



Online Ethics Center
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Integrating Ethics & Engineering: A Graduate Option in Systems Engineering, Ethics and Technology Studies

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Description

This paper describes an engineering graduate option that attempts to overcome the negative side effects of specialization and compartmentalization by building an intimate link between technical and ethical training.

Body

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Integrating Ethics & Engineering:

Case-Studies and a Graduate Option

In these days, when there is a tendency to specialize so closely, it is well for us to be reminded that the possibilities of being at once broad and deep did not pass with Leonardo da Vinci or even Benjamin Franklin. Men of our profession--we teachers--are bound to be impressed with the tendency of youths of strikingly capable minds to become interested in one small corner of science and uninterested in the rest of the world. We can pass by those who, through mental laziness, prefer to be superficially and casually interested in everything. But it is unfortunate when a brilliant and creative mind insists upon living in a modern monastic cell. We feel the results of this tendency keenly, as we find men of affairs wholly untouched by the culture of modern science, and scientists without the leavening of humanities. One most unfortunate product is the type of engineer who does not realize that in order to apply the fruits of science for the benefit of mankind, he must not only grasp the principles of science, but must also know the needs and aspirations, the possibilities and the frailties, of those whom he would serve. (Vannevar Bush, quoted in p. 70).

Bush, one of the architects of post-war science policy, understood the value of specialization. In the above passage, he is arguing that specialized knowledge is not enough, that engineers need to know the needs and aspirations, the possibilities and frailties of other human beings — and, we would argue, of themselves.

Typical participants in weapons laboratories and in defense-related work are trained to compartmentalize; they cannot even talk about their work to others that do not have their security clearance . Some of this compartmentalization is undoubtedly necessary, but with it can come a similar bracketing of moral concerns.

In this paper, we will describe an engineering graduate option that attempts to overcome the negative side effects of specialization and compartmentalization by building an intimate link between technical and ethical training. As part of their training, the students in this option produce case studies that emphasize ethical issues in the design process.

This phenomenon of compartmentalization is well known in the social psychology literature, and is illustrated by the famous (or infamous) obedience studies conducted by Stanley Milgram. Milgram wanted an empirical answer to a question raised by the Nazi holocaust: could it happen here in the U.S.? To find out, he asked for volunteers to be paid participants in a study of the effects of punishment on learning. These participants were told to shock someone they thought was another participant every time he made a mistake. In fact, the other participant was a confederate of Milgram's, who was tape-recorded in one of the early versions of this experiment. Voltage of the shocks increased with each error, and the confederate's protests became more and more vehement, until he refused to participate in the experiment any further. Unfortunately, he was strapped into a chair. The experimenter, in a white lab coat, responded to participants' concerns by directing them to continue shocks. To Milgram's surprise and dismay, a majority of participants continued to the highest level of shock.

One possible explanation for this result is that participants bracketed or compartmentalized their ordinary responses in assuming a role subservient to the experimenter. Milgram demonstrated this with a clever permutation of the experiment, in which the experimenter was forced to volunteer to receive shocks while the confederate who would have been the victim ordered the participant to continue them. As soon as the experimenter, now strapped in the chair, objected, participants overruled the confederate and released him.

Philip Zimbardo did a similar study in which he assigned volunteers at random to be prisoners or guards in a prison simulation. After six days, he had to cancel it because everyone had fallen too deeply into their roles. Zimbardo himself recalled preparing for a prison break by moving all the prisoners to another site, then sitting in the

empty prison and listening with annoyance while a colleague asked him intellectual questions about the experiment. Zimbardo later wondered why he didn't treat the potential prison break as an opportunity to study rumor transmission. Instead, he fell victim to the rumor himself. In this case, the experimenter became part of the experiment.

These studies show how easy it is for human beings to enter completely into a role and behave one way in one context and another in another, effectively compartmentalizing both roles.

In contrast, our goal is to turn out ethical professionals who are able to engage in moral imagination. According to Patricia Werhane, moral imagination involves recognizing the role, scheme, or mental model that one is adopting, disengaging from it and evaluating alternative perspectives and courses of action . Clearly participants in the Milgram and Zimbardo experiments were unable to disengage from their roles. According to the Hastings Foundation, moral imagination involves "the ability to gain a feel for the lives of others, some sense of the emotions and feelings that are provoked by difficult ethical choices, and some insights into how moral viewpoints influence the way individuals live their lives..." , p. 6). Participants in the Milgram experiment clearly felt for the person they were shocking; many protested, asked the experimenter to call the study off, required him to accept responsibility — but kept going.

A real-life example of moral imagination is Leo Szilard's role in the making of the atomic bomb. Szilard, a Hungarian emigre physicist living in Germany, watched the growing Nazi menace and left Germany a day before the Nazis began searching trains and preventing wholesale emigration. Szilard knew that the energy released in fission might be used as a source of power or as a new kind of bomb. He wanted the United States to possess such a weapon before Nazi Germany. Szilard helped Albert Einstein draft a letter to President Roosevelt in which he mentioned the possibility of "extremely powerful bombs of a new type" and warned that nuclear experiments were being carried out in Germany. Szilard, through Einstein, urged the President to consider development of an allied atomic weapon.

Szilard saw the bomb as a necessity only as long as the Nazis might build one. As soon as American troops captured German scientists like Heisenberg that were capable of designing such a weapon, Szilard lobbied for a termination of the program to build an atomic weapon. It was, in his view, no longer necessary. But few

other scientists listened to him. It seemed ridiculous to stop when they were so close to success, and after the government had invested so much.

Szilard next circulated a petition urging that no atomic bomb be used on Japan until the Japanese were given the chance to publicly refuse detailed surrender terms. When a majority of the scientists he was working with at Chicago objected on the grounds that more lives would be saved by using the bomb, Szilard responded that this was "a utilitarian argument with which I was very familiar through my previous experiences in Germany".

The day after the successful test of a Soviet hydrogen bomb, Andrei Sakharov was asked to offer a toast, and drank to the hope that they would never have to use such a weapon. The Soviet general in charge of the operation made a lewd joke whose essence was, you made it, but we will decide when and how to use it. Like Szilard, Sakharov had created a Frankenstein monster over which he would no longer have control. Sakharov wrote letters protesting Soviet atomic tests in the 1950s and 1960s, on the grounds that radioactive contamination was unethical in part because its effects were uncertain, especially on future generations that were defenseless against it. In effect, Sakharov was arguing that policy-makers should exercise a little moral imagination, anticipate the probable effects, and ban tests altogether. Because Sakharov was a Hero of the Soviet Union, he was able to make his protests personally to leaders like Khrushchev.

Sakharov remembered how the failure of these leaders to take any meaningful action gave him "an awful sense of powerlessness. I could not stop something I knew was wrong and unnecessary. After that, I felt myself another man. I broke with my surroundings. It was a basic break. After that, I understood there was no point in arguing".

In protest, Sakharov gave up many of the privileges he had earned as a Hero, including his special apartment. He was exiled to Gorky for seven years; the worst part of this ordeal was his exile from science. When Gorbachev called to announce his rehabilitation, Sakharov immediately demanded the release of other dissidents. Sakharov was eventually elected to the new Soviet Congress, where he was a strident voice for democratic reform. He drafted a new constitution for the Soviet Union, and died while writing one of his many speeches. Dr. Frankenstein disowned his creation. In contrast, Sakharov sacrificed a brilliant scientific career and his health in an effort to create a world in which his invention would not be a monster.

Szilard and Sakharov felt that both sides in a potential conflict situation ought to have nuclear weapons. In Szilard's case, when the other side didn't develop the weapon, he was ready to stop it. In Sakharov's case, when he saw his weapon had been incorporated into an unethical system, he became a dissident.

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Teaching Case Studies in Ethics

Nearly all educators understand the need to provide engineering students with ethical training lest these students find themselves ill-equipped and unprepared to handle difficult ethical problems in the workplace. Proper training and education prime students to recognize dilemmas, to employ moral imagination like Szilard and Sakharov, and to recognize compartmentalization when addressing these dilemmas. It also enables engineers to differentiate between common morality and professional ethics (Harris, Davis, Pritchard, & Rabins, 1996).

Most scientists and engineers, when pressed will argue that mentoring is the best way to teach ethics. Probably most engineering students at the graduate level pick up values, either tacitly or explicitly, from their advisors, along with career strategies and research styles. But for undergraduates who do not have the same mentoring opportunities, and for graduate students, who will be working in areas other than those covered by a mentor, there needs to be an alternative. Furthermore, some of these mentors may themselves compartmentalize aspects of their work from their responsibilities as global citizens (Logan, Roy, & Regelbrugge, 1997).

The major approach to teaching engineering ethics owes much to one of the pedagogical practices emphasized in law, medicine and business (Self & Ellison, 1998: case-studies, which are now being used increasingly to teach engineering design (Kagiwada, 1994) as well as ethics (Harris, Davis, Pritchard, & Rabins, 1996). Case studies provide an opportunity for a kind of vicarious mentoring, in which the student is taken through a compressed version of a real dilemma, debates alternatives, makes a choice, and is shown expert solutions. It is often productive to use codes with these cases to serve as a starting point for developing a deeper understanding of behavioral dilemmas.

Examples of hypothetical and real cases can be found at the Online Ethics Center for Engineering and Science (<http://www.onlineethics.org>). Cases of these sort are often taught as part of special courses on engineering ethics, but can also be used in a variety of classes to promote ethics across the curriculum . For example, the hypothetical Gilbane Gold case, developed by the NSPE, involves a young engineer who must decide whether to support his company's decision to release more waste into the water or blow the whistle. In fact, Pritchard & Holtzapple point out that this young engineer has engineering solutions he could pursue; they have modified the case in a way that makes it appropriate for use in technical classes (Pritchard & Holtzapple, 1997).

Unfortunately, hypothetical case sometimes lack credibility with students — they merely mentally concede to engage the case because they are required to, but then tell themselves that practicing engineers never actually encounter real ethical dilemmas, a case in point of compartmentalization. Hence, in order to not only further the roster of excellent case materials already in existence, a venture in more real-world, in-depth cases also give students undeniable evidence that practicing engineers do find themselves struggling with ethics. These cases also enable students to labor with difficult and multiple dilemmas, which they themselves might encounter. The conflicts, intricacies and complexities of situations, not uncommon in the real world, offer an effective exacting exercise in creativity and moral imagination.

Case studies can range from the simple, short cases based on the sorts of smaller ethical dilemmas faced by engineers on a daily basis, also frequently contained in guides to corporate conduct (see, for example, "Questions of Integrity, The Boeing Ethics Challenge"), to detailed examples of catastrophic failures involving engineering and management such as the Challenger and the Bhopal disaster (Martin & Schinzinger, 1989). One needs positive examples, as well. A good one is the case of William LeMessurier, who creatively handled a design flaw in the new Citicorp Building for which he and his firm were responsible.

It is sometimes more useful to create real-hypothetical hybrid cases, by changing names or altering circumstances. This is necessary when the outcome of the real case is known. Consider the Challenger case. Very few students, even when given all the information possessed at the time, will argue in favor of launch the Challenger. They know what happens! Carter Racing (Brittain, 1986) is a hybrid case which poses the Challenger dilemma as a problem with a racecar. Students are far more

likely to race the car than launch the shuttle, which makes students empathize more with the original Challenger decision and leads to a deeper discussion of the ethical and organizational issues (see Vaughan, 1996).

In addition to crisis cases, where the engineer her or himself is backed into a dilemma late in the design process that involves whistle-blowing and resignation as possible options, there is a need for cases involving preventive ethics early in the design process. The growing global economy has created enormous environmental, social, and cultural stresses, and enormous opportunities for improving the quality of life. Often engineers fail to see their part in this big picture. But then who designs energy systems that can be efficient and environmentally sensitive, or use up valuable natural resources and produce pollution? Who provides technologies that, consciously or not, embody cultural and political context? Engineers make these choices either directly or indirectly. These choices are typically made at the beginning of the design process; therefore, we need case studies that pose ethical and technical dilemmas that require students to exercise moral imagination from the beginning of the design process forward.

And so, encountering a carefully crafted story and playing out a role in that story gives students an experience they may remember well after graduation. If instructors manage to engage the students to this level, much will have been done to enhance their moral reasoning and moral imagination when addressing ethical dilemmas as engineers in the future, the engineers of the global world.

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The Engineer as a Global Citizen

As a multi-disciplinary team from the Engineering School and the Darden Graduate School of Business Administration at the University of Virginia, we propose to develop a research and educational experience that will focus on producing engineering graduate students who will be able to understand complex, heterogeneous technological systems and develop case studies from which we can derive models and tools for encouraging global citizenship. The global economy has made understanding the needs and beliefs of people very different from our own an essential skill for engineering students. We are dedicated to transforming engineers into ethical practitioners who will reflect on the consequences of their designs and

discoveries, especially for those traditionally underserved by technology.

"Companies as agents and drivers of global change, must be engaged in efforts to develop solutions to critical social and environmental issues" (, p. 115). Adding the word engineers to companies in this quotation serves as a statement of our goal.

Capital and consumer commodities, information, and technology throughput in an ever-growing global economy exert tremendous environmental, social, and cultural stress. Engineers often fail to see their part in the big picture. But then who designs the machine that gorge on gas and oil? Who runs the furnace that spews poisons as carbon dioxide? Who provides technologies ignorant of cultural and political context? Engineers make these choices. These choices are typically made at the beginning of the design process; therefore, we need case studies that pose ethical and technical dilemmas that require students to exercise moral imagination from the beginning of the design process forward. These types of case studies on design strategy advocates preventive, in contrast with crisis ethics commonly found in most cases, where the engineer finds himself already backed into a corner with no other recourse as whistle-blowing and resignation.

With support from the National Science Foundation, we have developed a graduate option in Systems Engineering that includes a strong ethics component.

This graduate option is, as far as we know, unique among engineering programs worldwide where actual immersion takes place. Students actually go to the case study sites, in some instances spending months in the host company's country, such as Eskom in South Africa, Unilever in the Netherlands, and Okosombo dam in Ghana.

Students then undertake a thesis that combines ethical and technical aspects of engineering by focusing on the case study. Under our supervision, graduate students have completed case studies on:

An environmentally-intelligent furniture fabric intended as a model for a 'Second Industrial Revolution'.

In 1993 Susan Lyons, Vice President for Design at DesignTex, hoped to revolutionize the "environmentally friendly" market of commercial fabric design by implementing the design principle "waste equals food" articulated by William McDonough, architect. She decided to recruit McDonough in July of 1993 after searching for several years on her own for a solution for the environmental product, but the

alternatives she discovered presented a tangled web of tradeoffs: Was it better to recycle fabric made from a man-made material, such as yarn from soda bottle plastic? Or was organic cotton a better option? What about a fabric, Climatex, produced by Albin Kaelin of Rohner Textil AG, a Swiss weaving mill, that had received the approval of an ecolabeling agency?

McDonough's idea for the fabric required that it should be composted, i.e., tossed into the ground where it would rot harmlessly, instead of being recycled. McDonough and his partner, Michael Braungart of the Hamburg, Germany-based Environmental Protection Encouragement Agency (EPEA), a group of consulting scientists, required the inspection of the entire material and process supply chain for the fabric's construction. They chose to modify the Climatex fabric so that it would fit the compostable design protocol.

Implementing this design strategy posed significant challenges to the network of participants and suppliers, even reaching the point when an international coalition of 60 dye manufacturers refused to grant Braungart and his scientists access to the dye formulas for proprietary reasons.

The case series continually poses the questions, What constitutes a "better" environmental design? How strictly should the network participants follow the "waste equals food" principles, even if it requires overcoming huge barriers, such as having dye companies stonewalling them? How does choosing an environmental design strategy require changes to the ways a business must operate? How can one decide which chemicals are "good" and which ones are "bad"?

The introduction of photovoltaic technology into rural villages in China and South Africa is an organization that introduces solar technologies into the developing world.

Many environmentalists argue that these developing economies represent one of the best opportunities for introducing environmentally sustainable technologies before they replicate the pollution that was a side-effect of our own industrial revolution. SELF seeks to fulfill two seemingly contradictory objectives: rural electrification and environmental preservation. Implicit in the case is that the method that China selects to electrify could result in serious environmental problems that affect the entire world. The students explore alternative energy options for developing countries such as China.

- An investigation of the original decision to produce a new form of silicone breast implants, and its long-term consequences .

This case illustrates the importance of Dow Corning's design decisions for the development and future use of a product. They also raise questions about moral imagination, because they exemplify what can happen legally as well as morally when one has a product such as a breast implant where one does not take into account the perspective of women who received the implant nor the added difficulties of doing business in our litigious and media-driven society.

Versions of all of these cases are available on the World Wide Web at http://report.tcc.virginia.edu/ethics/ethics_home.html, are also available through the Darden Case Library (www.darden/case/bib) and are described in a book (Gorman, 1998) .

Projects in progress include:

The evolution of Unilever's strategic development of sustainable business policies and procedures

Unilever, a major multi-national corporation, is: (1) developing a framework for understanding sustainability; (2) defining what sustainability means; (3) integrating that definition into the corporate mission statement; (4) transforming that mission statement into practical policy; (5) and disseminating that policy throughout the supply chain. This last stage (their current stage) of progression is a particularly challenging problem, because the company owns almost no means of production from which its raw materials are drawn. Unilever's most important step thus far has been the development of the "Triple Bottom Line," which states that the corporate responsibility to its shareholders is not simply stewardship of its financial resources; it is also responsible for stewardship of its human and ecological resources. The next stage in developing this case is to visit the sites of the company's pilot projects in sustainable fishing and agriculture in order to understand how the company is implementing these ideas on an operational level. We also hope to find more technical data to support the decisions and contrast this strategy with competing strategies.

The launching of Eskom's "Electricity for All" program to take black South Africans out of Africa.

Along side its bid to become the world's lowest cost supplier of electricity, Eskom launched a program in 1990, "Electricity for All". The program was born out of desire to rectify the skewed remnants of the Apartheid past, where 98% of all white households had electricity, while 80% of all black households were in the dark. However, such an enormous ambitious task has equally enormous formidable barriers to overcome. The company was confronted by a huge capital investment of \$3.5 billion dollars with a dismal payback period of 30 years. Moreover, the potential customers had limited and highly-variable income, if at all. The deficient economic viability of the program was further aggravated by the prevailing socio-cultural practices at that time. Wood and charcoal were popular, nonpayment of services was the norm, and theft/illegal connections were rampant. Eskom was facing a high-priced portfolio investment saddled with these dilemmas. How do strategy and technology save the program?

The challenge of providing enough energy for Ghana

In 1962, Ghana decided to build the Akosombo Dam on the Volta River in order to get sufficient power for the aluminum industry, and now needs additional power. In 1994, 1997, and 1998, water levels were not sufficient to power hydroelectric generators to meet Ghana's growing energy demands. This led to a nationwide electricity rationing schedule, reduction in exported electricity to Togo and Benin, and extensive negotiations and monetary compensation to the aluminum industry. Should the country build another dam? If so, the best site is in a national park. Should Nigeria try to expand its thermal plants? import power? Should it change its relationship to the aluminum industry? Who will benefit from each of these options? Who will be harmed?

These cases encourage students to see the ethical and social issues embedded in the design of complex technological systems. The goal is to produce what John Law has called a 'heterogeneous engineer', who understands that invention, design and discovery involve linking the technical, the social and the ethical . Such an engineer will need to be a reflective practitioner , capable of engaging in moral imagination.

These cases have been piloted in several engineering classes, including a first-year honors class on Scientific and Technological Thinking and a fourth-year required course that combines work on an engineering thesis with readings and discussion of ethical issues. Students and faculty have described the cases as interesting and relevant to their engineering education . Each case comes with a teaching note that

includes the best practices that emerge from classroom piloting.

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A Graduate Option in Engineering and Ethics

At the University of Virginia, several of us have created a graduate option in Engineering and Ethics that links the Darden Business School, the Division of Technology, Culture and Communications and the Department of Systems Engineering. The word 'and' in the title of the option is important: students obtain a graduate degree in Systems Engineering. Their theses typically focus on a case-study that links technical, social and ethical issues, like the examples in the previous section. Students entering the option obviously do not have background in all the relevant fields, and may have to take extra courses to supplement. Students who are not engineers, for example, typically have to take a couple of quantitative courses right away, before they can proceed farther.

The thematic core for both options for master of science and doctor of philosophy degrees involves uniting a research program with a case study and course of study. The case study provides unity and a capturing mechanism in a program designed to shift students' perspectives, or mental models, of technological design problems from among different competency areas: systems engineering, social studies of science and technology, and ethics.

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Master of Science (MS) Option

In the first semester of study students begin by identifying a real-world example in which practitioners are struggling to solve problems involving closely intertwined technical, social and ethical issues. Examples already mentioned include extending the electrical grid in South Africa to a group who previously suffered racial discrimination or designing products such as silicone breast implants in a competitive environment with human health implications.

Concurrent with this problem identification phase, students enroll in core systems engineering courses, such as mathematical programming, stochastic processes, and an introduction to systems engineering course which addresses problem outscoping, management, social issues, goal setting and quantitative and qualitative modeling. The core courses provide a framework and basic tools for constructing models of systems problems.

In the past this program has welcomed students from a range of undergraduate backgrounds. Students have come from more traditional engineering disciplines such as industrial, systems, aerospace, and applied mathematics. There have also been successful students entering with backgrounds in religious studies, English, history of technology, psychology and philosophy. Students who do not have exposure to three semesters of calculus, probability, and statistics enroll in articulation courses as needed during the early part of the program. Because the program as a whole emphasizes both qualitative and quantitative structuring of issues in the case studies, the core and articulation courses are designed to build a skills base for conducting these analyses.

In the second semester students enroll in SYS 782 Ethics, Invention and Design, the core course for this casewriting degree option. This seminar serves several purposes. First, the course provides readings and guidance about casewriting: framing ethics and design issues, conducting interviews, managing a network of contacts. Second, the course provides a forum for developing the particular case the student identified over the course of the first semester. Readings and discussion are directed at identifying key contacts involved with the case study and building a relationship of trust and open rapport with these contacts. The goal is to set up an initial visit with the contacts in the early summer with follow-up, extended visits to the various sites as is practical for the practitioners and the casewriter. Third, the course acts as a laboratory writing seminar. A separate meeting time is set up so that the students can work on generating joint publications related to the research effort. This current article was drafted during these lab writing sessions.

The readings for this course are drawn from several different fields of study. The central readings area comes from the social studies of science and technology, particularly from the literature on participant observation and anthropology (Latour 1979). Also emphasized from this area are different approaches towards framing technological change and development, such as actor-network and social worlds approaches, heterogeneous engineering and the social construction of technology.

Also part of the core readings for this course are readings from various philosophers in ethics, such as Kant, Mill, Locke, Rawls, Nozick, and Walzer. These readings are not meant to be an extensive portrayal of each of each philosopher's views but an exposure to various themes in the ethics of business and engineering. The unifying theme for the readings in ethics is moral imagination, or frame shifting , because the best cases are ones that capture many different points of view surrounding a design issue. These readings are supplemented by contemporary writings of scholars who work in engineering and business ethics (Davis 1998;). Finally, students read a range of case studies and supplementary writings that help them begin their research for their summer case work.

By the end of the course students typically have completed background research on their particular case project, have written case proposals requesting funding from the Darden Business School for their summer case projects, have made arrangements with contacts involved in their cases for coming to visit them for interviewing and data collection, and have begun to frame the technical, social and ethical issues involved with their case using the background readings.

In the past the casewriters have been well-received by the practitioners. The casewriters provide the practitioners an opportunity to reflect their ideas in an environment where they can be confident that the information is treated as confidential until the time when they are comfortable releasing the information, with the understanding that the casewriter will need to write a thesis or dissertation that examines the information from a critical perspective. We have found the practitioners eager to take advantage of an opportunity to have a thoughtful yet "safe" person with whom to discuss their ideas and challenges. Another motivation practitioners cite is that their projects, companies, or agencies are published and taught through the Darden School and the Engineering School, to both undergraduate and graduate students. In the case of the Darden school the cases have been used in the Executive Education Program.

Also in the spring semester students enroll in SYS 602, which builds off of the previous core courses in the fall semester. This course challenges students to attempt to model messy and poorly specified problems involving both quantitative and qualitative issues. Finally, students take an elective course. In the past many students have chosen to take a course offered by the architecture and planning schools, Environmental Choices, which features high practitioners who work in the area of environmental product and system design. Students are encouraged to take

electives that provide a shift in perspective, in effect applying the moral imagination concept reflexively to the educational program as well as capturing the process in the case studies themselves.

For the summer, students are not enrolled in courses but are paid interns at the Darden Business School as casewriters. Students continue to conduct background research on the various case subjects and go off to interview practitioners. The interviewing process depends entirely upon to what extent the case issues and context can be captured by outside sources and other means of communication with practitioners, such as email. In the past the interviewing process has been as short as a single day, such as a day trip to New York to visit a company, or has lasted as long as three months, such as visiting companies, NGOs and academic researchers in South Africa. The goal of the initial visit to the sites is to come away with the main issues framed for a case. The remainder of the summer involves follow-up questions, follow-up visits if necessary, additional supplementary research, and drafting of the case.

The goal is to have completed a draft of the case by the end of the summer. The case is then piloted in the fall semester in engineering and/or MBA classes. The case writer typically teaches the case and collects survey information about how the case can be improved. The student also writes a teaching note, or plan, based on his or her experience in the classroom. The plan acts as a guide for future instructors who will use the case. The case is then redrafted and sent back to the practitioners for final review and release. The case is published through the Darden Case Bibliography and is available in the following summer. The cases have also been made available on the World Wide Web. Students are typically employed as teaching assistants in the engineering school and are therefore familiar with the course in which they pilot their cases.

During the second year fall semester the emphasis shifts from framing the project as a case study into framing the project into a scholarly analysis suitable for a master of science thesis. Coursework consists of two electives chosen to supplement the shaping of the case or to meet general career goals. For example, students have taken additional courses in information technology, environmental design, and business. Students also enroll in a thesis writing course for which time is allotted for finishing the case and for conducting independent research. In the fall semester students also typically defend a thesis proposal before a committee of advisors. The students also present their research at a conference, such as INFORMS, Society for

the Social Studies of Science, or the Frontiers in Medicine.

The following spring semester is typically devoted to completing thesis work and finding employment after graduation. The students typically present their research at an additional conference, typically the Association for Practical and Professional Ethics or the American Society of Engineering Education. The thesis is defended before the student's committee members. To date, there are four students who have graduated from this option. One has found employment in the consulting field, one has gone on to management in the information technology field, one has gone on to a research division of a multinational corporation working in environmental sustainability issues, and one has decided to remain to pursue a Ph.D. in this area. All graduating students have participated in getting their research published successfully in journals and books.

Summary of Deliverables:

- One or more case studies published in the Darden School Case Bibliography
- Master of Science thesis
- Case teaching in at least one classroom setting
- Research presentation at one or two professional conferences
- Follow-up publications in a journal or chapter of a book

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Doctor of Philosophy Option

The Ph.D. option assumes the student already has a M.S. or M.E. equivalent in a technical field, such as systems or industrial engineering. The program has been structured around three "pillars" of competencies, a plan that differs from the usual structure of having a major and a minor area of expertise. The three areas of competence are Systems Engineering, Business and Engineering Ethics, and Social Studies of Science and Technology. The option is designed so that the coursework has the built-in concept of shifting frames, so that the student learns to participate in and to observe different academic cultures. Learning the wisdom of moral imagination becomes a part of the student's own educational experience in addition to how he or she applies the concept to research and case examples.

Students take two years of coursework, with two Ph.D. level courses in each area, concurrently with two Ph.D. level elective requirements spread among the three areas. Typically students enroll in SYS 782 (described above) as one of these courses. In this case the student conducts additional readings and writings that help shape the direction of the course itself and supplements the student's background in ethics and social studies of science, on participant observation, and the anthropology of technology. Students also take two additional courses in graduate mathematics.

Students take a Ph.D. qualifying exam in the spring of the first year, take a comprehensive exam at the completion of coursework, construct and defend a dissertation proposal, and defend the dissertation for this degree.

The tradeoff of this plan of study is that the student is not indoctrinated into the deep level of expertise in one particular like most Ph.D. students; however, this price buys the student a unique skill related to the ability to work in a cross disciplinary way at a level that goes beyond the usual loose stapling together of separate disciplines that leads to much shallower, compartmentalized, and "over-the-wall" types of interdisciplinary research.

Much like the M.S. option but to a greater degree of depth and breadth, extensive research based on in-depth casework is the unifying object for the program. The student is employed over the course of two or more summers conducting casework involving companies and practitioners who are solving a more protracted and extensive design problem. For these case studies, students are typically recruited by the case subjects into acting as participants in solving the research problems, while at the same time the students act as observers of the practitioners and their own processes. Therefore, the literature on participant observation takes on a larger role in the Ph.D. option. The student publishes several case studies over the multiple summers and is involved in drafting more articles and conference presentations. The emphasis is on a more scholarly treatment of cases involving engineering design with ethical, policy-oriented, and social implications, cases in which the students themselves become both an agent in researching the solution to a problem as well as an observer attempting to distance himself or herself to reflect on and shift frames from the process of solving the problem. Students exercise both experiential and reflective cognitive modes acting as both participants and observers. The results of both roles as participant and observer provide extensive research material for both a dissertation and scholarly publications and presentations. It is anticipated

that the knowledge, skills, and wisdom students gain from this program make them competitive candidates in business and engineering academic and commercial areas.

This graduate option is not solely designed for Systems Engineering; other engineering disciplines at other institutions could create options that combine ethics with technical training at the graduate level. Bio-medical and bio-engineering are obvious targets for such an approach, but every engineering discipline has its ethical issues. The ideal system would be one in which students from any department could sign-up for an ethics option that had a small team of multi-disciplinary faculty, ready to assist faculty in the department with special seminars, students supervision, places to publish and potential sources of funding. The reason to keep this an option, and not a program, is that it should always be a space of multi-disciplinary collaboration, and it should always depend on students who are 'following their bliss', as Joseph Campbell so aptly put it.

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Notes

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