USING CHILDHOOD EXPERIENCES AS AN ANALOGY TO TEACH STUDENTS ABOUT THE MORALITY OF EMERGING TECHNOLOGY

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1. INTRODUCTION

Engineers, educators, and society as a whole have long recognized the importance of teaching engineering students about ethics and its relationship to their future careers. The unique position occupied by engineers in modern society gives them a great deal of control over the development and application of emerging technology, and it is critically important to society that future engineers be able to recognize the larger societal context of their work. (Davis, 1999; Gorman and Mehalik, 1997; Kline, 2001; Nichols, 1999; Soudek, 1999; Stephan, 1999). The American Society for Engineering Education (ASEE) has gone so far as to say that, "to survive in the work world of the 21st century and to carry out responsibly their roles as agents of technological change, new engineering graduates need substantial training in recognizing and solving ethical problems." (http://www.asee.org/about/statementEngEthicsEdu.cfm)

Unfortunately, this is a very challenging topic to teach to undergraduate engineering students, who have typically selected this field because they have very strong skills in mathematics and science, skills that do not lend themselves to a philosophical discussion of the merits of technological development. Anyone who has ever tried to explain the difference between deontological and utilitarian ethics to a roomful of undergraduate engineering students knows what a true teaching challenge it is.

In order to help accomplish this important but demanding task, a number of ethics textbooks have been written specifically for engineering students (Johnson, 1991; Martin and Schinzinger, 1996; Petroski, 1982; Taylor, 1975; Gunn and Vesilund, 2002, among many others), and national organizations have published resources designed to help engineering educators impart ethical concepts to their students (Elbaz, 1990; Wujek and Johnson, 1992).

Engineering ethics education has been approached from a variety of different points of view over the past thirty years. Much early work focused on ethics as an exclusively moral issue (Goldman, 1979; Whitbeck, 1995), while recent work has also considered ethics as a component of professionalism, risk management, and legal liability (Firmage, 1980; Flores, 1988; Schaub

and Pavlovic, 1983; Vaughn, 1977). With an increasing emphasis by modern society on sustainable design, engineering ethics is also being tied irrevocably to environmental issues (Gunn and Vesilund, 1986). The emergence of massively powerful computer technology over the past thirty years has also led to a detailed study of the application of engineering ethics to computers and digital communication technology (Johnson and Snapper, 1985; Unger, 1982).

All of these emerging issues of engineering ethics have prompted the Accreditation Board for Engineering and Technology (ABET) to specifically identify "an understanding of professional and ethical responsibility" and "the broad education necessary to understand the impact of engineering solutions in a global and societal context" as two of only eleven specifically enumerated criteria that all engineering graduates must possess (Herkert, 1999; Pfatteicher, 1999).

In this paper, the authors present a novel and exciting new framework for helping engineering students to recognize and understand the ethical obligations that accompany their engineering education. This framework builds on the earlier work cited above, but it is specifically designed to address the issues in a way that is entirely familiar to twenty-year-old undergraduate engineering students.

2. WITH POWER COMES RESPONSIBILITY: A FRAMEWORK FOR ENGINEERING ETHICS EDUCATION

The underlying motivation for teaching engineers about ethics is that they are *moral agents* of society. In other words, they are endowed by society with special powers and authority to make decisions that have repercussions on the rest of society. This special authority comes directly from the fact that they have exhibited natural ability in mathematics, science, and technology, and this natural ability has then been increased by four or more years of formal education in the analysis and design of engineering systems. At the completion of this education, the newly minted engineer is capable of understanding, analyzing, and designing systems that are far beyond those of his or her non-engineering colleagues. It is precisely this fact—engineers having special knowledge and skills not available to the general population—that makes it so important for them to be taught to exercise that power with care and consideration of the repercussions.

In a way, this social contract is very similar to that held by society with physicians, political leaders, and the military. Each of these groups is given special authority to do things that would ordinarily be illegal for other citizens, and in return they are asked to exercise that authority with care and respect. The similarity is probably the greatest with physicians, who are also selected on the basis of intellectual ability and who also undergo several years of education that greatly increases that ability. However, whereas a physician's careless or unethical act would typically injure or kill a single patient, an engineer's careless or unethical act could lead to the deaths of thousands or even millions of people.

So, the foundational attitude that must be conveyed to engineering students is that their intellectual power carries with it very real ethical and moral obligations. This is a modern

application of the concept of *noblesse oblige*, a medieval belief that the wealthy and privileged are obliged to help those less fortunate. Literally translated, it means "nobility obligates." In the seventeenth century, this meant that those with financial resources and noble titles were obligated to help those in lower social positions. A useful way of conceptualizing today's nobility is that it consists of those with the intellect and education to understand and develop state-of-the-art engineering designs, and they are obligated to help the rest of society every bit as much as a French nobleman was three hundred years ago.

How, then, does one convey this concept to undergraduate engineering students? It seems logical that that most effective way to do so is to build directly on his or her own personal life experiences. Unfortunately, those experiences do not typically provide the degree of breadth considered necessary to recognize the need for exercising care in the use of power.

But, upon closer inspection, it is just possible that they have all had exactly the sort of experience that can help them to see how power brings with it moral obligations. Every student in every engineering classroom in the country has shared some very common experiences, and we can use those experiences to help them see that society has always assigned power and responsibility in equal measures. By presenting students first with the story of an infant growing successfully to adulthood, followed by a discussion of societies developing from hunter-gatherers to modern, power countries, we can help students to see how their personal actions as engineers must be made in the context of the effects of those actions on others.

2.1. A Life of Increasing Power and Responsibility

When an infant is born, it has essentially no ability to exercise control over its environment, and it is therefore assigned no ethical responsibilities. If an infant accidentally killed another person, it could not possibly be held responsible for that action, because it has no ability to control or even understand its environment. As the child begins to grow, s/he gains additional skills, including the ability to communicate with others. Once s/he has the ability to make her/his needs known, s/he has more control over her/his environment. Simultaneously, the child's parents begin to use that communication ability to teach her/him right from wrong, introducing the first ethical responsibilities of her/his young life. As the child gains the ability to walk and control of her/his limbs, s/he has for the first time the ability to inflict intentional injury on other people. This is another opportunity for the child's parents to teach her/him that it is wrong to hurt other people, introducing an additional ethical constraint.

As the toddler learns more about the world, s/he begins to understand that there are things s/he wants but cannot have. This is an important lesson, and it is only through the dedicated efforts of the child's parents that this "terrible two's" period is used to teach the child about delayed gratification and sharing precious resources (such as toys, candy, and attention) with others.

Once the child goes to school, s/he is faced for the first time with an expectation to complete complex and difficult tasks for a future reward. Skills such as arithmetic and reading are very challenging for the child to learn, and s/he may not be able to immediately see the need for such skills. At the same time, this is the first opportunity for the child to be part of a society, composed of his or her classmates. The classmates will probably be much more diverse in

background and ability than the child's siblings and pre-school friends, which leads to the possibility of greater conflict. These potential conflicts give the child many more opportunities to learn about the need for self-restraint and negotiation.

As the young person continues to grow through grade school, increasingly challenging academic demands are placed on him or her, leading to a continuing need for personal development. Social interactions become much more complex, and there is no longer a single clearly correct solution to most problems. At this point, the child is expected to anticipate the needs of others and to weigh them against his or her own needs when making a decision. Doing so correctly leads to rewarding interactions with others, while doing so poorly leads to negative interactions and the possibility of punishment.

As the child enters adolescence, the social interactions become even more complex, academic pressures continue to accelerate, and the young person is faced with the opportunity to make the first adult decisions of his or her life. The opportunities to decide whether to engage in smoking, sex, drinking, drug use, or other illegal activity all make these years some of the most difficult of a person's life. At the same time, parents may begin to treat the young person with more autonomy, allowing him/her to be unsupervised for short periods of time and giving him/her more privacy at home. For many people, this is the first time when they are faced with competing priorities: the messages they are getting from their peer group will frequently conflict with those from their parents, and they have to make their own decisions based on their own core principles.

In high school, the student is given even more individual authority and capability, along with additional ethical responsibilities. Driving a car is both an incredible power and an awesome responsibility. Being on extended unsupervised dates with members of the opposite sex similarly places one in a position of great authority to make important decisions and responsibility for making the right decisions. It is also at this age that many people begin to make decisions that will impact the rest of their lives. Poor academic performance, teenage pregnancy, and legal troubles can literally impact the rest of a person's life. Increasing power is coupled with increasing responsibility and increasingly long-term repercussions for acting irresponsibly.

In college, students are left almost completely unsupervised all the time. The temptations toward alcohol, drugs, sex, and academic irresponsibility are very difficult to resist. The repercussions of bad decisions are not immediate, which makes them even more difficult to resist. But those repercussions are severe and long lasting. Again, the young adult is faced with the opportunity to make even more important decisions, and society now treats him or her as an adult, with the opportunity and even the right to make poor decisions. At the same time, society is much less willing to give this young adult another chance if he or she makes a serious mistake.

As the person leaves college, gets a job, and starts a family, he or she will begin to be faced with decisions that impact not only his or her own personal well being, but also the welfare of spouses, children, and co-workers.

Eventually, as a person progresses up the career ladder, it is likely that he or she will be placed in a position to make decisions that affect larger and larger groups of people, whether they be customers, employees, or other constituents. This person has spent the first twenty or more years of his or her life developing and demonstrating the ability to make responsible choices, and now he or she has been given responsibility to make much larger choices that impact the lives of many other people. They have reached this point as a result of growing very gradually in power over a period of many years, and they have learned by repeated reinforcement (first from parents, and later from the rest of society) that their actions have consequences, both positive and negative.

2.2. A Society of Increasing Power and Responsibility

The development of power and responsibility within society parallels that of the development of the human child. Very early on, the members of a society are struggling just to survive by hunting and gathering the food they need every day. These nomadic peoples move to follow the food supplies, assigning little or no ownership rights to individuals. The concept of personal rights is almost unknown, with the most powerful members of the group taking whatever they want. Thus, although particularly strong individuals have a great deal of power (meaning here the ability to influence the behavior of others), the society itself does not have power to significantly influence the behavior of other societies. In such a setting, where every member of the society is required to expend almost all available energy to obtain sufficient food to maintain subsistence, it is difficult to characterize behaviors and decisions as ethical or unethical. In such a survival setting, decisions are better characterized as promoting or not promoting survival, and those behaviors that do not promote survival will be quickly removed from the society.

As the society progresses from hunting and gathering to a more agricultural base with domesticated animals and even irrigation, it becomes much more important to assign individual ownership rights to particular members of the society. By working hard, individuals can increase the value of a piece of land through clearing and irrigation, and it is only reasonable that the person who does that work should reap the benefit of it. The enforcement of these rights, both against local trespassers and foreign invaders, is one of the reasons why governments are initially formed. For the first time, ethical rules of conduct are established, clearly describing appropriate and inappropriate behaviors by members of the society.

As productivity increases and food surpluses develop, two things happen. First, the need for storage and recording the ownership of those surpluses leads to the development of pottery and writing. Second, some members of the society are freed up from the need to produce food every day, allowing them to develop other aspects of the society. Metallurgy, domestication of animals, and the development of early culture are the result of this free time. For the first time, people have the opportunity to build large numbers of weapons that can be used to wage war on competing societies.

As populations increase, the importance of government grows. Many of these early governments use religious beliefs to control their societies, telling the people that their leader is either empowered by God or is, in fact, a God himself. The ability of the society to do great things

increases, leading to wonders such as the pyramids and the architecture of Greece and the Roman Empire.

Sadly, much of this achievement is built on the labor of slaves. As one society becomes more powerful than another, it frequently decides to enforce its will on the weaker society, killing and enslaving its entire population. Only the technology and military power of the stronger society keeps the slaves in line. Indeed, entire societies (such as Sparta) have been shaped by their need to control slave populations that greatly exceed the population of citizens in the society.

As societies continue to proceed at different technological paces, the disparities become even greater. This leads to imperial actions by the more advanced societies, controlling and using the resources not only of individuals but also of entire races and cultures.

Eventually, technology is developed to the point where fossil fuels can be harnessed to create energy. This energy is used for transportation, automation, and heating. It is used indiscriminately at first, because it is so plentiful and easy to obtain. The new technologies that result (such as steam engines, railroads, and machine tools) have two primary effects: First, they allow even larger groups of people to be governed effectively as a cohesive unit. Second, they promote the growth of a large industrial base to take advantage of the new technologies. This industrialization continues to degrade the inherent value of individual people, treating them as replaceable cogs that compose a larger mechanism. An outcry against these human rights violation occurs, but is largely unheeded.

Of course, every pound of coal that is burned adds a small amount of carbon to the atmosphere, but the long-term effects of this air pollution are not apparent.

As technology continues to progress, societies continue to develop new capabilities (such as automobiles), and the immediate repercussions of this technology are not apparent. Increasingly, the technological breakthroughs are applied to the military, increasing the society's ability to enforce its will on others. Early chemical weapons prove to be very effective, but their use cause horrible disfigurement and continuing outcries against technological development.

Technology then makes possible increased communication abilities with the introduction of radio, telephones, and television, allowing government to effectively interact with ever-larger groups of people. It allows increasingly fast travel with the introduction of air travel, and this technology is translated to military applications with fleets of aircraft dedicated to shooting down other planes and bombing enemy targets.

The introduction of nuclear and biological weapons gives the society, for the first time, the technology necessary to destroy all human life on the planet. It is only through a policy of mutually assured destruction that these weapons go largely unused.

After one hundred or more years of fossil fuel usage, the cumulative environmental effects begin to become apparent. Persistent air pollution, destruction of the ozone layer, and global warming are all detected, and governments begin to take action to prevent further damage.

Emerging technologies, such as nanotechnology, robotics, artificial intelligence, and genetics all present the opportunity for self-replication. Such self-replication can be a tremendous benefit to society, because beneficial devices can quickly multiply, but negative repercussions of a self-replicating mistake are equally tremendous.

As technology continues to progress, abilities that used to require the dedicated effort of an entire society (such as the production of nuclear and biological weapons) become much more commonplace. These weapons become more dispersed, and previously powerless people can gain access to them. Their use of these weapons of mass destruction is a continuing threat into the future.

2.3. From Analogy to Education

This analogy can be a powerful tool for helping to teach our students about social responsibility and effects of unrestricted technological development on society. The power of this analogy lies in helping students to see the similarities and difference between these two scenarios.

As a child increases in capability, power, and authority, it is also assigned greater and greater ethical and social responsibilities to use that power wisely. Young children who abuse that power are punished by their parents, and adults who do so are punished by society's legal authority. In this way, increasing power is accompanied by an increasing sense of responsibility to use that power in the best interest of one's self and of the entire society. Even when immediate rewards or punishments are not assigned, people learn to accept delayed rewards or avoid delayed penalties that they can recognize.

However, as a society progresses in power, there is no agent outside of established societies with superior authority for providing society's members with the education, reinforcement, and punishment necessary to grow in ethical and social responsibility. The universe does not directly punish a country that enslaves the population of another country; to the contrary, the enslaving country is rewarded by an increased standard of living. When negative repercussions do occur (such as global warming and nuclear proliferation), they frequently occur decades after the initial decisions and actions that led to them. Thus, the repercussions are imposed on the society, but usually not on the individuals who caused them.

Most societies, then, are like children who grow up in the wilderness or in a house of no adult supervision. They have not been instructed in such a way as to form a solid set of ethical principles that control their behaviors. Rather, like a two-year-old with a driver's license, they make decisions that satisfy their immediate needs or impulses, leading to significant negative repercussions in the future.

It can only be hoped that, as civilizations continue to produce technical advances, some of those advances will help produce a similar advance in the ethical and moral capabilities of the civilization. For example, the industrial revolution introduced technology that eliminated the need for slavery, and so this once common institution is now essentially wiped out across the entire planet. Similarly, the tremendous improvements in digital communication systems over the past fifty years have increased the power of individuals to resist repression by governments

and corporations. Whereas those people would have been completely powerless fifty years ago, they can now make their plight known to a dozen newspaper editors and non-governmental organizations with a single email. This has helped to eliminate the most egregious repression of individuals, because the repressors know that their actions may well be on the front page of the newspaper the next day. In this way, technology grants power both to the societies and to individuals, and it is in the balancing of this power that true progress can be made.

The principle that increasing power and authority must be accompanied by increasing responsibility and care for others is one that is evidenced by the successful growth of an infant into a responsible adult. Sadly, societies have displayed such growth only in fits and spurts over the last five thousand years. We have survived until now because the repercussions of those irresponsible decisions were usually local. But now that technology has progressed to the point that poor decisions can impact the lives of billions of people, it is important that we teach our students not to behave like ethical infants. In short, we must teach our students that the power and authority conferred by advancing technology also confers on the developers of that technology increasingly greater responsibility for its ethical use by human beings, both individually and collectively.

3. IMPLEMENTATION

The principles described in the previous section provide a powerful tool for helping students to glimpse the broader socio-political and ethical implications of their work as engineers. The authors plan to introduce this framework into a course on engineering ethics and economics taught to all engineering students at Valparaiso University in the fall semester of 2006. At that time, it will be important to assess students' learning through the use of pre- and post-surveys to probe students' attitudes toward engineering ethics. This measurement will need to be made both in the short-term (at the end of the presentation) and in the long-term (the following year in senior projects). It will be interesting to see how the use of this framework affects students' attitudes about the ethics of their profession.

4. CONCLUSIONS

In this paper, the authors have presented a framework of two scenarios that can be used to help students recognize the key lesson of engineering ethics—that they have been endowed by society with special power and the authority to use it, and that it is natural for increased ethical responsibility to accompany an increase in power. By showing first how a person grows from infancy to adulthood, accumulating small degrees of both power and responsibility along the way, we show that it is natural and desirable to exercise all newly discovered power with care for others. Then, by showing how society's increasing power is not directly assigned an increasing degree of responsibility, we can show our students that exercising power without concern for others leads to an unnatural state that is neither sustainable nor desirable.

As Theodore Roosevelt said, "To educate a person in mind and not in morals is to educate a menace to society." Let us all work to the best of our ability to ensure that our students are both

technically skilled and ethically equipped to handle the increasingly complex dilemmas that will face them as they enter the working world. If we are successful in that goal, then we will be contributing not only to the lifelong success of that individual, but we will help society itself to take one small step toward adulthood.

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