Engineering, Philosophy, and the Will to Act

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What is engineering? What does it mean to be an engineer? For those studying engineering these are important questions. College is more than the knowledge gained in a succession of classes. Since for many students college is the first truly independent step in a process of growing and becoming, it is wise to understand where you may end up before taking a journey will change the course of your life; or in the words of Bilbo Baggins, "*It's a dangerous business…going out your door. You step onto the road, and if you don't keep your feet, there's no knowing where you might be swept off to.*" [1]. While you often hear engineering described as the application of science—and engineering does build upon science—most engineers would say their job is much more than applying others' discoveries. This essay starts from common definitions of engineering and explores the surprising role that philosophy, morals, and belief play in engineering.

There are over one hundred definitions of engineering, but perhaps the most common comes from the Accreditation Board for Engineering and Technology (ABET), the organization that monitors the quality of engineering degree programs. ABET defines engineering as "*… the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind*" [2]. While this definition has evolved over time, the original idea can be traced back to the very start of engineering as a formal profession at the start of the 19^{th} century [3]. A second, related definition comes from an engineering philosopher, Dr. Billy Koen, who defines the engineering method as "*…the use of state-of-the-art heuristics to create the best change in an uncertain situation within the available resources*" [4]. The word "heuristics" can best be described as "rules of thumb" that aren't precisely provable but help one arrive at a solution; engineers constantly use such heuristics in decision making. Both of definitions fit very well with our current ideas of how engineering should be taught since they focus on experience, making things, technical knowledge, and the need to work within constraints. Both the ABET and Koen definitions give guidance on teaching engineering since they imply that one becomes an effective engineer by gaining state of the art knowledge, experience, and effective heuristics.

To explore whether there more to engineering than technical knowledge and the ability to apply heuristics, I introduce an idea popular in thought experiments of past centuries by imagining a "demon" with superhuman powers capable of taking specific actions not possible for humans. LaPlace imagined a demon that predicted the future from knowledge of the position and momentum of all particles. Similarly Maxwell's Demon operated a small trap door to show that the second law of thermodynamics was probabilistic. Let us imagine a "professional demon" with superhuman perception who aids you in your professional tasks. While your professional demon can answer any question or perform tasks with superhuman skill, they need to be given a heuristic, or direction, to act; they are incapable of making choices that we ourselves are unable to. In other words, the Demon lacks independent volition and can only act if its actions can be defined before-hand.

One example of how to construct such a demon is suggested by the economist Milton Friedman's article "The Social Responsibility of Business is to Increase its Profits" [5]. Here the corporate executive demon, or Friedman's Demon, suggests actions to maximize the profits of a business as long as the actions are not deceptive or fraudulent. While the actual amount of data the demon must understand to make such decisions is overwhelming, the heuristic is simple- analyze all incoming data and take the action that maximizes profit. Similarly one can imagine Hippocrates' Demon in medicine that has keen perception of diagnosis and chooses a treatment that has the highest probability to cure an ailment while minimizing harm to the patient. Clearly such heuristics can't fully define a profession—Friedman's Demon cannot motivate employees and Hippocrates' Demon cannot comfort the sick. Nevertheless, identifying a profession's habitual actions—those that could guide our demon—sheds light on values and how performance is measured. The CEO that increases the profit made by a company is valued by shareholders and the doctor who cures a higher fraction of patients is a judged a better physician.

Of course not all human endeavors or professions can be fit so neatly into heuristics; it is difficult imagine the instructions given to Picasso's Demon for example. What about engineering? From the prior definitions of engineering ABET's Demon would supply the knowledge of mathematical and natural sciences, nature's forces and material, and access to others' judgments, leaving the engineer merely the task of deciding what most benefits mankind. Similarly Koen's Demon provides state of the art heuristics, available resources, and probabilistic calculations of uncertainty so that the engineer simply needs to decide what change is best. Here, however, even the best technically trained engineer confronts a potential dilemma. Unlike Friedman's Demon—maximize profits—and Hippocrates Demon—cure the sick—there is no heuristic to determine what is the best change (Koen) or what most benefits mankind (ABET). Technical competence alone is insufficient to guide action; definitions of engineering seem to *assume* either the engineer knows how to best serve the greater good, or will be told how by someone else. This is an important realization; to be able to act as an engineer requires us either to relinquish our judgment to our employer or to develop a moral philosophy that allows us to determine how to bring about a greater good.

Isn't this then the role of ethics in engineering? In a broad sense, yes, but not in the way ethics is commonly taught. Engineers have developed their own code of ethics to avoid the harm that comes from poor engineering decisions. In philosophy such ethical codes are broadly known as *deontological*, or rule, ethics. While deontological ethics provide broad guidelines for avoiding harm, they generally offer little practical advice on how to act for good. Such codes of ethics are also normative—they state how things *ought* to be or an individual *ought* to behave—and thereby may limit the right of an individual to determine for herself what is good. Alternatively one can look to the branch of ethics called *consequentialism*, where actions are judged by their consequences rather than whether they conformed to some predetermined rules. Consequences, however, can be very difficult to predict. The former president of the National Academy of Engineering, William Wulf, identifies ethics as a significant challenge for the engineering profession in the 21st Century since today's complex engineering projects, large teams, and the unpredictable effects of the aggregate of many small, sensible decisions make it increasingly difficult to predict the consequences of engineering actions [6].

If doing good is central to engineering, yet good can't be defined by rules or predicted from consequences, then engineers seem to require more than technical competence in order to be able to act. The engineer must be able to articulate and defend why their action benefits humanity even in the face of uncertainty. The question of how an individual acts when faced with uncertainty was addressed by the American pragmatist William James more than a century ago in his essay "A Will to Believe" [7]. James argues that belief as well as knowledge support action, and that basing behavior on one's beliefs need not lead to a completely relativist world. James recognized that to make completely rational decision we require proof. While for many problems it is possible to wait until sufficient proof is accumulated, moral issues—"*a question not of what sensibly exists, but of what is good, or would be good if it did exist*"—cannot always wait for rational decisions. In these cases one should be guided by one's beliefs. James distinguishes between true beliefs and fantasies by arguing that real belief is living (you care about it), forced (you must make a choice), and momentous (unique, irreversible, and with high stakes).

As engineers we are trained to think rationally in the way of scientists, and James eloquently explains why it can be very difficult to argue an engineering decision from personal beliefs:

> *When one turns to the magnificent edifice of the physical sciences, and sees how it was reared; what thousands of disinterested moral lives of men lie buried in its mere foundations; what patience and postponement, what choking down of preference, what submission to the icy laws of outer fact are wrought into its very stones and mortar; how absolutely impersonal it stands in its vast augustness, then how besotted and contemptible seems every little sentimentalist who comes blowing his voluntary smoke-wreaths, and pretending to decide things from out of his private dream!*

Yet I argue that it is in belief the differences between engineering and science emerge. Where science seeks truth, engineering seeks change. One of James' major claims is that when fully rational decisions are not possible we should be guided our beliefs, when science cannot guide action then truth becomes what you are willing to stand behind. Engineers make uncertain decisions and must be prepared to stand by them. Belief is implicit to being an engineer; what you believe directly influences the outcomes of a project. By being willing to stand by our belief, by having faith in certain outcomes, we help make these outcomes possible. Since beliefs guide actions and the actions of engineers affect others we must both acknowledge, yet be wary, of the power of our belief. Bridges built only from belief collapse, planes designed without the best rational science behind them fall from the sky, and engineering done even for the right reasons is often later seen to cause harm.

How then should an engineer walk the invisible, ever-shifting line between belief and rational decision making? First, do not substitute belief for the empirical methods of science when they are available. Second, practice humility, not hubris, by recognizing that what you know is only a small part of what is known. Seek knowledge as well as change, and realize that the social sciences, humanities, and philosophy have much to offer about how to do good in the world. Finally to trust your beliefs you must be willing to actively develop them and change them at need. Seek to understand where your beliefs originate and test them against the beliefs of others by becoming an active member of an intellectual community. James argues that we have the right to believe what we will, at our own risk, as long as our belief is living, forced, and momentous; but that we must respect the freedom of others to believe as they will. I would add to this that engineers also need to understand that the consequences of their beliefs are real, significant, and may be impossible to predict. As another famous engineer has stated, “The bottom line is that the things engineers do have consequences, both positive and negative, sometimes unintended, often widespread, and occasionally irreversible” [8].

In conclusion, this essay argues that implicit to definitions of engineering is not just technical prowess, but the assumption that the engineer knows how to work for the good of humanity and thus has a keenly developed moral philosophy. Given the complexity and interconnectedness of today’s world, it is becoming harder through rational means to know with certainty the outcomes of one’s actions, to make ethical engineering decisions, and address moral questions. Yet the problems faced by the world that will be solved by tomorrow’s engineers are fundamentally moral in nature, cannot wait for rational certainty, and thus must be guided by a living, forced, and momentous moral philosophy. To be able to act, except in the most narrowly technical fashion, requires that engineers develop a personal philosophy that is grounded in community since our actions affect others. The role of the university is not just to provide vocational training, but to serve as this community to hone one’s philosophy and discover our shared humanity. Wrapped in our own technological hubris and rational mindset engineers often fail to understand the extent to which our beliefs affect our actions and thus the lives of others. Although all actions have consequences, still we must act and in the final analysis engineers can make human choices because we are human.

"The thought manifests as the word;
The word manifests as the deed;
The deed develops into habit;
And habit hardens into character;
So watch the thought and its ways with care,
And let it spring from love
Born out of concern for all beings…
As the shadow follows the body,
As we think, so we become."

- *Dhammapada (The Sayings of the Buddha)*

[1] J. R. R. Tolkien, *The Lord of the Rings*. New York: Ballantine Books, 1954.

[2] Accreditation Board for Engineering and Technology, "Criteria for Accrediting Engineering Programs " Engineering Accreditation Commision, Baltimore 2008.

[3] C. Mitcham and E. Schatzberg, "Defining Technology and the Engineering Sciences," in *Philosophy of Technology and Engineering Sciences*. vol. 9, A. Meijers, Ed., ed Amsterdam: Elsevier, 2009.

[4] B. V. Koen, "Quo Vadis Humans? Engineering the Survival of the Human Species," in *Philosophy and engineering: an emerging agenda*, I. van de Poel and D. Goldberg, Eds., ed New York: Springer, 2010.
[5] M. Friedman. (1970, September 13) The Social Responsibility of Business is to Increase its Profits. *New York Times Magazine*.
[6] W. A. Wulf, "Engineering ethics and society," *Technology in Society,* vol. 26, pp. 385-390, 2004.
[7] W. James, *The Will to Believe and other Essays in Popular Philosophy*. New York: Longman, Greens, and Co., 1912.
[8] N. R. Augustine, "Ethics and the Second Law of Thermodynamics," *The Bridge,* vol. 32, pp. 4-7, 2002.