS graduates to date. (Gorman et. al. 2000)

N. Swami
NER: 3D nanostructures for enhanced DNA Hybridization (BES Award # 0403963 – PI: N. Swami): This work seeks to enhance the sensitivity of biomolecular devices using electric-field methods for selective pre-concentration of target DNA or other biomolecules in close proximity to capture probes. A recent publication and support to a graduate student resulted from this award (Swami et. al. 199a, 1999b, 2005)
RET Workshop on Nanofabrication (Award # 0321851 – Co-PI: N. Swami)
To address the expanding need for a workforce with diverse skills for employment in industries enabled by advances in the nanosciences, a hands-on training workshop for 13 Virginia teachers was conducted through instructional and laboratory activities by the Pennsylvania NMT (Nanofabrication Manufacturing Technology) Partnership at Penn State in collaboration with the Initiative for Nanotechnology in Virginia (INanoVA).

Analysis of Regional Nanotechnology Coordination Programs (#0335961, N. Swami)
In order to understand the approaches being followed by various regions in laying the foundation for nanotechnology coordination, this study analyzes the investments aimed at enhancing regional research infrastructure, workforce programs, and technology commercialization. The agenda of an NNI workshop held in September 2003 was developed as part of this work to collect data on these topics, and an NNI/NNCO report is due shortly (Murdock et. al.)

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