Do Technologies Impoverish or Improve the Lives of Those They Touch? A Student's Perspective on the Ethics of Engineering

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ABSTRACT: *Engineers, in their professional lives, face ethical dilemmas. The values and morals engineers use to deal with such dilemmas are those with which they are brought up or those, which exist in society and with which they tend to comply. The author has been a part of two significant engineering group projects, described in this paper, which illustrate examples of certain ethical dilemmas. It may be concluded that holistic engineering education is one key in broadening younger engineers' social perspectives. This is an education where the goal is not only to give training for technical demands but also to stress critical thinking, foresight, conflict management, and consider the role of values underlying future choices. This paper presents the points of view of a young engineer facing these issues.*

1 ETHICS IN TECHNOLOGY

An engineer has always been in a great position of responsibility, beyond the technical dimensions of his/her speciality, affecting all aspects of society. A holistic engineering approach is one way to lead ethical engineering. It incorporates a perspective beyond the technical and into the legal, social, religious, and natural aspects of engineering. Aristotle once said that morality is not as precise and clear-cut as arithmetic [4]. Therefore the exercise of moral autonomy does not carry a guarantee that everyone will arrive at the same truth. One requires tolerance to allow for disagreements between responsible moral agents. It can be seen that right from the beginning, issues of ethics were in existence. 'What is the right thing to do?' Is it what the government says? Is it what is most profitable? Is it what maximizes one's own well-being? There are several perspectives to consider in the answer to this question, however, what is *morally* correct is the reflection of theoretical perspectives of right and wrong, which is ethics.

In 1758 B.C., Hammurabi the King of Babylon, set up a number of laws (remnants of which are at *The Louvre* in Paris). One of these laws pertains to the discussion of engineering responsibility, as follows [5]: "If a builder has built a house for a man and has not his work sound, and the house which he has built has fallen down and so caused the death of the householder, that builder shall be put to death. If it causes the death of the householder's son, they shall put that builder's son to death. If it causes the death of the householder's slave, he shall give slave for slave to the householder. If it destroys property he shall replace anything is has destroyed; and because he has not made sound the house which he has built and it has fallen down, he shall rebuild the house which has fallen down from his own property. If a builder has built a house for a man and does not make his work perfect and the wall bulges, that builder shall put the wall into sound condition at his own cost."

Although most ethical codes today do not specify punishments, this clearly demonstrates the significance and importance one gave to ethics of what we today call engineering. The seriousness of this law's tone indicates the gravity of the situation and the job of the engineer. It shows the responsibility the engineer owed to the people by doing a job. When the implicit social contract between engineers and society and the issue of public risk is involved, it seems clear that the engineer must assume this responsibility as it is a licensed seal which is stamped on engineering drawings. However, the complexity of engineering today demands intricate synergies and thus fixing responsibility is difficult. An engineer may have to take greater responsibility than that demanded by a technical role, without a claim for corresponding credit. One often hears of a 'scientific success' and an 'engineering failure'!

Kenneth Humphreys, in his book 'What Every Engineer Should Know About Ethics' outlines various models of responsibility [1]. The *subjective* model relates to the ethics recognized by each person in a profession individually. The *legal* model suggests that paramount moral obligation lies in the duty to obey the law. The *societal* model of moral responsibility is built upon the conventions, customs, and set practices of a given society. The *religious* model states the right and wrong are defined in terms of the established religious beliefs. The *natural law* model judges by what is 'natural' and 'not natural'; current cloning technology debates can be said to be based in peoples' natural law model of moral responsibility.

There is no doubt that successful technology has in uncountable ways improved tremendously the lives of people. Highly developed medical technology continues to heal and save lives. Space technology has enabled humankind to answer questions beyond what was previously believed about our planetary systems. Continuing progress in civil engineering has made our bridges and buildings several figures safer. Computer engineering, a product of which is the Internet itself, has made the world virtually closer. Daily appliances have improved people's lives, from can openers to washing machines and dishwashers. Mobile phones, computers, and even wheelchairs that can climb stairs are all technological deeds and advancements, which have made one's life easier and more comfortable.

The increasing concern for the value dimension of engineering comes to some extent from the attention media has given to disasters such the Challenger space shuttle, and the Chernobyl catastrophe, and the Exxon oil spill to name a few. Engineers face ethical dilemmas. These exist wherever moral reasons support conflicting courses of actions. The values engineers use to deal with such dilemmas are those with which they are brought up or those which exist in society and with which they tend to comply. Governments have a key role as they facilitate and encourage ethical standards to follow. As is known, engineers have a significant role in enriching or impoverishing people's lives with their design and manufacturing of technology.

Consider the heavy field of nuclear technology. In 1939, nuclear fission by Otto Hahn showed that science was able to release energetic processes with destructive powers way beyond anything ever known before. When Albert Einstein wrote the symbolic and crucial letter to President Roosevelt warning of Germany's speculated plan to use nuclear fission in the construction of a super-bomb, he submitted what was read as an appeal to the United States to build the bomb. He was known as a pacifist and a devout scientist, and in fear of Nazi Germany, loyal to the US government [3].

Robert J. Oppenheimer led the Manhattan Project. He was then accused by the American Atomic Energy Commission of espionage when he delayed the hydrogen-bomb project by 18 months. An interesting and ethically fascinating case to study is that of the court hearings based on these proceedings. One can clearly see that Oppenheimer was 'trapped' in a moral conflict much deeper than merely his loyalty to the government. He shows an obligation to the government as a technical man, but more poignant is his responsibility towards humanity. He was well aware of the consequences of his work; he was in an engineering sense very successful but the consequences of his work were impoverishing and killing the lives of people. He said once, 'Nuclear energy is not the atomic bomb.[…] It is our misfortune that people rather think of the reverse kind of uses.' This implies that whether engineering is geared towards a positive use or a negative use depends not on the engineer but on the user; the means exist and the power to improve or impoverish life with these means is up to the people concerned. He defends himself in the court by saying, '…dropping was a political decision – not mine. I was doing my job.' [3] One can notice that when the question of ethics comes into play, there is often a naïve side and/or a schizophrenic perspective, oscillating personalities, and confusion in behavior.

The famous rocket engineer, Dr. Wernher von Braun, said when once asked about the consequences of his work, 'Once the rockets are up, who cares where they come down? That's not my department.'[7] He was unconcerned about the effect of his technology on the lives of people. It is plausible that if Wernher von Braun were more involved with his society, he would have addressed these issues from a different angle. Ethics is a sensitive and multi-dimensional topic to address.

In aircraft engineering, safety is one of paramount concern. But despite quantifying safety, it is more a social than technical question. All parameters and possible situations cannot be simulated and taken into account before an aircraft takes off for its flight, and yet an engineer has to sign a release allowing for this to happen. For example, an investigation after the infamous American Airlines Flight 191 disaster in 1979 revealed that the engine was situated in such a way that when it separated from the aircraft, so did all the hydraulics and hence controls got disabled. [2] Whether the pilot was experienced enough to deal with a situation like this or if an engineer knew of a possible engine problem but gave it a green light because of 'high' chances of a safe flight are concerns which arose in this situation. The judgment of system reliability was questioned. There are many underlying issues and several questions can be posed with regard to safety. The engineer takes risks and huge responsibility in making these decisions and answering these questions, and so arise possible ethical dilemmas.

2 STUDENT'S PERSPECTIVE

Two engineering group projects are described, in which the author faced the beginnings of ethical dilemmas in her engineering career. They both illustrate the need for a holistic view of engineering, its applications and consequences. Decisions that are made are often trade-offs and although a design may be the best in engineering, several other factors must be considered.

A circus clown gave rise to this exciting project due to his need of stilts, those with which he could depict a four-legged animal in performance. Aware that this design work would directly affect a player in the entertainment industry, a number of interacting implications of the design had to be critically considered. Many models out of ice-cream sticks were made to verify Pro-Mechanica simulations on the computer screen. One had to ensure that although the forces and moments on screen were proper, the stilts would in practice serve their purpose.

Possible problems associated with walking on stilts had to be examined. There were certain risks the designer could assume the user would take. For example, if there were to be water or even a banana peal on the circus ground, the stilts and their walking style had to be such that the clown would not slip and fall. If there were to be an unfortunate situation of slipping and falling, it would be desirable to fall in such a way as not to seriously get injured. The software and the ice-cream sticks were limitations to the designer, who often had to be in an abstract field to analyze the issues.

To clear some queries, the author learned to walk on stilts bringing about a personal feel for the challenges involved and consequently making changes to the design knowing the level of comfort. This, among other things, highlights the importance of class projects in the real-world scene, beyond the classroom. It brings about a strong sense of responsibility to the team of engineering students, a responsibility that goes beyond just correct numbers and affects the life of a player on the street.

Another exciting engineering project the author undertook was the design and manufacture of a model remote-controlled aircraft for the Society of Automotive Engineers AeroDesign 2002 Competition. This entailed all aspects of systems engineering; aerodynamics, finite element methods, computational fluid dynamics, composite materials, manufacturing methods, team management and dynamics, and the underlying consequences with view to the related values and ethics.

The team was being evaluated based on several criteria. The planform area of the aircraft had to be within $0.775m^2$. High lifting capability was of prime importance and therefore the total weight of the aircraft had to be minimized. One of the aims of the game was to carry the maximum weight and fly a given round of the airfield. This aircraft was to fly at a public competition, with a spectator audience of hundreds of people in the Mohave Desert in California. Unfortunately, like in the previously described project, ice-cream stick models were not possible with an ambitious project of this size and dimensions. Questions also arose, but to be answered, one had to depend on the computer screen or at later stages on the prototypes constructed.

One key decision to be made was the mounting of the engine of the aircraft. The engine also contributes to the pitching moment; its thrust and the propeller wash all affect the angle of attack of the aircraft. The time-and-again arising question was whether the team should deploy a pusher or a tractor propeller. This distinction relates to whether the propeller would sit in front of or behind the main section of the aircraft. Both had specific advantages but the tractor (front)-type was more widely used and known with model aircraft. Aerodynamically the difference was small for the application purposes but this small difference may have ultimately been the deciding factor in the competition. The team chose to use the pusher mounting and the main reason was as follows: The plane was to fly in open ground with hundreds of students watching, with hot sand and other aircraft also in the vicinity. If, for any unforeseen reason, the propeller was to dismount from the aircraft during take off or landing, a tractor-type would displace backwards, thus possibly injuring the remote-control pilot and other people standing behind the plane as it goes. With a pusher propeller, the perceived accident would result in the propeller being thrown in the direction the plane is going. This was clearly a safety issue.

The decision was completely that of the team's (a team which did have an engineering ethics course in first year). There were no laws or guidelines neither from the competition side nor from the country influencing this decision. However, ethics is in a way a law at a higher level and the team remains proud that a responsible and ethically sound decision was taken.

Credited to good engineering and manufacturing, the propeller did not get dismounted. This aircraft won the award for ‘Best Design’ and it was noted that no other design deployed the pusher propeller. The propeller wash of the tractor propeller is aerodynamically slightly more suitable, however, what is the price one pays for safety? In an engineering project, this is a social and *subjective* question, not a technical one.

Accurate and proper dissemination of information is another key area of engineering ethics faced in this project. The aircraft was to be made of the best carbon fiber and Kevlar available to ensure high strength and durability and at the same time minimize weight. The team had to be flown to California to compete. This could only be possible through external funding and hence the beginning of a tedious information dissemination campaign, building good human relations with companies, and a view of a scope beyond the competition itself. These need to be done without slipping to unethical steps of commercial advertisements and the like.

There were several attempts to secure funding. A farm in South Australia producing honey agreed to donate for the cause only if the aircraft would be painted yellow and black, symbolizing a bee. Although the symbolic value was of no significance to the team, the paint would be undesired added weight. Many companies wanted to possess the plane after the competition (for their advertising campaigns), however there was a *legal* responsibility the team owed to the university, who ultimately had ownership rights on the students’ projects. The first question from Defense was whether the plane could be customized to fly around Australia’s large coast, to protect it. Antarctic researchers, at a conference attended by the author, suggested that the plane be used in research in the South Pole, where it is difficult and dangerous for human beings to wander. These were not issues that questioned the team’s ability to implement, but rather asked ‘Should we do it?’ So as one can see, there were several hurdles, some ethical, to cross in the acquisition of funding.

Professionals face the issue of making themselves and their projects known. The team faced this to some extent during the efforts of advertising. Brochures, TV interviews, and speeches were given much before the first prototype was out. There was even the question of whether the aircraft, so promised, would fly! There were these tensions because to acquire support, the team had to provide a good result. However to provide the good outcome, funding was needed. It was too risky to promise too much and yet futile to promise too little. Fortunately in the end, the team met its expectations and, with the support of the university, acquired most of the desired funding for the completion of the project.

Engineering projects in the beyond the classroom give a real feel for the dimensions associated with engineering products. They give a chance to analyze situations in the context of society and the related effects.

3 CONCLUSIONS

Engineers often face dilemmas between being good professionals on a technical level and making ethical decisions. These dilemmas can also be between accurate dissemination of information and outright commercial advertisement or between reasonable statement on the outcome of project and glorious promises of political demagogue. Recognizing the importance of technologies in affecting the quality of people’s lives, professional societies play a large part in assessing the roles and responsiblities of their engineers. They have codes of conducts which are to be adhered to and they promote the personal obligation that engineers have towards their work and society.

Key to modifying existing attitudes is sound education, which would aim to broaden younger engineers’ social perspectives. There are role models to follow, engineers who look at engineering as also a science of economy in that it should use the energy provided by nature to its best advantage with a view to minimal wastage.

Some aspects of engineering education may also reorient and rediscover terminology. Expressions such as ‘kill’, ‘destroy’, ‘execute’ do not reflect a positive state of mind and the best aspects of humanity. Since sensitive engineering education is the key to the realization and sound direction of technology improving life, it is important to cultivate an optimistic and lively language.

Studying ethics while receiving an engineering education is a way of stressing related critical thinking especially in the areas of moral autonomy, conflict management and values in decision-making. Because engineers and their work have a profound influence in the lives of people, the habit of thinking rationally about ethical issues on the basis of moral concern should be trained. This also trains tolerance, which is paramount in dealing with ethical issues. An engineer is to be sensitive and understand delicate and fine issues pertaining to an ethical dilemma. Some uncertainty is expected and should be tolerated, as is the case with the judgments made.

Debating is a key skill in the analysis of a problem. Being able to take either side of the fence and critically evaluate the pros and cons of a moral dilemma question means that one is imaginatively conscious and alert to various issues. Talent in debating is nurtured from childhood, especially through school competitions, but can also be started at later stages in one's life via practice and repeated attempts.

Responsiveness to moral values is a quality one picks up as a child. When sensitivity towards society is not trained, an adult may also learn this from peers, friends, religious groups, teachers, and other influencing factors such as the media. Foresight and other practical skills, which encourage independent thought and thus moral autonomy, come often from real-world projects that students may undertake.

It can be seen that a grip on a holistic view of engineering promotes a sense of moral responsibility from many dimensions. Considering underlying influences and moral issues affecting other related fields such as legal issues, environment, society, religion, economics, and even *natural* laws broadens perspectives.

The responsibilities engineers have towards society are multifold. Engineers are also managers in society who take charge of planning, coordination, and control of their technologies. Doing this in a positive and constructive manner has developed many worlds and advanced many systems. This creative process of synthesizing and implementing knowledge to humanity demands and expects the highest level of standards. The ethical and moral values which engineers incorporate into their professional lives have a direct and vital impact on the quality of life for all people and therefore their services require honesty and integrity and must be aimed at the protection of society. Once the engineer is intimately involved with society and applies the highest form of ethical conduct, technologies will tend to enrich further the lives of those they touch.

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