BECOMING AWARE OF ENGINEERING CULTURE: TOWARD SCULPTING A MORE HUMAN IMAGE OF THE ENGINEER

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Abstract – In this paper the problem of “engineering culture” is explored through the lens of Cultural Anthropology. A literature review of papers which have examined engineering culture in various university environments was conducted and preliminary conclusions drawn. Anthropologists define culture as how groups and individuals respond to dominant images. Of the various images in the literature, the image of the engineer as “problem solver” is most helpful in diagnosing the issues with engineering culture – a culture that has been found to lack in promoting self awareness, political awareness, understanding perspectives of others, and hearing marginal voices. A proposed new image of the engineer as a “problem solver and problem definer” helps move engineering educators toward the practice of teaching problem definition in core technical courses so that a new culture can be sculpted; one that encourages political and self awareness, understanding others’ perspectives, and the ability to listen to traditionally marginalized voices.

Keywords: culture, cultural anthropology, curriculum, engineering studies, self-awareness, marginal voices

1. INTRODUCTION

The conception of this paper began with an informal conversation about the issue of engineering. We asked the question of one another, “Why is there an issue with regards to gender and diversity in engineering, and what is the cause? Does ‘engineering culture’ influence how gender and diversity is thought of and reacted to by engineers?” [1] The content of this paper is the research that followed this question. In the following sections we will define the concept of culture in anthropological terms, explore various conceptions of engineering culture, and finally suggest what we as Engineering Educators can do to improve engineering culture in our contexts.

2. DEFINING CULTURE

To delve into the issue of culture we need to use the tools of anthropologists: how do they define and understand culture? Martin defined culture as “ways of acting, thinking, and being in the world” [2]. Although the history of the understanding of culture could be a paper of its own, an important development is the significant shift that has been made in the understanding of what culture is in the anthropological community. In the past said communities (and perhaps most laypeople today) had thought of cultures as groups of people who share the same beliefs or assumptions about the world [3]. Using this definition was helpful in understanding differences in the way people lived in different parts of the world; however, it became a hindrance when trying to understand differences within a particular culture. Dividing a world into smaller and smaller subcultures becomes overly complex and the practice then has limited usefulness in helping humans understand one another better [3]. Such an approach has been abandoned for the idea of defining a culture by its “dominant image” [3]. The idea of the dominant image helps people understand one another in terms of how they respond to the same or different dominant images [3].

3. DOMINANT IMAGES

Given that to understand culture one must understand the key images that dominate that culture, what does that mean for engineering? Table 1 is a survey of various authors who presented what they believed to be dominant images in engineering. However, many of the writers were not necessary concerned with the “remedy” of the situation so did not explicitly state what an alternative image could be or how one would achieve such an image. Other authors did explicitly share what positive alternative images could be but not precisely how said images might be developed. In these two cases the authors noted in the table if there was no explicit image or remedial action proposed and instead described the image and method of remedial action that seemed to be in the spirit of the initial critique.

The papers and books reviewed were almost exclusively written by anthropologists and/or sociologists, historians, and engineering educators or engineers. The authors summarized varying dominant images into five images as shown in Table 1. The first three images are those posited by anthropologists and sociologists; the fourth is from historians, and the last from engineers (see next page).
Table 1: Proposed Dominant Images, alternative images, and methods to achieve alternative images

<table>
<thead>
<tr>
<th>Image</th>
<th>Proposed alternative image</th>
<th>Method to achieve new image</th>
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<tbody>
<tr>
<td>The “macho” technophile middle-class white male with few soft skills “defending” his profession from “invaders.” [4] [5] [6] [7] [8]</td>
<td>Engineers as curious and creative people who turn ideas into reality [9].</td>
<td>“Clear, consistent, and highly coordinated actions at all levels of management” to recruit and retain more people from marginal populations [4].</td>
</tr>
<tr>
<td>Believers that technology in and of itself will solve key social problems [10] (scientists and engineers) as well believers that technology is value-neutral [11] [12] [13]</td>
<td>Technically adept persons who are aware that their creativity and hard work are required to truly make technology successful [10].</td>
<td>(Not Explicitly Stated) Self-reflection and self-awareness.</td>
</tr>
<tr>
<td>Engineer as technical problem solver [3] [14].</td>
<td>Engineer as problem definer and problem solver [15].</td>
<td>Showing how problems can be defined in multiple ways by multiple stakeholders in engineering science courses. [8] [15].</td>
</tr>
<tr>
<td>Engineers as aloof to their role facilitating the dominant classes remaining dominant [13] [16] focussed rather on struggling between identity as business person or professional [5] [17].</td>
<td>(Not Explicitly Stated) Engineers as those who work for societal good; help society use technology responsibly.</td>
<td>(Not Explicitly Stated) Seriously challenge the current political and economic system.</td>
</tr>
<tr>
<td>Dependable, thorough, consultative, evidence-based, concerned with public safety [18] renaissance man (sic) [16].</td>
<td>The renaissance man (sic) [16].</td>
<td>More positive media portrayals of engineers [16].</td>
</tr>
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</table>

The anthropological and sociological descriptions are convincing. The papers in Table 1 give evidence to suggest that engineering indeed is disproportionately masculine, white, and middle class. Engineers seem to be technophiles who believe that technology is inherently good yet they are paradoxically unaware that they are the agents who are tasked with the very difficult job of integrating technology into society. Lastly, engineers are described as problem solvers who think little about who they are solving their problems for. This last description overlaps with historians who critique engineers as servants of the dominant class in society. They do solve problems, but they are at the disposal of those with significant power (corporations) and do not have much ability to slow down or stop misuse of that power. The last descriptions are from engineers who paint themselves in a positive light as good practitioners of science who produce useful products for the public good. Although somewhat defensible, this simplistic view of engineering does not address the critical points made by anthropologists and historians.

What do we as engineering educators do in the midst of these valid critiques? The reader would likely agree that all the alternative images in Table 1 are positive as well as the method through which to achieve them. Which image(s) and method(s) should we choose to move forward with? The authors would argue that from an engineering education perspective that one image stood out above the rest: the image of engineer as problem solver. This may be surprising as it seems overly simple; perhaps even simplistic. Far from crude, the authors believe that it is sophisticated in its simplicity. The following paragraphs make the case for using the image of “problem solver” above the other images described in Table 1 as an aid in facilitating fruitful change in engineering culture.

The authors believe that what is offered by the other images can be incapsulated in the move from “problem solver” to “problem definer and solver.” Downey et al. were responsible for developing ethnographic studies which helped them uncover the image of the problem solver and pursue it in depth for the purposes of exploring an alternate image that would remedy some of its negative consequences; something none of the other authors were precisely aiming to do. The goal of the scholarship in the

2 Downey states that his unique approach “…avoids the comforts of resolute pessimism but risks the dangers of co-optation.” [14] In other words, Downey was not content to create a work only critiquing engineering culture but is also aware that any work that attempts to change the way engineers are educated can be used in such a way that it does not work to change the status quo but only further maintain it. We believe engineering educators must take this risk, since, as engineers we are
study of engineering as “problem solving” and toward “problem solving and definition” was done in order to help achieve almost all the goals as stated in Table 1: to change teaching practices so that students would become more politically critical and self-aware [14]; to understand perspectives other than one’s own and value those perspectives [19]; and to address the “weeding out” of students from marginal populations by including more in the development of “soft skills” in the core curriculum in addition to the highly technical content [8]. The next section explores in a more in-depth way the image of the problem solver, how it helps to encompass the various characteristics observed regarding engineers in the above literature, and how moving toward problem definition should help. (It is important to note that the method of addressing gender and diversity issues suggested in the first row of Table 1 by [4] should not be ignored. Universities should make a concerted effort change the culture with a “top down” approach (recruitment, policies, etc.). These are crucial strategies that administrators in our engineering schools should be aware of and implement with vigor. However, such strategies are outside of the scope of this paper. This paper aims to provide instructors with the tools necessary to help change engineering culture with teaching practice while our colleagues are working to ameliorate the issue with other strategies.)

4. THE IMAGE OF “PROBLEM DEFINER” ACCOUNTS FOR KEY CULTURAL PROBLEMS

At this point it may serve as a good reminder that although we could view the above discussion as mainly a summary of unsavoury characteristics of how engineers “act, think, and be” in the world we are not defining culture as a collection of those actions or beliefs. We think of culture as how a group of people reacts to a dominant image. Rather than asking what may seem to be the more natural questions such as “how might we change various beliefs in the engineering community?” we may wish instead to ask, “what is the dominant image of the engineer and how might it be changed?” As stated above, Downey in many papers has argued the dominant image of an engineer is that of a problem solver [3] [14] [8] [15]. This image is helpful in that it is a single unifying concept that can help us understand where some of the common behaviours seen in engineers and engineering students may have come from. Instead of thinking of engineering students as a group of people who just happen to believe certain things about the world, we can think of the more dynamic interplay between challenge and response of an image that demands the attention of a particular people-group.

The reader may be asking if the image of the problem solver really helps to encompass most of the characteristics described in the literature. Consider the following observations from various anthropological studies in engineering.

Engineers were observed to be consistently and repeatedly over a period of years “programmed” in a machine-like way to follow a strict problem-solving process that will promise tangible results (the right answer) [8]. The negative characteristics described by other authors may indeed be ways individuals and groups are coping with the challenge of the image of the engineer. Such an image may be encouraging students to put on a “macho” veneer, to never admit defeat, to defend their work no matter what the cost as described in [7]. A pure “problem solver” is one step removed from a machine – could it be that successful engineers have tried so hard to conform to this image that they have become machine-like: anti-social, seeking to minimize communication with others, and apparently preferring the company of technology to humans? [3] [6] [7] [20]

Being machine-like has some positives but there are human costs associated with increased efficiency and productivity. Ethnographic studies expose such costs: engineering students feel the need to make themselves become “invisible” [8]. Human practitioners feel that in order to be a “good” engineer they must hide the human elements of themselves – especially their feelings [3]. They must contort themselves into the particular shape provided by the curriculum, have machine-like habits, and consider the “other self” as distinct from and subordinate to the “work self” [8]. Downey, trained initially as a mechanical engineer, states the conclusion of one study bluntly: “Learning problem solving is precisely about making the bulk of ones identity invisible in one’s work” [3].

The engineering faculty member may be well versed in the idea of a “weed out” course: a difficult course in terms of content and workload that separates those who can succeed in the face of adversity from those who

3 Leonard [7] points out an interesting example of a non-technical engineering book that sought to help engineers navigate the human dimension of engineering by explaining human-to-human interaction in terms of apparently easier-to-understand (perhaps more “logical”) actions of computers [20]. In a similar vein Kleif and Faulkner explore the male “love” for technology and surmise that perhaps the dependability and certainty of technology attracts said demographic [6].
cannot. Downey and Lucena observe that even if students are not “weeded out” part of their humanity is [8]. Engineers are thought of as round pegs made to be shaped into square holes: their habits must be machine-like – even fun must be had “efficiently” [19]. Emotions are not valued in problem-solving process as it is taught now; nor is much else besides studying technical concepts. If one wishes to pursue something else at the same time (e.g. one student was passionate about dancing), then there comes a point at which the student must choose to pursue one or the other [8]. Oldenziel argues women have had to conform to male models of what a professional engineer should be rather than more naturally filling the role in ways that were appropriate given their identities [5]. For example, to be respected as a true engineer Lillian Gilbreth’s had to be more qualified, self-reliant, and hard-working than her fellow “Sons of Martha” [5]. Similarly, African-American students were told by an African-American corporate recruiter that they should be careful about appearing “too black” on their resumes; he was suggesting that they should think of themselves as engineers who happen to be black and not black engineers [8]. The contrast of this strict impersonal work versus life identity is stark when compared with other professions such as law or medicine [8].

In summary, Downey and Lucena make a claim that the “engineering self” is meant to be the primary identity of a person at the expense of any other identity; they also make the equally pointed claim that it is easier for white males to accept this demand than any other demographic [8]. They argue that, of any segment of the population, the personal identity of the white male is more likely to overlap with the desires to fix/tinker with mechanical things, seek upward mobility, and minimize the use of emotions in their work life [8]. So far then, in this paper the authors have argued that “unsavoury” aspects of engineering could very well be in large part due to the current dominant image of the engineer – the problem solver. To conclude this section we propose the problem with the image of the problem solver is that it forces engineers to divorce their humanity from their work and favours white middle-class males entering the profession over other groups [5] [8]. Engineering educators may be unwittingly asking their students to become like Charlie Chaplin in “Modern Times” causing the students to feel their humanity being forced to conform perfectly with the modern assembly-line way of life [21]. How can one be an effective, reliable, consistent, low-variability, and an efficient cog in a corporate wheel unless he or she brings as little of his or her humanity to the world as humanly possible? We are convinced that this image must change if engineering is to transform into a more wholistic profession that can have a greater positive impact on society. Before we explore how we as engineering educators may influence engineering culture for the better we will offer one example of how we have seen the negative effects of the image of “problem solver” in our own experience.4

Students in Engineering Economics were given an exam problem detailing the costs and benefits placed before Ford in the 1970s with regards to what to do about the Pinto’s exploding gas tank. They were given realistic data that Ford itself was using at the time and asked to decide on a course of action: should they decide to fix the fuel tank at a cost of approximately “x” or decide to simply pay any legal damages at a cost of “y” (with y<>x)? The question was not explicitly labelled an ethics question (although ethics routinely came up in the course) but appeared like the other computationally-heavy questions on the exam. During the next lecture it was revealed to the class that they would lose marks if they decided to produce an inferior product and risk being sued only because it was less expensive. The news was not taken well. Many students were upset and thought it was not fair to ask an ethics question in a technical course. “This is an economics course, not an ethics course!” one student exclaimed angrily. This notwithstanding, the Instructor did remind them the night before the exam to review the ethics chapter of the course and the question itself asked what their action should be a as a “professional engineer” thus suggesting that they should be thinking in terms of the Engineers Canada code of ethics.5

One student spoke to the professor after class and shared her reflection on what had happened: she said that she did not feel that she was allowed or that it was appropriate to choose the ethical option. She felt that she was forced to choose the cheaper option and that the context of the computationally-heavy exam meant that all other aspects of a question should be “externalized.” That, in other courses these sorts of details were not important. Our interpretation of this event coincides with the literature: that the dominant image of a true engineer

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4 Another concept that the authors feel is helpful in describing the conflict between our humanity and the image of problem solver is the idea of the Heisenberg uncertainty principle. This idea is that it is impossible to measure both the velocity and position of a sub-atomic particle at the same time. Any attempt to do so will render the calculations invalid [30]. This truth causes anxiety in the engineer who is supposed to somehow be invisible in his or her own work – how can one be invisible if the very nature of the work (e.g. precisely measuring scientific metrics) is obscured by one’s presence? This scientific reality and the image that suggests the engineer should be “invisible” are irreconcilable concepts and have forced the authors to conclude that engineers ought not be invisible after all.

5 Note: when students were shown the crash-test video (available on YouTube) of the Pinto most of them ceased to complain about losing 2 points (8%) on their midterm exam.
seems to encourage us to make our human selves scarce at the risk of becoming less than human.

This reaction of making oneself invisible is in stark contrast to the Arts and Social Sciences where the person/individual is prized as a source of knowledge – that if one knows oneself then they become a better actor, thinker, or doer in the world. In these academic contexts seeking to become a whole human being is encouraged rather than discouraged [3] [8]. Could engineering benefit from an image that allowed for a more humane and human image of the engineer?

5. SCULPTING A NEW IMAGE

Where then do we go from here? How can we imagine new images, and if we do, how can we begin to shape them? What do we want engineers to be – what should they be? Whom should they serve – perhaps not the status quo? The Engineers Canada code of ethics states that the ultimate priority for an engineer is to “Hold paramount the safety, health and welfare of the public and the protection of the environment, and promote health and safety within the workplace” [22]. Initially, this image appears superior to that of the “problem solver”; however, there is always the question of “how.” How can engineers become leaders of society for societal good from various walks of life? Can we imagine engineers as key leaders in municipal, provincial, and federal politics – those who know how to solve well-defined technical problems [8] [19]. After five years of this activity, why are we surprised when students resist doing anything else? A study of engineering students who were in their senior-year design course showed that students typically expressed great resistance in “thinking outside the box” [19]. It seemed very difficult for them to try and get out of the “just-solve-the-problem” mindset and get into the mindset of a group of people who were faced with an open-ended problem where the exact procedure to solve the problem was not yet known [19]. The students appeared very uncomfortable in the face of amorphous problems. For perhaps the first time in their four or five years of study they were presented with a complex and real-world issue that was not well-defined and had many stakeholders.

The way that the observed students coped was to continually ask authority figures until they were given a clear task. In the absence of this, they would turn a suggestion from an authority figure into a directive and complete those tasks frustrated that they were not using their technical skills they way they thought they were supposed to [19]. As engineers who went through this process ourselves these descriptions resonate with the authors (and perhaps also the reader) as true-to-life. Is it fair for us to expect much different from undergraduates given they are rewarded again and again over a period of years for following precisely various well-defined methods of solving well-defined problems? Do they feel in their last year of study they are all-of-a-sudden asked to be a different sort of engineer?

Downey and his colleagues’ response to this was to develop an elective course called “Engineering Cultures” where he introduced engineering students through the definition of an engineer in different geographic locations and over various periods in history [3] [24] (access lectures here [25]). This course, which contained much self-critical reflection, resulted in evidence that suggested students who took the course were able to listen more effectively to people different from themselves and understand better the human dimension of engineering work [24]. Downey concludes however that he believes that the approach of exploring the idea of problem-definition and listening to various perspectives would be far more effective if that approach were included in most if not all engineering science courses [3] (in addition to design courses). He confesses that as an “outsider” his influence is limited and including such an approach in an elective only serves to further silo the human dimension of engineering from the technical.

Downey and his colleagues suggest the best next-step in this “problem” of engineering culture is to begin to re-cast the engineer not just a problem solver but also one who defines problems [3] [14] [15]. Although a rather simple idea, Downey suggests the practice of entering into the problem-definition space is more complex than it seems and can significantly disrupt the current image and its negative consequences. When students were studied it became evident that the day-in day-out activity of an undergraduate engineering student is almost exclusively

6 The most recent article of the MIT Technology Review has an article entitled “What I learned from the People who built the Atom Bomb.” The author (US Secretary of Defence from 2015-2017) suggests that “technologists” have a key part to play in making sure technology is used wisely and for the good of society [31].
6. PRACTICAL IMPLICATIONS

What then can we do as insiders who care deeply about engineering education? The initial steps to make change in engineering culture are within our grasp: to begin to include the more human side of “problem definition” in our courses as much as possible. Although it appears simplistic, the research suggests that adding the task of “problem definition” to engineering science courses can begin to dismantle the image of pure “problem solver” that brings with it challenge of creating a culture hostile to persons who are not white middle-class technophile males. The authors believe there is convincing evidence to suggest that expanding engineering teaching practice to stress problem definition can result in the production of politically and self-aware engineers who are able to listen to and understand the perspectives of traditionally marginal voices [8] [14] [19]. It is our hope that changing the pedagogical approach in this way will lead to a more welcoming environment to the women and other underrepresented groups that currently feel unwelcome in the engineering profession [4].

7. CONCLUSIONS AND FORTHCOMING WORK

This paper has sought to provided a framework for understanding the idea of engineering culture and some of the current aspects of the culture that must be changed if engineering is to become a richer and more humane field of study and practice. To move forward there is much work to be done to understand precisely how curricula can be changed so that engineering students truly are encouraged and allowed to express their human selves and integrate these into their work for their benefit and for the benefit of society.

In the future the authors plan to follow up this initial literature review with (1) an exploration of best practices in bringing problem definition into particular engineering science courses, and (2) methods of assessing how such changes may be positively influencing engineering culture.

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8. REFERENCES


[23] J. Schneider, "Engineering and the values of social justice".


