GENERATING JUSTICE THROUGH NORMS, DESIGN AND STANDARDS (or what to do after you fall out of love with Moore's Law but still love math)

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Abstract. This paper describes the curriculum for my one credit engineering course on "engineering social change". The course empowers engineering students to enable generative justice through engineering norms, engineering design, and engineering standards in their organizations, communities, and teams. I developed this curriculum over six years and have taught it twice to a total of approximately 74 men, women and non-binary persons. The curriculum walks students through the constraints of the average corporate engineering workplace (in terms of norms and ideologies) and different design theories and practices engineers can follow in enacting social change. This curriculum emphasizes contextual (anti-sexist, anti-racist, anti-ableist, and anti-transphobic) engineering design, it also touches on collective actions of engineers to create social change. Ultimately, I use 15 weeks to help students realize that to enable generative justice, they must do four things: (1) realize that technology is not neutral but biased, discriminatory, and extractive; (2) shift their ideologies or mental models from corporate-interests to public-partners; (3) understand how normal users are overlooked through status quo design-practice and how these users' motivations and situations can be incorporated into designs; (4) consider when technical standards and classifications should be responsive to social and environmental pressures.

Keywords: *generative justice, PLACE norms, traditional engineering ideology, gendered innovation analysis, persona spectrum, Black-centered design, design standards, performance standards, classification.*

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1. Introduction

As a student who loved math, I felt an intense (but implicit) pressure from parents, peers, and teachers to utilize my knowledge and skills to change the world – while also making a lot of money. I was fascinated by microelectromechanical systems and Moore's Law, represented by an exponential curve where the world's computing power doubles every two years (Moore, 1965). I wanted to be a part of the fascinating technological changes that come from the imaginations of engineers, other designers, and users. Plus, there is not necessarily anything wrong with making a lot of money – as long as one is not naïve about balance. This question about balance is why we individuals organize ourselves into communities, regions, and nation-states with governments: so that we have a forum to ask questions and make decisions about who or what loses and gains, and who or what is represented or voiceless.

Returning to Moore's law, a democratically organized capitalist society might ask whose resources and labor makes the doubling of such computing power every two years viable, and who produces the answer to this question. If you look around for examples from nature, there is no plant or animal that can eat all of its food, kill many of its cousins, have an exponential birth rate, and take over a space without consequences to its environment and its species. Yet, we somehow believe that an exponential growth rate in technology, orchestrated by a few monopolizing Big Tech companies, is not only reasonable but exciting and enviable. Granted, Gordon Moore was referring to the number of transistors per silicon chip, so in that sense there is no material increase (just increasingly small transistors). But we all know this is only exciting because of the things we envision being built from the chips: robots, microsurgery, driverless cars, the sci-fi future. In retrospect, my excitement about Moore's law as a twenty-year-old seems entirely naïve. The bottom line is that balance is necessary, and if we do not participate in striving for particular types of change, then change will still occur without our preparation or our consent (whether you believe in God, other deities or are an atheist). This is not just true for people and the planet (i.e., climate change) or people and inequality (i.e., revolution). It is also true for people and technology.

Technology design, development, and diffusion into a society (thought of as the domain of engineers and other technical professionals) is equivalent to technological change. Technological change is closely related to social change[1]. As an engineer, I believe that technological change is beautiful, but as a social scientist, I also recognize that societal implications of technological change, especially unanticipated consequences, are inevitable. Therefore, engineers and other technical professionals must pay careful attention to how and why they conduct their work so that they do not reinforce status quo inequality. Even for engineers who want to participate in socially just change, their first exposure is likely to be limited to readings on some of the minor amendments common to technical literature on environmental sustainability and social responsibility:

- work for firms with the B corp™ designation whose vision aligns with social responsibility;
- create products that are cradle-to-cradle certified™ to meet specific standards for environmental sustainability and the circular economy;
- construct buildings that can be certified as meeting LEED™ standards for energy conservation and environmental conservation;

These are important and useful actions to take but do not yet get at the heart of the engineering profession, its ideological orientation, and goals. Therefore, it is hard to understand why these concrete action items might, eventually, move us towards generative justice. Generative justice is defined as "The universal right to generate unalienated value and directly participate in its benefits; the rights of value generators to create their own conditions of production; and the rights of communities of value generation to nurture self-sustaining paths for its circulation"(Eglash, 2016, p. 255). Therefore, it's the idea that instead of extracting and transferring value out of a particular community, we can participate in circulating value within the local community, and this includes within the local ecology (the “generators” are not limited to humans).

[1] Here, I am not subscribing to technological determinism as the sole organizing force of society. Instead, I am suggesting that because of the interconnectedness of people to artifacts, policies, regulations, ideologies, and social norms within a socio-technical system (see Geels & Schot, 2007), one cannot contemplate the design and maintenance of technical artifacts or systems without simultaneously considering how they are both shaped by society and change society.

This paper asks: how might engineers put generative justice into action? Where does the role of engineers begin? Engineers are responsible for creating artifacts that extract value. Eglash (2018, p. 75) has previously suggested that "the destructive force of artifacts is immune to politics." By this, he means that the political-economic system, whether socialist or capitalist, often has little to do with the destructive qualities of technology. He justifies this by demonstrating the similarities between how these political-economic systems develop and use technology: while striving to extract labor value from workers, each political-economic system also extracts ecological value from nature and expressive value from individuals or communities. In socialism, this extracted value is returned to the state and is wielded by powerful politicians, while in capitalism, this extracted value returns to corporations and is wielded by powerful shareholders. Meanwhile, their impact is similar: the conditions for many workers in society are unsafe and/or unenjoyable; while providing minimal compensation. In his own words, "radioactive waste left over from the USSR will kill you just as fast as General Electric's radioactive waste in the US"(Eglash, 2018, p. 75). One argument that might be made is that, in each political-economic system, the indifference of elites means that the public masses suffer.

However, by saying that the destructive force of artifacts is immune to politics, I believe that Eglash is gesturing towards three arguments within technology studies: that artifacts have embedded politics (Winner, 1980), that artifacts are wielded by the powerful for political purposes (Hård, 1993), and that artifacts, once well-established in society, are harder to change (Collingridge, 1980). Thus, instead of emphasizing the authority of the political-economic system that commissions and implements technologies (including products, software, and infrastructure), Eglash's implicit argument is that technology's destructive capacity is embedded in its design.

Technologies have embedded scripts that control user behavior (Akrich, 1992). Similarly, technology's destructive force is also embedded by design: deskilling workers; changing craft labor to repetitive tasks; replacing human labor with machine labor; amassing negative environmental impacts; and increasing environmental health harms of marginalized laborers. Engineers are responsible for technology's destructive force because we have not carefully considered how to design otherwise. Meanwhile, the destructive force of technology is useful to the power elite in any political-economy that emphasizes extraction of labor, and thus is developed in every political economy. Eglash's solution is to level power relations by striving towards a different "generative economy: “leave value in unalienated form, and circulate it through a commons"(Eglash, 2018, p. 77).

An important next question therefore is: if past technology was designed to be extractive, how can we design it otherwise? Or to rephrase, what is the role of technology design in a generative economy? Expanding upon these earlier arguments in technology studies, I suggest that technology design has three roles in a generative economy: (1) to embed the ideology of non-extractive technology into artifacts (2) to involve marginalized people in controlling technology; (3) to establish new standards for circulating unalienated value locally.

To clarify how those goals can be articulated in the engineering context, let me start by describing a one-credit capstone course I teach entitled "Engineering Social Change". This is held for the *Women in Engineering Program* at the University of Maryland (about 74 students per class). Just to be clear, this is not “social engineering” in the sense of the latest techniques for psychological manipulation; it is engineering for liberation. I first started dreaming up this curriculum at Michigan State University in 2014 in response to the police shooting death of unarmed high school graduate Michael Brown (St. Louis, MO), an 18-year-old future maintenance technician and business owner (Crouch, 2014). This curriculum is for engineering students who want to know how they can marry their love for math, and their need for a livelihood, with their love for people, social justice, and environmental sustainability.

Many such students are appalled and confused by what they hear about in the news in terms of racist policing and health insurance algorithms; racist and sexist health instruments and facial recognition algorithms; racist stormwater, transportation, and public sanitation systems; sexist, homophobic, and ableist mobile phone apps; and transphobic airport security systems. However, this curriculum is also for students who don't care about the news and don't understand why, as engineers, they should have to think about societal impacts or ancient history. I held both perspectives at different points in my early academic career, and I appreciate the challenges in bridging that gap.

Those bridges in my career (and thus in my class) come from the field of science and technology studies: first that technology is not neutral (Balabanian, 2006; Winner, 1980), and second the specific means by which technology discriminates (Benjamin, 2019; Hård, 1993; Hess *et al*., 2016; Wittkower, 2018). It is my perception that students likewise enjoy learning that there are different ways of thinking about technology development and change that intertwines their interest in technology design with helping people, helping the environment, and being economically self-sufficient.

The women, men, and non-binary students in "Engineering Social Change" learned about three ways any engineer intervenes in a socio-technical system. I taught that engineers intervene through design/maintenance, standards-setting, and engineering ideologies & norms, and they do so typically in places such as professional teams, professional standards committees, daily engineering practices, and engineering activism. In particular, I underscored exploring with the students how engineers can create social change with a strong emphasis on design. Below, I have annotated my curriculum (see Table 1). Despite the evidence of humanity's progress, students are often skeptical that transition to a truly generative society is even possible. Understanding some of the conceptual barriers for these young engineers is therefore of critical importance.

Table 1. Curriculum for one credit class "Engineering Social Change" created by Logan D. A. Williams

Week	Topic & Introductory Reading/Video	Intermediate Reading
1	Course Introduction; No Readings/Videos Due	
2	Engineering Problem: **Ethics of New Technology** **Watch Before Class:** *Coded Bias*, Netflix	
3	Engineering Social Change: **Ideology &Norms** **Read Before Class:** Robbins, Peter T. (2007). "The Reflexive Engineer: Perceptions of Integrated Development"	Karwat, Darshan M. A. (2019). "Self-Reflection for Activist Engineering."
4	Engineering Problem: **Sexist Design** • **Read Before Class:** Dryburgh, Heather. (2002). "Learning Computer Skills." • **Watch Before Class:** Cornelia Brunner, Google Talk –(April 6 2006). "On Girls, Boys and IT Careers", YouTube	Oudshoorn, Nelly, Els Rommes, and Marcelle Stienstra. (2004). "Configuring the User as Everybody

5	Engineering Social Change: **Anti-Sexist Design** **Read Before Class:** Schiebinger, Londa, and Schraudner (2011)."Interdisciplinary Approaches to Achieving Gendered Innovations in Science, Medicine, and Engineering."	Rommes, Els. (2013). "Feminist Interventions in the Design Process."
6	Engineering Problem: **Racist Design** **Read Before Class:** Hankerson, Marshall, Booker, El Mimouni, Walker, and Rode. (2016). "Does Technology Have Race?"	Benjamin, R. (2019). Default Discrimination. In *Race after technology* (pp. 77–96)
7	Engineering Social Change: **Anti-Racist Design** **Watch Before Class:** Eglash, Ron. (2007). *The Fractals at the Heart of African Designs*	Eglash, Ron. (2016). "Of Marx and Makers: an Historical Perspective on Generative Justice."
8	NO CLASS	
9	Introducing the Final Assignments; No Readings/Videos Due	
10	Engineering Problem: **Ableist Design** **Read Before Class:** Ebner, Victoria. (2019). "Many Buildings at UMD Aren't Accessible. This Student Made a 43-Page Report to Track Them."	Moser, Ingunn. (2006). "Socio-technical Practices and Difference: On the Interferences between Disability, Gender, and Class."
11	Engineering Social Change: **Anti-Ableist Design** • **Read Before Class:** Shew, Ashley. (2018). "Different Ways of Moving through the World." • **Watch Before Class:** Holmes. (2019). *Rethink What Inclusive Design Means.* YouTube	Holmes, K. (2018). There's no such thing as normal. In *Mismatch* (pp. 91–113)
12	Engineering Problem: **Discriminatory Standards** **Read Before Class:** Costanza-Chock, Sasha. (2018). "Design Justice, A.I., and Escape from the Matrix of Domination."	Costanza-Chock, S. (2020). Introduction. In *Design Justice* (pp. 1–24)
13	Engineering Social Change: **Liberatory Standards**	Costanza-Chock, S. (2020). Design values: Hard-coding liberation? In *Design Justice* (pp. 47–68)
14	NO CLASS; Work on Final Assignments	
15	Course Wrap Up	

2. Ideology of non-extractive technology should be embedded into the design of artifacts

"The universal right to generate unalienated value and directly participate in its benefits"(Eglash, 2016, p. 255)

Any engineer intervenes in a socio-technical system through their ideologies and norms carried out in their daily practices of work. An ideology is a set of beliefs or worldview that shapes your perspective. Typically, corporate interests shape new innovation around bandwagons and blockbuster innovations (Williams, 2017). In comparison, generative justice as an ideology might be both productive (in terms of a sharing and circular economy) and less extractive if embedded into technology design.

Ideology can be embedded into technology because artifacts have politics: technologies can make decisions for a community, or can organize a community democratically or autocratically (Winner, 1980). Examples of ideology embedded into artifact design include: "free participation" and the third person "neutrality point of view" (journalistic objectivity) in Wikipedia; "openness" and "transparency" in government data-sharing initiatives; and "sharing values, resources, and saving money" in a collaborative housing design project (Détienne *et al*., 2019). Ideology is related to engineering culture because typically, folks in the same culture tend to share the same ideology, although this is not always the case.

Engineers exist in different cultures with their own political regimes that control design, standard-setting, and freedom to dissent (Downey & Lucena, 2005). In France, engineering knowledge is mathematically-based, and engineers typically work for the government and have very high status (Downey & Lucena, 2005). In the US, we throw around the term "German engineering", but that is usually just a synonym for high-quality engineering. A closer examination of actual engineering in Germany reveals that their educational system emphasizes standards for quality, and their engineers have the opportunity to work for either corporations or the government (Downey & Lucena, 2005). Finally, in the UK, engineering knowledge has a greater contribution from tradespeople, artisans, and apprenticeships in private industry and tends to have a lower status relative to its social position in other nations. Understanding the impact of national cultures on engineering is important because it helps us see some possibilities by which "technology could be otherwise". Conversely, the fact that the universals of engineering ideology tend to outweigh these cultural influences underscores the challenges we face if we are to develop more generative forms of engineering.

There are many ways of thinking that comprise traditional engineering ideology (Cech, 2013; Pawley, 2019; Riley, 2008; Robbins, 2007). At least three are important for engineers to unlearn: meritocracy, deficit model, and technocracy. Unlearning these three is required so that engineers can break free of narrow ways of thinking and consider alternative ways to reflect and act as we intervene in socio-technical problems.

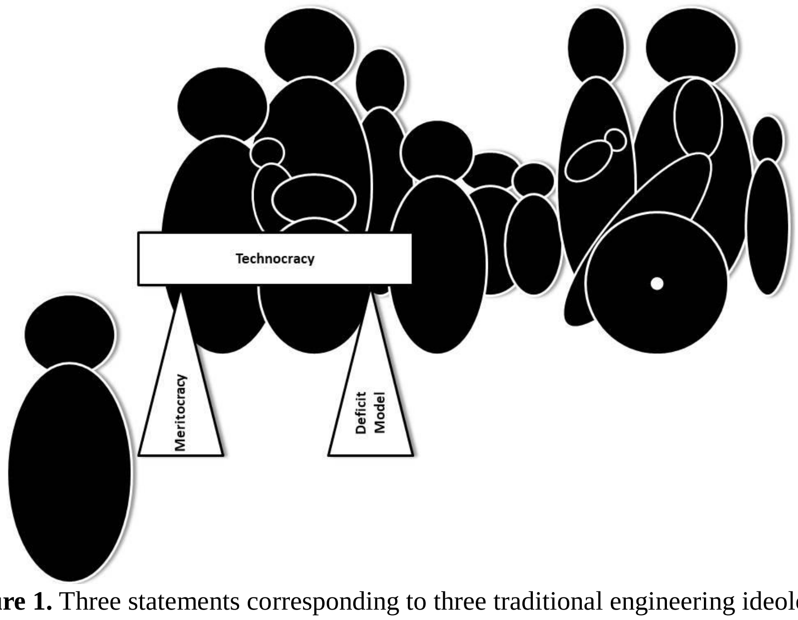

Figure 1. Three statements corresponding to three traditional engineering ideologies make a barrier between engineers and the public

First statement: "As an engineer, I deserve everything I have because it is all due to my own hard work." (Meritocracy)
Second statement: "Engineers are experts. We don't need information from the public who lacks appropriate understanding of math and science." (Deficit Model)
Third statement: "Engineers will solve the problem with data. If we could only explain it to them, then the public would accept our decision." (Technocracy)

> Meritocracy: The world is a level playing field, and everyone born into it has the same opportunities and rewards for their hard work. If I am successful, it is because of my hard work, and if you are not successful, it is because you did not work hard enough.

Meritocracy assumes that cumulative advantage is possible for everyone when, in actuality, cumulative advantage is only available to already elite people and professionals (Merton, 1973, 1988). Marginalized people instead suffer from cumulative disadvantage (Rossiter, 1993). Meritocracy is exemplified by the first statement in Figure 1.

> Deficit Model (of communication between experts and the public): Experts have all the information, while the general public lacks an understanding of mathematics and science.

This deficit model is a way of understanding an engineer's relationship with the public. In this model, the engineer assumes that members of the public do not have information useful for problem-solving and design. In contrast to this assumption, the public often has local knowledge, place-based knowledge, and relationship-based knowledge that is highly important for the engineer to solve a problem appropriately (Lambrinidou, 2018; Williams & Moore, 2019; Wynne, 1992). The deficit model is exemplified by the second statement in Figure 1.

> Technocracy: Scientific information and technological applications are the best way to inform the making of a public policy decision, and thus engineers are best equipped to make these decisions.

Many engineers see themselves as the most intelligent agents of technological and other social change as they are best able to design instruments, measure data and act on that data (Wisnioski, 2003 citing Layton, 1971). This is because they have already convinced themselves of the rightness of the deficit model and meritocracy, and thus a technocratic worldview is a natural progression. Technocracy is exemplified by the third statement in Figure 1.

While these three ideologies are pretty common as part of traditional engineering ideology, they do not provide an accurate picture of socio-technical systems. A more accurate representation of the socio-technical system also includes the durable, embedded inequality that disadvantages marginalized people (Cech, 2013; Hess *et al*., 2016; Pawley, 2019; Riley, 2008; Slaton, 2010).

These three ways of thinking create a barrier because they lead step by step to engineers separating themselves from the public whose good they purport to serve. Meritocracy allows engineers to feel entitled to have the financial and reputation advantages of experts in comparison to the non-expert public. The deficit model encourages engineers to discount or disbelieve the knowledge of non-engineers. Finally, technocracy is propped up by meritocracy and the deficit model: it allows engineers to self-justify the exclusion of non-technical perspectives from decision-making.

Part of the reason why engineers and computer scientists are trapped by this trinity of traditional engineering ideologies is that they are reinforced by a set of behavior and conceptual norms that Ziman (2000) summarized with the acronym PLACE (Proprietary, Local, Authoritarian, Commissioned, and Expert).

Wisnioski (2009) notes that like all norms, PLACE acts as unwritten rules of a culture. Engineers need not be taught them explicitly, they learn these as if through osmosis, by being engaged in engineering work in an industrial workplace and by conforming to what they unconsciously observe. The PLACE norms of an industrial workplace are Proprietary – It is owned by that workplace; it is not owned by you. Local – what you create is local and controlled by that workplace. Authoritarian – you don't get to choose your task. You and your boss are told to complete certain projects. Commissioned – This project is mandated on a specific timeline. Expert – not everyone in the workplace is responsible for every task or project, but is assigned such based on their certified knowledge.

I believe my students' instinct that generative justice and a generative economy is not 'realistic' is because they have already absorbed the PLACE norms of the industrial workplace. You can see the relation to the trinity of engineering ideologies through the problem in technological pacing that is sometimes called Collingridge's dilemma. Once we have seen the problems a technology creates--say, for example, the fossil fuel automobile—it is too hard to replace. But the foresight that could warn us early on is too contradictory to engineering ideology. If engineers did it, meritocracy proves that was the only way we could have proceeded. If the public objects to it--say, for example, thinking that nuclear power is not safe—it only highlights their lack of knowledge. The focus of the PLACE norms--that engineering should act as if it was expert-based commissioned work, owned by a corporation, even when federally funded--could easily exclude common-sense ideas such as partnering with the public or learning from the public's local-based, place-based, and relationship-based knowledge. Yet, these relationship-based practices are key to a more reflexive engineering practice (Robbins, 2007).

There are at least two alternatives to uncritically following the PLACE norms and traditional engineering ideologies: reflexive engineering and activist engineering. The first, reflexive engineering, is defined as such,

> "having a holistic and flexible understanding of socio-technical dynamics; seeing publics as a resource and partners in decision-making processes; viewing education as a two-way process between engineers and communities; striving for a multifaceted understanding of social, economic and environmental barriers to uptake of new technologies; and having an integrated approach to technological problems and solutions." (Robbins, 2007, p. 100)

You can see from this definition that reflexive engineering is more engaged with the public, which it sees as a partner for making decisions, and a resource for sharing and receiving knowledge. It also emphasizes that engineering problem-solving involves understanding the context, the social, economic, and political factors that are embedded and interwoven in the problem.

It makes you a better engineer to be reflexive and to work more closely with the public. Moving away from traditional engineering practice to become a reflexive engineer involves actively seeking the perspectives of non-engineers (including expert knowledge from other disciplines and lay knowledge from users) in order to solve problems best.

The second alternative to thoughtlessly following PLACE norms is activist engineering, "Activist engineering is about having engineers make explicit the values and key drivers of why engineering is done, and having that knowledge shape how engineering is done"(Karwat, 2019). Similar to Eglash, Darshan Karwat (2019) thinks that much of current technology design could be otherwise, saying, "Many blame politicians, governments, and markets for the technically-driven problems the world faces. But why is it that there are almost always engineers and corporations willing to design and build the technologies that cause those problems, many times in spite of knowing about the negative consequences of those technologies?" Answering the suite of self-reflection questions Karwat (2019) proposed prepares engineers to be better leaders of organizational change in their workplaces and better designers of technology in a complex world. Since powerful institutions can be racist, sexist, homophobic, ableist, imperialist, etc., resulting in inequities, sometimes engineers must go beyond reflexive and activist engineering; they must lead collective action in the public eye.

According to Wisnioski (2003), engineers engage in collective action for public benefit in at least three ways: Socially, by participating in civil disobedience such as a strike, sit-in, event disruption, or protest. Professionally, by changing their everyday intervention work from one topical area to another. In one example, an engineering research laboratory switched from military applications to environmental remediation applications. In another example, an engineering course curriculum switched from engineering design to the implications of technology in society. Finally, engineers may straddle the professional/social divide by publishing political critiques of technological designs and government or corporate aims and objectives. The engineering connection can also happen at the public end: legal action, for example, collectively undertaken by marginalized groups interested in engineering and denied training or other opportunities (Slaton, 2010). There are also other forms of individual-based action, such as whistleblowing and public resignation, discussed in the standards section below.

The above discussion of ideology and norms emphasizes that engineers have worldviews that are shaped in part by their personal experience, their society, and culture, as well as their industrial workplace. However, traditional engineering ideology makes engineers less responsive to the needs of the public and more than willing to create extractive technologies. Therefore, if the goal is that the ideology of non-extractive technology should be embedded into the design of artifacts, then first engineers should be taught that artifacts can have embedded ideologies, and second, engineers should be trained to recognize more generative modes of living, and to see them as a valuable and productive ideology to adopt during design.

3. Technology design should involve marginalized people

"the rights of value generators to create their own conditions of production"(Eglash, 2016, p. 255)

Engineering design is a team-based endeavor; therefore, I like to spend a little bit of time engaging my class in thinking about why diverse team composition is important. Management studies scholar Astrid Homan writes that diverse teams have "a greater pool of information, perspectives, and ideas than groups in which everyone is similar" (Homan, 2019, p. 3). Likewise, she reports that, while diversity fault-lines around gender, race, and nationality (i.e., all men are Japanese and all women are Canadian) may cause problems in a team, cross-cut diversity (i.e., Japanese and Canadian men and women) causes team benefits from diverse perspectives (Homan, 2019). This discussion is usually picked up and amplified as engineers learn about different ways of creating inclusive designs. Below, I describe how engineers intentionally or unintentionally design discriminatory technologies and how we can intentionally create inclusive technology designs.

One form of exclusive design is based on gender stereotypes. Gendered stereotypes are best represented by the colorful artifacts in the toy aisles of 1990s US big box stores: blue and pink. However, gendered stereotypes are also used to design items such as microwaves, bicycles, razor blades, and computer software (N. E. J. Oudshoorn et al., 2002). One surprising artifact that discriminates against women is commercial building air conditioning. The formula that guides complex HVAC systems in commercial buildings depends upon the metabolic rate of "a 40-year-old man weighing about 154 pounds" (Belluck, 2015) and "may overestimate resting heat production of women by up to 35 percent" (Belluck 2015 quoting Kingma & Lichtenbelt, 2015). Another surprising artifact that discriminates against women and has since been retired from use is Amazon's algorithm-based automated hiring tool. When it evaluated resumes, it demoted those that included women's colleges and failed to include key phrases such as "executed"(Goodman, 2018).

The problem is that designers have their own biases about gender roles; often, these are stereotypes. The designers, therefore, embed these biases into gender scripts that configure how men and women users are expected to use the design (N. E. J. Oudshoorn *et al*., 2002). For example, social users versus trial and error users are different approaches to learning a new technology, and men commonly prefer the trial and error approach (Dryburgh, 2002; N. Oudshoorn *et al*., 2004). Commonly, European and American designers and advertisers assume that women do not have the same technical competence as men (Cockburn & Ormrod, 1993; Kline & Pinch, 1996; N. Oudshoorn *et al*., 2004). Frequently, companies look only at a narrow set of users, and this is true whether their design teams are gender-diverse or gender-homogenous (N. Oudshoorn *et al*., 2004). Designers try to design for everybody, but they typically use the “I-methodology”; that is, they end up designing for themselves, including their own preferred ways of learning about and interacting with new technologies (N. Oudshoorn *et al.,* 2004). It is important that engineers know a variety of ways to counter this tendency to use the I-methodology.

There are five ways to create gender-sensitive technology designs that go beyond gender stereotypes and explore user motivations: feminist technology assessment (Morgall, 1993), gender stereotype design (Rommes, 2013), reflexive i-methodology (Rommes, 2013), participatory design with women potential users (Rommes, 2013), gendered analysis of innovation (Schiebinger & Schraudner, 2011). Feminist technology assessment moves beyond asking whether a technology is good for an individual woman to ask whether it furthers the interests of women collectively and democratically in their social and economic spheres of life (Morgall, 1993). This may sometimes mean that the technological fix is entirely rejected (Layne et al., 2010; Morgall, 1993). Gender stereotype design and reflexive I-methodology are fairly resource-efficient and easy to implement in the fast-paced world of corporate technology design. However, these techniques share the weaknesses of I-methodology (Rommes, 2013). In contrast, participatory design is slower and resource-intensive but usually produces excellent results in terms of consumer satisfaction. Finally, gendered analysis of innovation is an emerging case-study-based approach, and it is unknown how well it works in the corporate world of PLACE norms. While each strategy has its pros and cons, raising awareness of the multiplicity of approaches can help us build incrementally on their strengths to move towards gender-inclusive design.

Like gender-inclusive design, racial inclusion in design is crucial to moving towards more generative systems that prevent the extraction of value by the few from the many. The status quo for engineering design can be either intentionally or unintentionally racist. Examples of this are easily found in older technology, such as the

Shirley Card for color photography (Roth, 2009) or the race correction for measuring lung capacity with the spirometer (Braun, 2014). Examples likewise abound for newer technology, such as algorithms in the Google Photo App labeling Black people as gorillas (Guynn, 2015) and digital redlining (Noble, 2018).

Ruha Benjamin (2019) offers a framework for describing the relation of social power to negative impacts of various digital technologies on specific racial and ethnic groups, and understanding the motivation, neglect, and other conditions in which technology discriminates against racial minorities. These negative impacts often occur through one of two mechanisms: deliberately engineered inequities or unintentionally embedded default discrimination. Addressing these racist technologies requires anti-racist design.

Challenging inaccurate depictions of innovation history as primarily white is part, but not all, of anti-racist design. Although Eurocentric history frequently discounts us, Black and indigenous people of color have long been innovators (Williams, 2021 citing Eglash, 1999; Fouché, 2003, 2006; Gaskins, 2019; Johnson, 2017). Indeed the generative justice framework emerged in part from a focus on Indigenous invention. The earliest formulation was the circular flow resulting in fractals (self-similar forms) in Africa, where recursive structuring is used for cosmologies as well as practically in the design of homes, communities, fences, artwork, cornrow braids, etc. (Eglash, 1999). Later research added recursive exchanges with ecosystems: for example how Indigenous people in Central America created nanostructured pigment--the famous “mayan blue”—long before nanotechnology became a buzzword in the electronics industry (Eglash, 2011).

In my own work studying the attempts to eradicate blindness, I came upon Black physician Patricia Bath, who invented the practice of community ophthalmology and patented a cataract surgery technique called LaserPhaco – both of which are important in the effort to eradicate blindness due to cataract disease, which impacts millions globally (Williams, 2019). Unfortunately, most Americans are unaware of the Black and indigenous science and technology innovators in our young country's history. Instead, there is an incorrect perception that Black, brown, and indigenous people of color are not able to succeed in rigorous mathematics and science curriculums and are therefore unable to innovate. This deficit narrative should be challenged (Williams, 2021).

Challenging these erroneous perceptions is necessary, but does not complete the conditions that would shift engineering as a whole in the direction of anti-racist innovations. It is important to intentionally pursue inclusive innovation (Williams & Woodson, 2019). One emerging way of doing this is through Black-centered design; that is, privileging the needs and perspectives of Black people during the design process. But engineering is also about envisioning what does not exist. Afrofuturism is one mechanism for combining the passion for innovation and envisioning with the lived experiences of Black people to create more inclusive designs (Benjamin, 2019; McDowell, 2018; Winchester III, 2020). I like to teach about Afrofuturism using examples from *Marvel's Black Panther* (Dujmovic, 2018) and the action role-playing video game developed in Cameroon called *Aurion: Legacy of Kori-Odan* (Friederici *et al.*, 2020). I have students practice Afrofuturism in design through an exercise I created based on Nettrice Gaskins’ Afrofuturist project at Culturally Situated Design Tools (https://csdt.org/culture/scifi/afrofuturism.html).

Some people might argue that Black-centered design disadvantages non-Black people. In contrast, Black feminists (Hall *et al*., 2007) and white feminist philosopher of science Sandra Harding (1992; 2015) suggest that focusing on the needs of this particular marginalized group of people produces benefits for everybody. Economist Lisa Cook (2014, 2020) points out the result of years of not doing Black-centered design: our current racist technological innovation regime in the US has resulted in less economic productivity for the nation, which negatively impacts all races.

Discriminatory technologies affect people in the US and also globally. The World Health Organization reports that one out of five people globally are disabled. Yet, intervention programs for persons with disabilities, while well-intentioned, often operate out of silos. They do not always address the full identity of the person, including their gender, race, relationship needs, or income needs. Likewise, technology designs do not address how the needs of persons with disabilities change at different stages of their life and in different situations (Moser, 2006). Engineering often uses the phrase “universal design” to describe the needs of persons with disabilities, but this only underscores how particular circumstances might drop out of sight. For example, wheelchair lifts on buses, far from ensuring equitable transportation access, are frequently noisy and often break-down, making a spectacle of the wheelchair user (Velho *et al*., 2016). With everyone on a timetable, such frequent breakages cause immense frustration to the wheelchair user, bus driver, and other passengers (Velho *et al.,* 2016).

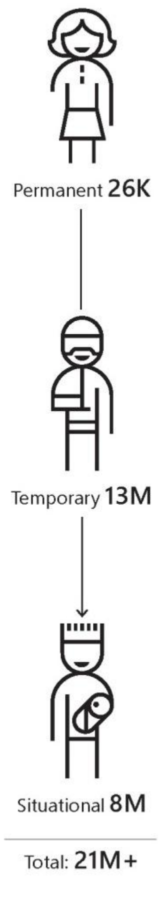

Figure 2. The Benefits of the Persona Spectrum, Solving for one-person with upper extremity loss and extending for many. Image Created by Microsoft 2016 Licensed under Creative Commons Attribution-Non Commercial-No Derivatives (CC BY-NC-ND)

Likewise, disabled philosopher of technology Ashley Shew (2018) suggests that when engineers and other professionals design, they often think in individualistic terms and they create devices that are unaffordable or not useful. Shew (2018) asks engineers to consider communal space. For example, the transition between outside and inside, wet and dry, carpet and hard flooring is particularly troublesome for those disabled individuals with mobility challenges (Shew 2018). An example that hits close to home for my students is that of another college student (and wheelchair user). He utilized the maps and tools available to him on the campus of the University of Maryland to plan a surprise birthday party for a friend. On the day of the event he realized those maps were inaccurate with a disheartening impact: he was unable to join the party he had planned (Ebner, 2019).

The persona spectrum is a design tool where, "When we design for one person who experiences mismatches in using a solution, we can then extend the benefits of that design to more people by asking who else might want to participate but is excluded on a temporary or situational basis" (Holmes 2018, 108). In Figure 2, there are only 26,000 people in the US who suffer from upper extremity loss: too small a number for a company to consider, resulting in an orphan or undone technology (see Williams, 2017). However, the problem is that companies are designing for average users that are normal, instead of recognizing, firstly, that there is no normal average user, and, secondly, that they should design for human motivations which change with permanent, temporary, and situational disabilities (Holmes, 2018). Doing so makes the design product more beneficial for a greater variety of people and demonstrates how focusing on problems of "edge cases" can actually be economically viable for companies.

The above literature on technology design really emphasizes the need for diverse design teams as one way of avoiding the I-methodology (N. Oudshoorn *et al*., 2004). If a greater variety of cultural and geopolitical perspectives are represented at the drawing board, then they can better inform the design and make it work well for more people. However, there is a caution from feminist technology studies that suggests such a reflexive I-methodology (Rommes, 2013) is necessary, but not sufficient to improve design practice. Diverse engineering design teams, by dint of being engineers, still share a meritocratic and deficit model perspective that differentiates them from the public users of technology. This shared ideology may cloud the diverse engineering design team's ability to create inclusive designs even if that is their intent. That is why it is so important that engineers be aware of the assortment of newer approaches to create inclusive designs: empower prospective users early and iteratively throughout the design process (participatory design), imagine non-Eurocentric technologies through Afro-futurism (Black-centered design), and emphasize human motivations in different situations (the persona spectrum). Also self-assessment tools are available to use during the design process: feminist technology assessment, gendered innovation analysis and inclusivity mainstreaming.

If the goal is that technology design and technology standards should involve marginalized people in developing and controlling technology, then the above approaches do so by including them as physical participants or including their cultural ways of knowing, and their differing motivations based on their situations. However, there is a further role for standards in generating justice.

4. Standards for technology should encourage the circulation of un-alienated value locally in a community

"the rights of communities of value generation to nurture self-sustaining paths for its circulation"(Eglash, 2016, p. 255)

Standard-setting gets at the heart of engineers' technical expertise and how it shapes and is shaped by ideology and social norms. Standards are invisible to most people but wield a lot of material power (Busch, 2011). Because I have taught this curriculum as a one-credit class, and I primarily focus on engineering design, I have been unable to cover all of the standards topics with the same class of students in one semester. So I offer two approaches: the first is at the intersection of standards and engineering expertise; the second is the interaction between design standards and social justice.

a. Standards and Engineering Expertise

The first approach, standards and engineering expertise, emphasizes the power of standards, the role of standards in shaping historical technological trajectories, and how engineers are involved in shaping standards through collective action.

Standards have the power to include and exclude specific users. Sometimes technology designers choose not to follow standards, and then specific users suffer.

Persons with blindness, colorblindness, or other disabilities find it difficult to navigate the internet and may use electronic readers or other assistive devices. For this reason, accessibility standards have been built into HTML and CSS practices since the beginning of web design (Fodness, 2016, pp. 205–208). While many web developers have good intentions of creating accessible websites, they often do not follow through with these intentions, and status quo web design remains inaccessible to many (Fodness, 2016, pp. 179–182).

Responsive design is a set of practices and technologies that ensure websites will render well on smaller screens. It is essentially privileging the mobile phone user over the desktop computer user (Fodness 2016 citing Marcotte, 2010). More importantly, responsive design represents a shift in norms for how web developers imagine their users (Fodness, 2016, pp. 208–214). While responsive design was not intended to benefit persons with blindness or colorblindness, its push to change the norms of web designers towards "mobile first" code has benefited persons with disabilities who use the web, if unintentionally. This form of design is closer to the universal design that web developers need to practice to address the injustice of status quo web design for internet users with disabilities (Fodness, 2016, pp. 208–214). We can think of responsive design as encapsulating a mental model (Gorman, 1992). This example showcases the power of a mental model to change design norms by shifting commonly understood ways of reflecting and acting in technical design.

Standards are not uniform; there are different types. For example, performance standards are different than design standards, but both are important to make automobiles safe for consumers (Vinsel 2015). Bowker and Star (1996) argue that "Every successful standard imposes a classification system", and thus classification systems are also very important to understanding how standards embody a mental model or set of typologies.

Recently, the news has underscored how classifications have become really important in mediating and defining the inequality of computer vision algorithms. Facial recognition and other such computer vision algorithms are re-producing inequality in: policing for Black Americans (Buolamwini, 2019), public perceptions of beauty for all women and men of color (Benjamin, 2019), and the safety of transgender men and women traveling through airports (Costanza-Chock, 2018, 2020; Scheuerman *et al*., 2019).

Standards are created by deliberation bodies in industry and government (Batik, 2018). The need for standards frequently arises through economic pressures in industry. Cronon (2009 [1991]) describes how the railroad car full of grain became a pseudonym for trading grain commodities on the Chicago Board of Trade. This is an example of a standard created through economic pressures. Another similar example is McLean's Sea-Land Service to create intermodal shipping containers. To save costs, Sea-Land Service wanted to create shipping containers whose contents were loaded and unloaded at only two points. Therefore, they wanted to create an international chain of transportation that went something like this: (1) load container; (2) transport container by truck, rail, ship, rail, and truck; (3) unload container (Tomlinson, 2009). The result meant increased international trade and decreased costs for shipping companies (Murphy & Yates, 2019; Tomlinson, 2009). However, this went hand-in-hand with lost jobs for dock workers and increased technical skills required of them (Tomlinson, 2009).

Professional technical committees, composed of engineers from government, industry, and academia, create technical standards (Batik 2018). One example is the work on intermodal shipping containers performed by the ISO (International Standards Organization) in Geneva, Switzerland, and led by secretary-general Olle Sturén. Sturén was an engineer, and his method of creating international standards involved travel to 60 countries over his first ten years in office and many face-to-face conversations over dinner (Murphy & Yates, 2019). Initially, even just within the US alone, there were multiple burgeoning standards for shipping containers. After the US Maritime Administration formed committees to standardize container sizes and construction in June 1958, the American Standards Association formed their committees in July 1958. Ultimately, the American Standards Association became the secretariat for the ISO Technical Committee 104 on Freight Containers in 1961, which was the most prominent global authority on freight shipping containers moving forward (Murphy & Yates, 2019).

Sometimes engineers working for federal or state regulatory agencies can be involved in creating high-quality technical standards to ensure ease of commerce or to enhance public safety. The US Department of Commerce has two examples of important federal regulators that employ engineers: the National Institute of Standards and Technology (Gaithersburg, Maryland) and the Patent and Trademark Office (Alexandria, Virginia). Likewise, engineers are employed at the US Department of Health and Human Services Food and Drug Administration (White Oak, Maryland) and the independent federal executive agency Environmental Protection Agency (Washington, DC).

Public resignation can be a powerful way of emphasizing the importance of high quality, technical standards that ensure public safety. For example, this is seen with William Stieglitz's resignation from the National Highway Safety Bureau in February 1967 when they failed to take his recommended advice for automobile safety standards (Nader et al., 2018). Similarly, whistleblowing is another compelling way to uncover bad actors or insufficient standards: companies or regulatory agencies not following standards or the need for new or better standards. Unfortunately, whistleblowing frequently results in being fired from a particular company and barred from an entire sub-industry. However, you can prepare to become a whistleblower, step-by-step, in a way that results in continued employment while also serving your conscience (Fitzgerald, 2018; Kumagai, 2018; Martin, 2013). One way of preparing is by learning the common narrative techniques of whistleblowers as they share their stories publicly and the laws that protect whistleblowers in the United States (Vaughn, 2012).

Collective action around standards is not always the responsibility of individual engineers resigning or whistle blowing. My favorite example of standards, regulatory agencies, and collective action is from the EPA. Environmental racism exists in policies like redlining, urban renewal, eminent domain, and racially restrictive zoning. These racist policies help to disproportionately create communities of color as "fenceline communities" sited near polluting industrial plants, waste facilities, sanitation facilities, and recycling facilities (Taylor, 2014). Environmental racism has also arisen from treaties that historically disadvantaged native indigenous populations (Taylor, 2016). Likewise, US policies, e.g., Jim Crow, segregated national parks, etc., and US practices, i.e., lynching/ picnics, deliberately excluded non-White people from enjoying the outdoors and punished non-White people in the outdoors (Walker, 2019).

One of the most profound examples for thinking about design and standards comes from a predominantly Black community that lives near a corporation that was a significant source of pollution in Louisiana. They united together with scientists, engineers, and government regulators to solve a problem: how to quickly and reliably measure air pollution locally? The Louisiana Bucket Brigade implemented a citizen science project where community members could collect their own air samples in EPA-approved "buckets" and send these samples to a professional laboratory for air quality testing. Gwen Ottinger (2010), who carried out participatory research in the Bucket Brigade, arrived at the following conclusions:

- Standards coordinate the work of scientists; knowing standards for the evidentiary base helps scientists check if an opinion, position, or hypothesis is relevant or not to their work;
- Standards serve to limit how science is performed; they create a path for carrying out science that is accepted by expert scientists as producing authoritative knowledge;
- Standards help the average citizen to do science; this provides a knowledge baseline for them to create assertions about air pollution in their communities
- Standards increase credibility (respectability, integrity, repeatability) of citizen science.

While many factors shape the ability of citizen scientists to influence scientists and decision-makers, Ottinger highlights how changing the standards by which research is performed is particularly important. Some engineers conduct research along the same hypothesis-driven principles as scientists, and they rely upon standardized instruments to do so. Therefore, the designers of standards for instrumentation have a unique form of power that impacts citizen science, natural science, and engineering science.

b. Design standards and social justice

The second approach, design standards and social justice, also emphasizes the power of standards but specifically reiterates the previous emphasis in the curriculum on anti-sexist, anti-racist and anti-ableist design and their relationship to standards.

To further help engineers think about inclusive design through standards, I would reconsider examples I have already described above for:

- Anti-sexist design and standards – A variety of artifacts have been standardized for men, not women. Gendered innovation analysis (Schiebinger & Schraudner, 2011) is a useful assessment tool during or after the design process to reconsider who is excluded and what might need to change, including standards for instrumentation (such as the car crash human model to include pregnant women) and standards for testing and identifying diseases among men and women (such as cardiovascular disease and osteoporosis).
- Anti-racist design and standards – A concrete example of how anti-racist engineering design meets standards is to accurately test the average levels of cancer-causing pollutants (smelly chemicals and particulate matter) in the air. Engineers are often very interested in learning more about environmental racism, Black fenceline communities, and the work of the Louisiana Bucket Brigade with the US Environmental Protection Agency on clean air measurement standards described above (Ottinger 2010).
- Anti-ableist design and standards - Fodness's (2016) dissertation, which describes responsive design as being created for mobile-first users, and extended

to users with disabilities, is an example of anti-ableist design and standards in web design (see above).

Engineers might further consider where anti-transphobic design meets classification typologies, especially in the many emerging information technology-based systems. Education scholars argue that fantasies about technology are gendered as masculine/butch or feminine/femme (Bennett *et al.*, 1999; Brunner *et al*., 1998; Google Talk [Online Lecture] On Girls, Boys and IT Careers, 2006). These non-binary gendered fantasies do not always directly correspond to self-identified gender expression; that is, both women and men can have femme or butch fantasies about technology (Google Talk [Online Lecture] On Girls, Boys and IT Careers, 2006). This insight is important because it expands designers' imaginations about their potential users by expanding potential gender classifications from binary to multiple. Similarly, Scheuerman et al. (2019) argues that we must expand past binary gender classification for more accurate computer vision software, suggesting seven genders, some of which might overlap each other in a self-identified gender expression (e.g., man, woman, nonbinary, genderqueer, transman, transwoman, and agender). Yet, they are also wary of making computer vision software work better to identify transgender individuals. It is only since June 2020 that sexual orientation and transgender status have become protected by federal law in: Bostock v. Clayton County, Georgia, a recent Supreme Court reinterpretation of Title VII (US Equal Employment Opportunity Commission, n.d.).

The older work on non-binary gender in educational information technology informs my thinking about how to expand Holmes' (2018) persona spectrum. Elsewhere I have described an intersectional persona matrix that accounts for user motivations when their gender or sexuality is disclosed, transitional or undisclosed, in addition to accounting for race and disability (Williams, 2020).

After reviewing various readings on engineering design, performance, and instrumentation standards, a couple of things become clear. For technology standards to encourage the circulation of un-alienated value locally in a community, that community should be involved in creating the standards, similar to the citizen scientists of the Louisiana Bucket Brigade. However, there are a wide variety of standards, and in addition to the place-based and local knowledge of citizens, the expert knowledge of engineers is required to make standards viable. Also, in some cases, such as facial recognition, improved standards may result in further exclusion and oppression of marginalized groups such as Black Americans and transgender people. Finally, standards are typically created in response to economic pressures or concerns about public safety. Knowing this, we should move forward with incentives and disincentives to standards-making bodies to be more responsive to environmental pressures such as climate change, and social pressures, including the need for local control of expressive value.

5. Conclusion

All teachers are well-aware that curriculum design is a never-ending, incremental process. Above, I have shared with you some curriculum that helps engineering students answer the question: what is the role of technology design in a generative economy? In this course, engineering students learn some design concepts and practices that help them consider their societal and environmental impact and opportunities to create change.

First, engineers should become aware of the commonly extractive (and thus destructive) nature of technology that removes technical skill from workers, eradicates free expression from crafts persons, and does away with the need for a labor pool while contributing negative environmental impacts to the planet. They should make technology that is non-extractive. They can do this by reflecting upon traditional engineering ideologies and norms, how their own values are similar or different, and any values they may want to reconsider. Must their fidelity always be to their employer, or should it be to the public first and foremost? Making non-extractive technology will require working closely with the public as a partner; the public as interested stakeholders should become an everyday part of an engineer's work. In such cases, it might behoove engineers to set aside traditional engineering ideology to work closely with the public as lay experts with their own place-based and experiential knowledge to create new engineering designs.

Second, engineers should involve marginalized people in controlling technology. Doing so requires changing engineering teams to become more diverse, with the consequent improvements in decision-making. However, it also requires individual engineering designers to be responsive to potential users, considering their identities and social contexts in detail. In other words, inclusive engineering design practice involves: gendered innovation analysis (Schiebinger & Schraudner, 2011); Black-Centered design (Winchester III, 2020); analyzing user motivations in different situations on the persona spectrum (Holmes, 2018); and utilizing non-binary gender classifications (Google Talk 2006).

Finally, engineers should establish new standards for circulating unalienated value locally. It is easy to discuss, but challenging to invest time, money, and effort in projects where there are direct returns to a local community. This might mean developing standards together with community members who are citizen scientists or DIY-ers. Engineers should also consider serving on technical committees to create standards that are more responsive to social and environmental pressures instead of just economic pressures. This includes understanding when better or more standards will disadvantage an already marginalized group and campaigning for a hiatus or dissolution. This also includes moving beyond corporate interests to create standards that decrease waste circulation and other negative environmental impacts.

Ultimately, engineers cannot rely on design, norms and standards alone to generate justice. In addition to changing the focus of your day-to-day engineering work in response to social or environmental pressures influencing social, environmental and economic change may additionally require becoming an activist engineer. This may involve civil disobedience, public thought leadership as political critique, resigning, or whistleblowing.

It is thought-provoking to contemplate the variety of ways that engineers can make the destructive force of technology into a non-extractive force for improving society.

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