What is Engineering?

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INTRODUCTION

As a senior in high school, I was offered a full scholarship to university for an engineering program, which immediately yielded two reactions: 1) accept the offer, 2) figure out what is an engineer. The former reaction was easy; the latter has taken years of observation, study and experience to understand. Initially, I was able to ascertain that engineers were important, otherwise this sort of opportunity would not have been afforded me. The program was funded by a large company that was commonly known to create calculators, so technology in the form of electronic devices must be what engineers create. I thought to myself, "I'm going to solve the problem of carrying so many electronic devices in my school bag. Could I design a way to integrate my cell phone, personal digital assistant, camera, and calculator?" So, at 18, eager to start college to become an engineer, I was satisfied with knowing I'd be important and would design cool electronic gadgets. Not much of a foundation in understanding engineering as a discipline, but enough to motivate me to pursue it.

During my education, I had three internships (totaling 18 months) at the sponsoring company in three businesses in different geographic locations, and acted in two different engineering roles. I interacted with hundreds of people who did lots of different things; they all called themselves engineers and had business cards to prove it. Whether in marketing, sales, manufacturing, managing, or design, everyone supported the development, release, and maintenance of a product portfolio, ultimately striving for a bigger bottom-line. After finally graduating, and well into my career as an engineer, I was still struggling to wrap my head around what we as engineers did within this space of engineering. Though it seems I wasn't alone. One of the key reasons I couldn't define engineering is because the general public understanding of engineering, that which I'd frequently polled, was very different than what I'd come to learn and experience.

It seems my efforts to ultimately define and in turn establish a perfect little black box to carry this idea of engineering were futile. In reality, there is and should not be a rigid boundary defining engineering, but

instead a border around certain territories, or qualities of engineering, that remain flexible. As Gieryn discusses in his work on *The Cultural Boundaries of Science*, "boundary-work is strategic practical action (Gieryn, 23)." The 2008 report by the National Academy of Engineering, *Changing the Conversation*, addresses the need for improvement of the public's inaccurate perception of engineering. Perhaps the misconceptions are the product of forced boundaries. The evolution of engineering requires flexible borders that allow for subtle adaptations. By actively and strategically challenging the boundaries, we may potentially yield an improved public understanding of engineering.

Though my objective is not to define engineering, it is important to address some qualities and characteristics that will push on the current boundaries to increase awareness and understanding. First, I will discuss how engineering is different from science. The second part will address how engineering is a purposeful process of design that produces some artifact. And finally, I will describe engineering as a profession.

ENGINEERING IS DIFFERENT FROM SCIENCE

Bucciarelli quotes Theodore Von Karman, "Scientists discover the world that exists; engineers create the world that never was (Bucciarelli, 1)." Scientific knowledge and engineering knowledge can be nearly indistinguishable if one is merely comparing texts and other forms of information. This introduces a blurred boundary between the two. However, only "through consideration of what engineers *do* and what scientists *do* can one come to distinguish what engineers *know* from what scientists *know* (Bucciarelli, 47)." The process by which a scientist discovers and an engineer creates establishes an object world that is the knowledge of a particular domain. Science provides a theoretical sandbox for engineers to play, where they can, in a multitude of ways, apply existing theory and methods to design and create their castle (Bucciarelli, 70). Layton claims that "the cement binding the engineer to his profession [is] scientific knowledge," essentially branding the engineer in the sandbox an applied scientist (Layton, 58).

In Diana Forsythe's ethnographic study of an artificial intelligence (AI) team, she noted that there is debate on whether AI is science or engineering. Even though scientist John McCarthy, who coined the term AI in 1956, defined it as "the science and engineering of making intelligent machines," the engineers in her study identified themselves as scientists. (Forsythe, 43) Noble describes how science has in the past provided engineers their identity (Noble, p. 42). The result of the identity issue in the AI study is clearly a matter of boundary-work. Forsythe identified their work to be that of an engineer. Ultimately it doesn't matter what they call themselves. *A rose by any other name would smell as sweet*.[1] The difference is not in a name, but in the results. As science and engineering inevitably continue to battle over arguable congruent territories, the boundaries will be blurred because the two are intimately intertwined. Scientific knowledge informs engineering design, and engineering design provides for more scientific knowledge. Within this framework exists a proverbial circle of life.

ENGINEERING IS A PROCESS

The language of an engineer is "rooted in a particular scientific paradigm which serves as a basis for conjecture, analysis, testing, and designing within that world (Bucciarelli, 15)." Science and engineering use similar reasoning processes for problem solving; however, there are key divergences that separate the two. Constraints are common to both processes, but are fundamental to engineering design. Constraints may include cost, margins of safety, legal regulations, customer wants, aesthetics, ways of manufacturing, and maintenance procedures (Bucciarelli, 44). The idea of trade-offs, the balancing of constraints, is another divergence, as well as the possibility that there are multiple solutions. The basic difference between the two methods are: "scientists investigate and engineers create (NAE, 41)." Engineers develop plans or directions for how artifacts, or products, are to be constructed. "A product is in some measure material, made to fulfill some intended function, but it is better construed as a human creation which reaches out beyond the box it came in to enable and to affect our thoughts, our values, our beliefs as well

[1] From Shakespeare's *Romeo and Juliet,* 1594

as our practices (Bucciarelli, p. 5).” It is important to note that engineers most often do not make or build things, but rather design and develop the plans for another to build. Engineers may also design processes (NAE, p. 27).

The engineering design process is:

- Situated problem solving: “the subject that does the problem solving actually influences the very nature of the problem (Dorst, 6).”
- A social process; it requires exchange and negotiation of people (Bucciarelli, 21).
- Purposeful: a designer begins with a specific goal (NAE, p. 38)
- Systematic and iterative (NAE, 38)
- Creative in nature (NAE, 28)
- Optimization (Bucciarelli, 21), the testing and improvement of the design in a non-linear, iterative process.

Engineering is a purposeful process of creative design that produces a product. It is a process of being situated in an object world and using language to communicate a design. The characteristics of engineering as a process and the way it relates to other processes forces continued boundary work. The design process relates to the scientific inquiry process, and also shares similarity with the creative writing process. One can use the other familiar process models as a scaffolding to teach the engineering design process; however, the noted divergences are important and specific to engineering.

ENGINEERING IS A PROFESSION

In a report released in 2008 by the National Academy of Engineering (NAE), a new positioning statement was established as the conceptual foundation for a campaign to improve public understanding of

Engineering. This statement is not merely adjusting the previous boundaries, but is setting forth a new shape that is poised and ready for the borders to be adjusted as the needs of the 21st century lead.

> No profession unleashes the spirit of innovation like engineering. From research to real-world applications, engineers constantly discover how to improve our lives be creating bold new solutions that connect science to life in unexpected, forward-thinking ways. Few professions turn so many ideas into so many realities. Few have such a direct and positive effect on people's everyday lives. We are counting on engineers and their imaginations to help us meet the needs of the 21st century.

The NAE positioning statement highlights engineering as an innovative profession that impacts and improves lives, is an application of science, and is a profession that is needed to meet the demands of the 21st century. Engineering is a profession with many disciplines that each address technological innovations in social contexts, and Layton describes how engineers came to identify themselves in this space.

> "Engineers emphasized the importance of technological innovations" for the good of humanity to yield a social revolution. "***Social responsibility***, then, was a means whereby the group might gain power, independence, and social recognition (Layton, pp. 55, 62)."
>
> "Modern technology, as the mode of production specific to advanced industrial capitalism, was both a product and a medium of capitalist development. So too, therefore, was the ***engineer who personified modern technology***. As he strove to create a professional identity for himself, the engineer commonly tried to present himself to the public as ***technology itself***, the great motive force of modern civilization (Layton, pp. 33-34, 44)."

Engineers within different object worlds can engage in numerous tasks or roles such as design, research, product development, manufacturing, project management, sales, or teaching. (Bucciarrelli, p. 44) In Layton's discussion of the evolution of the engineering as a profession, he identifies the tension between a practicing engineer and an engineer has advanced to a managerial or business role. He articulates that those in charge of engineering work are in some sense professional engineers, so this idea of "responsible charge" is a common denominator between the engineer and the businessman. "Responsible charge" is a compromise which orients the engineer toward both his profession and his employer. "Creativity" tends to ally engineers with science rather than with either business or engineering. (Layton, p. 27 -28). Therefore by Layton's definition, an engineer can be a businessman or a manager, but a manager or businessman can't necessarily be an engineer. This introduces the idea that the transferability of engineering skills is higher than other professions (such as business, marketing, etc.) and can provide greater flexibility in one's career.

Engineers stand as society's role model of rational, instrumental thinking; however, over-confidence may often shadow judgment (Bucciarelli, p. 38). An interesting quote from a TV show that aired in October 2009 on ABC supports this notion:

> "He's an engineer. Many of them are like this… Convinced that in two weeks [he] can take a problematic, mistake ridden, advanced technical project to a working prototype stage. [It's] a case of confidence and drive overwhelming practical judgment."
> - *From ABC Television show, NUMB3RS*

Bucciarelli claims that engineers are responsible for the development of technology (Bucciarelli, p. 3), though Layton explicitly says that not all engineers are designers (Layton, p. 27). It is true that not all engineers may be practicing as designers, but designing is a cornerstone to an education in engineering. This leads to Bucciarelli declaration that engineers need knowledge (Bucciarelli, p. 45). As previously stated, scientific knowledge informs engineering design. In order to design, you must have a foundation

of knowledge. Engineers should have a balance of theory (most often from a formal university setting) and practical knowledge. Engineers must have a good grasp of how systems work and the factors that influence the performance of the system. Engineers must be *comfortable* with math such as: modeling & predictive analysis, statistics, graphical data description, data analysis, etc. (Engineering K-12) From a practical perspective, experiential, hands-on learning is important as well as the following traits: work well in teams, communicate ideas effectively, understand other cultures, understand effects of technology on societies and individuals, and flexible (able to respond quickly to emerging challenges). Bucciarelli also states how engineers are to be multidisciplinary and able to work in teams (Bucciarelli, p. 4).

CONCLUSION

As I consider my first introductory understanding of engineering, I remember finding it too simple. I struggled to pack the idea into a smaller and tighter box, but always struggled to close the lid on a final definition. In this exercise, I've determined the best solution was to dump everything out of my crumbled box and throw it away (in the recycling, of course). In summary, I tie back to my initial assumptions of what is engineering and who are engineers. Engineers are important. They create the technology all around us, and design things that can make like easier and more convenient. I wasn't the one to create the integrated device I dreamed of at 18 years old, but I now have one that surpassed my imagination, and honestly never leaves my side. Engineering is a socially responsible profession that is broad in scope as it spans so many disciplines. Engineers are creative problem solvers with an educational foundation in sciences, math, and theory. I am an engineer, and very proud to be a member of the engineering profession. I am even more proud and honored to be a member of the community that is challenging the boundaries of engineering and leading initiatives for change.

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